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Transportation Implications of *Telecommuting*

CORRECTION

Through an unfortunate oversight, no attribution is given for Figure 11, appearing on page ***54*** of the U.S. Department of Transportation report ***Transportation Implications of Telecommuting.*** It is taken, with slight revision, from a limited-circulation paper, ***Telework and Business Strategy: Leading the Information Age,*** presented in 1992 by Jack M. Nilles, JALA International, Inc., as part of a JALA seminar presented in the United Kingdom.

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Executive Summary

Objective

This report, addressing the potential cost and benefits of telecommuting, has been prepared by the Department of Transportation, in consultation with the Department of Energy and the Environmental Protection Agency, as required by section 352 of the Department of Transportation and Related Agencies Appropriations Act for fiscal year 1992. The report focuses on future impacts of telecommuting on transportation, environment, and energy use. Despite the existence of many telecommuters and numerous pilot projects and studies, telecommuting is still in a very early stage. The projections of future telecommuting and transportation impacts provided here could change substantially as technology continues to develop, and experience is gained in understanding employer **and** employee response to this new form of working.

Principal Conclusions

- **Telecommuting is now practiced by approximately 2 million workers and could reach 7.5 to 15 million within a decade.**
- **Estimates of the future level and impacts of telecommuting are highly uncertain.**
- **Telecommuting has the potential to provide significant transportation-related public benefits in this decade.**
- **The actual amount and impact of telecommuting in any particular region will depend strongly on the local transportation environment and travel demand measures.**
- **The congestion and air quality improvements potentially attainable through telecommuting could be substantially diminished if telecommuters removed from the highways are replaced by the emergence of latent travel demand.**
- **Direct energy,air quality, safety, and time benefits of telecommuting will be increased as the degree of congestion is reduced.**
- **Telecommuting could stimulate urban sprawl and have other adverse impacts on land use and public transportation.**
- **Factors which will impact the rate of growth of telecommuting include uncertainty of benefits for employers and the considerable time and effort inherently required to bring about major changes in workstyles and ways of doing business.**

- **Telecommunication services and equipment are adequate for most current telecommuting, but high-bandwidth capabilities will be needed in the future and would be beneficial now.**
- **Government agencies can play a significant role in facilitating and encouraging teleconunuting.**
- **. Teleconnnuting can be an effective tool for travel demand management, but cannot be mandated.**
- **Continuing research is needed to clarify teleconunuting costs, benefits, and future impacts.**

Background

Computer and telecommunications advances in recent years, including computer networks and data systems, FAX machines, and electronic mail, have dramatically widened the choice of workplace for information workers and others so they can work wherever these tools are available, including at home. This development has paralleled trends toward a service economy, greater worker flexibility, empowerment of employees, and rising frustration from the irritation and time loss associated with commuting. One result is that a substantial portion of the U.S. labor force, perhaps as much as 30 percent, now works at home at least part of the time. In addition to self-employed individuals, contract workers, "moonlighters," and people simply bringing work home from the office, an estimated two million of these people are full-time employees who otherwise would commute daily to an office or other workplace. Most can be characterized very generally as "information workers," in that their work focuses substantially on the creation, distribution, or use of information. In effect, telecommunications services are substituted, partially or completely, for transportation to a more traditional workplace. This practice is called "telecommuting. "

Telecommuting does not necessarily imply working at home. Satellite "telework" centers near or in residential areas, fully equipped with appropriate telecommunications equipment and services, can serve employees of single or multiple firms, co-located on the basis of geography rather than business function. In many cases a shared facility provides a more practical and satisfactory location for telecommuting than the home, and a setting less threatening to traditional business management styles. Telecommuting is often practiced as little as one or two days each week, although it can be full-time. While today's most visible telecommuters are predominantly managers or professionals, telecommuting is potentially relevant to most information workers, as well as to some other types of employees.

As corporate information technology and public telecommunications services have advanced, interest in telecommuting has increased markedly in recent years. A major reason is its

reported potential to improve significantly both the productivity and quality of life of employees. Employers are attracted not only by the potential productivity gains, but also by greater success in recruiting and retaining employees.

From a national perspective, telecommuting is of current interest because of its potential transportation implications, especially with respect to air quality and congestion relief. The public cost of urban traffic congestion is not limited to personal stress and costs of delays and corporate productivity losses; commuting in general, and peak-hour congestion in particular, are major sources of air pollutants. The Clean Air Act, as amended in 1990, requires that stringent measures be taken in many regions to reduce air pollution through constraints on vehicular traffic. Telecommuting is seen by many as an important tool in managing demand for transportation. In addition to lower congestion and less air pollution, potential benefits could include reduced national petroleum use, fewer highway accidents, and eased transportation infrastructure requirements. Telecommuting can also expand opportunities for people with impaired mobility or tied to the home for any other reason.

Telecommuting is not without possible negative effects. Concerns expressed in the literature include conversion of employees into contract workers lacking job protection and benefits, and perception of pressure to work excessive hours. Maintenance of a clear distinction between work and home life can be difficult for some, leading to serious stress and burnout. So far, these problems have proven minimal for most telecommuters, who continue to go to the office several days per week. Another concern is whether those who telecommute, particularly from a remote satellite center, will move still further into rural areas, thus negating the energy and emissions benefits and accelerating urban sprawl. Other negative impacts on land use, public and urban transportation are possible. From the employer's perspective, concerns include the cost and effort necessary to implement a program and the challenge of remote supervision.

Although telecommuting is conceptually simple, it touches on many areas of life and raises important questions and issues for which answers are not yet available. The degree to which telecommuting is adopted, the specific forms it takes, and the magnitude of the public benefits actually obtained depend largely on attitudes of people toward their work and workplace, the adaptability of corporate culture, the nature of the work performed, and the specifics of changes in their travel behavior. Not surprisingly, there is wide variation among predictions of the future of telecommuting and its impacts on transportation.

Current and Projected Levels of Telecommuting

Telecommuting activities are often carried out on an informal basis and are not captured in any comprehensive statistical data base. The principal source of statistical information as to current practices is an annual commercial random telephone survey that explores aspects of working at home. In addition to that survey, several studies based on state

telecommuting pilot programs provide insight into the suitability and acceptability of telecommuting for individuals, jobs, and organizations. This technical literature, which generally indicates a substantial increase in telecommuting through and beyond the next decade, provides a foundation for projections of telecommuting behavior over the next 10 years. The margin of uncertainty is quite large; upper and lower bound projections, differing by a factor of two in number of telecommuters, have been developed. These projections are shown in the table below.

PROJECTED FUTURE TELECOMMUTlNG	1992	1997	2002
Number of Telecommuters (millions)	2.0	3.1 - 6.2	7.5 - 15.0
Percent of Labor Force	1.6%	2.3% - 4.6%	5.2% - 10.4%
Percent of Telecommuters Working at Home	99.0%	74.3%	49.7%
Percent of Telecommuters Working at Telework Centers	1.O%	25.7%	50.3%
Average Days per Week	1-2	2-3	3-4

Transportation Impacts of Telecommuting

Potential beneficial transportation impacts of telecommuting include reduction in highway congestion and associated lost time, reduced emission of pollutants, savings in energy and petroleum consumption, and fewer highway accidents. Telecommuting is already widely seen as a potentially valuable travel demand management measure to reduce congestion and meet existing ambitious national air quality goals.

The projections of numbers of telecommuters were combined with current travel-related statistics to develop estimates of transportation impacts over the next 10 years for the upper and lower bound scenarios. The results, presented in the table below, suggest that substantial benefits could be attainable by the end of this decade. These projections make clear that telecommuting could eventually play a significant role in addressing problems of urban congestion, safety, air quality, and energy use, but also indicate that it is neither a near-term nor complete solution to these concerns. However, the actual amount and impact of telecommuting in any particular region will depend strongly on travel demand management measures in place and other aspects of the local transportation environment. In some cases the transportation implications could be substantially greater than suggested by the table below.

TRANSPORTATION IMPACTS	1992	1997	2002
Saving in Vehicle Miles Travelled (VMT) (billions)	3.7	10.0 - 12.9	17.6 - 35.1
Percentage Saving in Total Passenger VMT	0.23%	0.49% - 0.63%	0.7% - 1.4%
Percentage Saving in Commuting VMT	0.70%	1.6% - 2.0%	2.3% - 4.5%
Saving in Gallons of Gasoline (millions)	178	475.9 - 619	840 - 1,679
Percentage Saving in Gasoline	0.25%	0.6% - 0.8%	1.1% - 2.1%
Value of Gasoline Saved (millions)	$203	$543 - $706	$958 - $1,914
Percentage Saving in Emissions			
NOx	0.23%	0.6% - 0.8%	1.1% - 2.2%
HC	0.31%	0.8% - 1.1%	1.4% - 2.7%
CO	0.36%	1.0% - 1.3%	1.7% - 3.4%
Annual Hours Saved for Average Telecommuter	77	93	110.3
Total Annual Hours Saved (millions)	156	444 - 577	826 - 1,652

Telecommuting is at such an early stage that prediction of its rate of growth and transportation impacts is difficult. Many factors contribute to a high level of uncertainty in the estimates presented above. The actual degree to which jobs, individuals, and employers will be suited to telecommuting is not clear. Most demonstration or pilot programs have been limited in scale and have involved carefully selected workers and managers. Directly relevant data concerning travel behavior, emissions, and fuel use are not available and would vary from region to region.

The figures shown in the preceding tables do not tell the whole story. Where congestion is severe or strong disincentives to vehicle use are in place, telecommuting might be much more attractive to firms and individuals than in an "average" location. In addition, even a modest decrease of traffic due to telecommuting could reduce congestion significantly, thereby magnifying savings in time and fuel use, and reduction in emission of pollutants. Conversely, telecommuters who at one time commuted by carpools or public transportation, may now choose to drive single-occupant automobiles due to the reduced congestion. In the latter case, congestion reduction would be diminished, and transportation benefits associated with the telecommuter would be partially nullified. The magnitude of these factors, and the balance struck between them, will vary considerably from place to place. Generalization as to the net result is not possible. **The benefit estimates shown above do not include either of these important but unquantifiable effects.**

Factors Affecting the Future Course of Telecommuting

Telecommuting is not suitable to every job, person, or situation. Whether an individual telecommutes, and how often, are results of the decisions of employer and employee, made within the constraints of the existing physical and institutional environment. Conditions that must be met before a person can become an active home-based telecommuter include the following:

- The job must be suited, at least in part, to performance at a remote location.
- The capabilities and personal characteristics of the employee must be appropriate to working with little or no direct supervision.
- The employing firm must accept telecommuting as a legitimate and desirable activity, provide necessary support, and have appropriate information technology in place.
- The supervisor or manager of the employee must accept the concept and practice of telecommuting.
- The employee must feel comfortable with telecommuting in terms of its suitability to his or her personal work habits and style, its effect on social interactions and on advancement and career.
- The employee must have a suitable workplace and working time free of distractions (such as child care responsibilities).
- Available technology, particularly telecommunications services, must be adequate and cost-effective for the work to be performed at home.

While all of these conditions clearly can be met in many cases, each will filter out a portion of the potential telecommuting population. Some of these elements are eliminated or modified for the case of satellite telework centers, but implementation of centers is more complicated, costs could be higher, and depending on specific circumstances, vehicle-miles and emissions reductions could be zero or even negative.

Even when these conditions are satisfied, telecommuting will only occur if businesses and workers are sufficiently motivated toward it. The local transportation environment will be important in establishing the level of motivation. Severe congestion, stringent travel demand management measures, and lack of widespread convenient public transit are all factors that can increase the incentive for establishment of telecommuting programs and participation in them. Similarly, factors affecting the cost of commuting -- vehicle and fuel cost, or dispersion of workers over a large area, also encourage telecommuting.

The rate at which telecommuting is adopted will also be constrained by the still-uncertain cost-benefit implications for businesses and the pace at which employers and workers become familiar and comfortable with this new way of working. Employers naturally await more definitive evidence for claims of dramatic productivity increases. Employees often have initial misgivings about social isolation, being “out of the office loop”, being at a disadvantage for career advancement, and mixing their home and work lives. Other concerns revolve around the process of selecting who can telecommute, remote supervision,

and fears of some telecommuters that they must work extra hours to justify and protect their status. Overall, a high level of trust is required between worker and employer.

In pilot programs, these potential problems generally have not proven to be serious, and impressive productivity improvements have been reported. However, in many of these cases telecommuting is practiced only a few days per week, and participants have been carefully selected. These programs, thus provide valuable insight and mitigate some key uncertainties, but do not permit firm conclusions to be drawn.

Major uncertainties with important implications for transportation include the form and importance that local telework centers ultimately achieve and the degree to which telecommuting is center-based as compared to home-based.

Establishment of remote telework centers is a complex undertaking that may require several years to come to fruition.

Barriers to Telecommuting

For the most part, available telecommunications services appear adequate for a large range of telecommuting situations. Of course, a more advanced telecommunications infrastructure would enable more widescale and sophisticated telecommuting to occur. Today, wide-bandwidth services required for video functions or transfer of very large quantities of data are often lacking. While this can be an obstacle to "high-end" telecommuting and other telework situations, availability of telecommunications services do not appear to constitute a serious limitation at present, although this could change in the near future. The need for major advances in the nation's telecommunications infrastructure to support general business, commercial and home uses, an explicit objective of the Clinton Administration, will create markets and drive development of infrastructure to a much greater degree than telecommuting applications. However, many complex and contentious regulatory and legislative issues arise in creating the sophisticated, efficient, high-capacity, broad-bandwidth U.S. telecommunications infrastructure; resolution of these issues could accelerate future telecommuting and other business and societal uses.

A variety of obstacles to telecommuting are identified in the literature, including liability considerations, zoning and tax laws, labor union concerns, and occupational health and safety issues. Pilot program experiences to date suggest that none is a serious constraint to widespread adoption of telecommuting. Nonetheless, as telecommuting becomes more common, issues such as tax codes, liability, and labor laws could become more intrusive. Those topics and related issues will have to be addressed in a responsive and fully informed manner by the responsible Federal, state, and local agencies if telecommuting is to achieve its full potential.

Other Telesubstitutions

Many activities, other than commuting to work, are already affected by the availability of sophisticated telecommunications services and computer networks. In general, those services provide convenience and access, and may not significantly affect transportation. These effects are largely unquantifiable at present. These "telesubstitutions" include the ubiquitous automated teller machine (ATM); shopping by catalog and toll-free telephone calls, or home shopping services using cable TV; and electronic submission of tax returns.

Particularly in rural areas, there is increasing interest in providing educational services and medical consultation via telecommunications, as well as establishing telework centers that might provide more and higher-paid employment than could otherwise exist locally. Full-time telecommuting from these regions could also favorably affect the character and economic structure of these areas. However, most observers find that the degree to which rural development in general can be stimulated in this way is likely to be quite limited, at least in the near term.

Governmental Roles

Telecommuting can lead to a reduction in the number of commuting vehicles and thus contribute to the attainment of cleaner air and congestion mitigation. Therefore, many communities view telecommuting as a transportation demand management measure and provide government assistance for establishing a telecommuting strategy. Federal assistance is also available. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Public Law 102-240, provides Federal assistance for "operational improvements" which include" . . . transportation demand management facilities, strategies, and programs.. . "(Section 1005(f)). Therefore, ISTEA funds may be used to support the planning, development, and marketing of telecommuting programs designed to improve air quality and reduce congestion.

Several states have established telecommuting programs for state employees and actively promote telecommuting in the private sector. At the Federal level, the Flexible Workplace Project, sponsored by The President's Council on Management Improvement, is testing the feasibility and utility of flexible workplace arrangements for Federal employees. This project, managed by the Office of Personnel Management and the General Accounting Office, is designed to facilitate the implementation of pilot programs in Federal agencies.

The telecommunications environment for telecommuting will be significantly affected by the Clinton Administration's stated goal of encouraging investment in the national information infrastructure. The President's recently-announced technology policy specifically notes the importance to the U.S. economy of stimulating development of a broadband, interactive telecommunications network -- an "information superhighway" -- linking the nation's

businesses, schools, libraries, hospitals, governments, and other users.

The Department of Transportation will work with states, local governments and the private sector to monitor teleeommuting activities, collect and analyze data and disseminate relevant information concerning the growth of telecommuting and its implications for transportation and land use.

Future Research

Telecommuting is a diffuse activity, not well captured in current statistics, and transportation impacts are unlikely to be directly measurable. Needed information, particularly involving transportation-related behavior, can be acquired only with a special effort. The Department of Transportation, working with other Federal agencies, states, local governments, and the private sector, will consider undertaking research, as appropriate, to assure that telecommuting policies and programs are based on an in-depth understanding of this new phenomenon, its growth and future course, and its transportation-related implications.

Chapter 1 - Background

INTRODUCTION

Approximately 30 percent of the U.S. labor force, roughly 38 millon people, currently work at home at least part of the time as shown in Figure 1. While most are self-employed or are simply working after regular hours, a growing number of them are full-time employees who otherwise would commute daily to an office or other workplace. Most can be generally characterized as "information workers" in that their work focuses substantially on the creation, distribution, or use of information. The ability to work at home has in large part been made possible by corporate use of computer and telecommunications advances during the last several years. Sophisticated telephone services, personal computers linked by phone lines to central networks and data systems, facsimile machines, and electronic and voice mail systems have dramatically widened the choice of workplace for information and other workers so they can work wherever these tools are available, including at home. In effect, telecommunications services are substituted, partially or completely, for transportation to a conventional office or other workplace. This practice is called "telecommuting. "

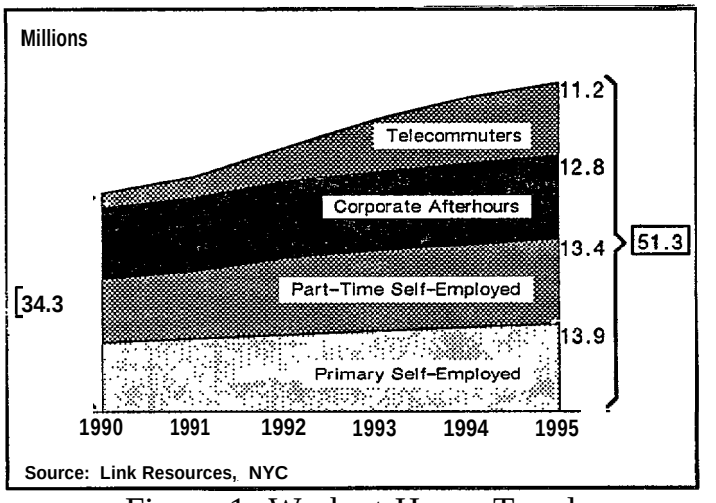


Figure 1. Work-at-Home Trend

As commonly used, the term telecommuting does not always imply working at home. Satellite or local work centers, fully equipped with telecommunications equipment and services, can serve the employees of one or several firms, collocated on the basis of geography rather than business function. In many cases, a shared facility provides a more practical and satisfactory environment for telecommuting than the home. Telecommuting is often practiced only one or two days each week, although it can be fulltime. While today's telecommuters are predominantly managers or professionals, many observers see this practice as potentially relevant to most information workers, as well as to other types of employees.

Interest in telecommuting, now that the enabling technologies have reached satisfactory levels of cost and performance, has increased markedly in recent years. In part, this is because in many cases it can significantly improve the productivity and quality of life of employees. From the public perspective, the principal attraction lies in its implications for transportation and air quality. The public cost of urban traffic congestion is not limited to personal stress experienced by commuters and the associated delay costs and corporate productivity losses; commuting in general, and peak-hour congestion in particular, are major sources of air pollutants, energy uses, and accidents. Because of this, the Clean Air Act, as amended in 1990, requires stringent measures be taken in many regions to reduce air pollution through constraints on vehicular traffic. In addition to more familiar approaches such as flexible working hours, carpooling, and use of public transit, telecommuting is seen by many as a potentially important means of managing traffic demand. Other significant possible benefits include reduced national energy and petroleum use, fewer highway accidents, and eased transportation infrastructure requirements. Telecommuting can also be of great value in expanding opportunities for people of impaired mobility or tied to the home for any other reason.

While the basic concept of telecommuting is simple, it touches on many areas of life and raises questions and issues difficult to answer on the basis of current limited experience. The degree to which it is adopted in the future, the specific forms it takes, and the magnitude of the benefits actually obtained depend not only on the technologies involved and the capabilities of the U. S . telecommunications infrastructure, but much more importantly on factors such as attitudes of people toward their work and workplace, the suitability of telecommuting to corporate culture, and the nature of the work performed. There is wide variation in predictions of the future of telecommuting and its impacts on transportation.

Purpose and Scope

This report has been prepared by the Department of Transportation (DOT), in consultation with the Department of Energy and the Environmental Protection Agency, in response to a statutory requirement to conduct a study of the potential costs and benefits of telecommuting, focusing on the impact of transportation on energy use and air quality. The report provides a description of the nature of telecommuting and estimates of its near-term future prospects and implications for transportation and related areas. Although there are many telecommuters and a substantial number of pilot projects and studies have been conducted or are in progress, telecommuting is still in its infancy. The congressionally requested estimates of the potential reduction in commuting and associated pollution, energy use, and lives lost, as well as other social impacts, should be viewed in the context of a full discussion of the many issues and uncertainties that surround the subject.

Accordingly, this report addresses the following topics:

- The nature of telecommuting in its various forms, its current extent, and how new uses of telecommunications will substitute for transportation.
- The forces, both positive and negative, shaping the future course of telecommuting, including barriers to its growth that are within the purview of the Federal and state and local governments.
- Estimates and projections of the growth of telecommuting in the next 10 years.
- Estimates of the effects of telecommuting on transportation, including estimates of:
    - The amount and type of reduction of commuting;
    - Associated safety, environmental, and energy benefits;
    - Impacts on other modes of transportation; and
    - Other social impacts of telecommuting.

Many of the studies surveyed project the numbers of telecommuters 15 to 30 years into the future on the basis of a high level of substitution for transportation. However, these long-term projections have necessarily been developed with a very limited foundation of data. Since this report is to provide information to facilitate formulation of government policies regarding telecommuting, its focus is relatively near-term - the next five to ten years. The principal topic of the report is the potential reduction in highway traffic associated with use of information technologies that permit working at home or at local facilities rather than commuting to a conventional workplace. Although the substitution of telecommunications for transportation has intriguing potential in many areas of life, in most other cases (telemedicine, teleeducation, teleshopping) near-term transportation implications are modest; the real benefits are in providing convenient and efficient access to various services. Those topics will be discussed briefly but will not be examined in depth. Although the emphasis is near-term, many of the issues raised have clear long-term significance.

This report is based primarily on a careful examination of the large and diverse body of literature on the subject, most of it produced in the last few years. The literature covers a broad range of applications (remote work, teleconferencing, teleservices) and issues (transportation, urban and regional geography, economics, management, social and psychological, technical). Types of publications examined include books, policy overviews, various academic research reports, demonstration projects/studies, expert testimonies, personal interviews, in-depth articles from specialist computing and management press, general office automation literature, futurist publications, popular press articles, surveys of teleworkers, and how-to manuals. The effort was initiated by a 2-day workshop at the Department of Transportation which focused and elicited the views of a wide range of individuals knowledgeable in various aspects of telecommuting (see

Appendix E) .

Historical Evolution of Telecommuting

One of the first people to foresee the coming of "telework" (as it was termed in Europe) was Norbert Wiener in his landmark book ***The Human Use of Human Beings: Cybernetics and*** Society published in 1950. Wiener discussed a hypothetical example of an architect living in Europe but supervising the construction of a building in the United States. Using the recently introduced facsimile transmission service "Ultrafax," he said, "...even without transmitting or receiving any material commodities, the architect may take an active part in the construction of the building.... In short, the bodily transmission of the architect and his document may be replaced very effectively by the message-transmission of communications which do not entail the moving of a particle of matter from one end of the line to the other."

Interest in telework did not spread widely until the early 1970s, as terminal-based use of corporate and time-share mainframe computers became widespread. Portable terminals, using voice-quality telephone lines, permitted system access from any location that had telephone service. Gradually it was understood that telecommunications and data processing could be meshed into integrated systems. In the late 1970s, the French neologism term "telematique" (English: telematics) was coined by Simon Nora and Alain Minc in order to describe this growing interconnection of telecommunication and computers into one, integrated national and international system. Also, the early 1970s saw an international oil crisis, which focused critical attention on the waste of energy in private and public transport systems. The combination of technical potential and social need served as a strong stimulus for innovation. The dominant view of telework in this initial phase was the potential to save energy by substituting electronic communication for physical transportation. In 1973, Jack Nilles introduced the term "telecommuting" as the U.S. equivalent of "telework."

In 1980, Alvin Toffler incorporated the idea of telework or telecommuting into his three-phase world history, making it one of the basic elements of the emerging "Third Wave." In his book, ***The Third Wave,*** he predicted that the new information-based production system would move millions of workplaces from factories and offices back to where the workers had come from: the home.

At the organizational level, many studies have forecast radical changes to existing hierarchical institutions. In his 1979 paper, Daniel Bell refers to the change in libraries - where the world's recorded knowledge housed in buildings may become only a monument of the printed past (Bell, 1979). Wilfrid Lancaster of the University of Illinois suggested the imminent disappearance of the book, to be replaced by the year 2000 with a computer network (Lancaster, 1982).

A number of writers have speculated about the impact of telecommuting on the working

community. In the early 198Os, Starr Roxanne Hiltz put forward the concept of the "online community" which would gradually replace the physical office. According to Hiltz, these office networks can best be thought of as a new kind of social system: one in which the familiar social processes of the workplace and the organization are replaced by electronic online communities (Hiltz, 1981; Hiltz, 1984).

In the 1970s and 1980s some writers predicted that major portions of the workforce would be working from home within this century. Although many of their predictions have been scaled back from year to year, home-based telecommuting has shown rapid growth in the last few years and still is widely expected to become a significant substitute for commuting as a result of advances in technology, lower costs, recognition of productivity benefits, increasing governmental encouragement, and resolution of numerous organizational, social, and legal issues.

Telecommuting and Transportation

Telecommuting is currently of particular interest to public agencies struggling to relieve local highway congestion and meet legislative mandates for improved air quality. For them, it is an important Transportation Travel Demand Management (TDM) tool -- a strategy that reduces congestion by eliminating a trip or shifting it out of the peak period. Other such strategies include car, van and bus pools, public transit, compressed work weeks, and flextime.

Although telecommuting alone is not a solution to congestion and pollution problems, it could be important as one of several measures for addressing these problems. There is growing interest among planners, researchers, and policymakers in telecommuting as a strategy for reducing travel demand. This can be traced to several different factors:

- For public policymakers, "telecommuting is an attractive TDM strategy because it supports several agendas. It contributes to policies supporting: transportation, energy independence and conservation, improvement of air quality, employment for people with
. limited mobility (disabled retired, low income, single parent), rural economic development, global competitiveness of American business, effective health care management, the American family and increased community involvement."'

- Telecommuting can be implemented now, as it does not require any additional planning, design, and construction lead times and it can be relatively inexpensive to implement.

- Telecommuting expands rather than restricts personal choices by offering more flexibility in workstyle and lifestyle.

- It addresses a variety of private sector concerns. For businesses, it offers the potential

for improved productivity, recruitment and retention, savings in space costs, and other benefits.[2]

Telecommuting and the Public Sector

Telecommuting has found its way into a number of governmental statements and actions, especially as a transportation strategy, but also addressing other policy concerns. For example:

- At the Federal level, the Flexible Workplace Project, sponsored by the President's Council on Management Improvement, is testing the feasibility and utility of flexible workplace arrangements for Federal employees. This project, managed by the Office of Personnel Management and the General Accounting Office, is designed to facilitate the implementation of pilot programs in Federal agencies. Currently with 800 participants, this undertaking has yielded good initial results in terms of productivity and reduced sick leave.

- The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provides funding to States and local governments to support compliance with Clean Air Act and to increase the efficiency of existing transportation facilities. Since telecommuting can lead to a reduction in the number of commuting vehicles, it is considered to be a travel demand management measure eligible for funding under the National Highway System program, the Surface Transportation Program, and the Congestion Mitigation and Air Quality Improvement program. Eligible activities include the planning, development, and marketing of an area wide telecommuting strategy designed to improve air quality and reduce traffic congestion.

- The 1989 Air Quality Management Plan for the South Coast (California) Air Basin sets the ambitious goal of reducing work trips by 30 percent in the year 2010 through the combined impacts of telecommuting and alternative work schedules.

- 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. Regulation 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.

- Upon the successful conclusion of the 2-year pilot project for State of California employees, legislation was passed authorizing the establishment of telecommuting programs for any state agency. Following the October 17, 1989 Loma Prieta earthquake, California Governor George Deukmejian issued an Executive Order which directed state agencies to include telecommuting in their emergencyresponse to the earthquake.

- In introducing the Statement of National Transportation Policy on March 8, 1990, President Bush said, “Sometimes the best transportation policy means not moving people, but moving their work.. .atrend 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 State of Washington has passed legislation requiring trip reduction plans to be prepared at the local level. The statute sets targets for reducing commute trip vehicle miles 15 percent by January 1, 1995; 25 percent by January 1, 1997; and 35 percent by January 1,1999 (from a 1992 baseline). A bonus for work-at-home and alternative work schedules is built into the legislation: each commute trip reduced by these means “shah 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 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 workforce, improved ability to recruit and retain valuable employees, and reduced costs for office and parking space. ”

- Commonwealth of Virginia House Joint Resolution (HJR) 77 requested the Virginia Employment Commission to prepare a report to the legislature on the feasibility of telecommuting . The resulting document recommended establishing telecommuting programs in state agencies, followed by promoting and assisting its implementation in the private sector. 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, “encouraging efforts to foster and promote telecommuting in the workplace. ”

- A number of other legislative initiatives are underway at Federal and state levels. Telecommuting is a recommended strategy in a variety of local and regional transportation plans, corridor studies, and trip reduction/mitigation ordinances, especially in Califomia.[3] For example, “proposed California legislation (State Assembly Bill 374) would provide tax credit to employers implementing telecommuting programs, provided participants telecommute three or more days per week. "[4]

DRIVING FORCES

Telecommuting is merely one expression of a variety of fundamental changes occurring in U.S. society. The adoption of telecommuting is shaped by technical, economic, environmental, legal, social, and demographic factors and trends. These indicators of telecommuting potential suggest both the limits and the possibilities of telecommuting activity. While influenced by many factors, it has risen in prominence primarily through the convergence of trends and developments in the following areas:

- Telecommunications and Information Technology
- The Nature of Work
- The Workers
- The Workplace
- Urban Highway Congestion and Its Consequences
- Environmental Legislation

Telecommunications and Information Technology

The rapid development of telecommunications and information technology during the latter part of this century has transformed many aspects of life. Live television images of events occurring anywhere on earth have affected our perceptions of ourselves, our society, and our world. In the 19th century, the telegraph, soon followed by telephone and then radio, introduced the concept of substituting telecommunications for transportation of mail and other messages. As computer technology has more and more packaged information in digital electronic form, telecommunications advances permit the convenient transmission of that information anywhere in the world almost instantaneously. One minor result of that revolution is that people whose work deals primarily with information may be able to work wherever they can "keep in touch" via telecommunications. While the revolution is far from complete, these technologies have already come to play a significant role in most business activities and in many homes.

The telecommunications environment for telecommuting will be significantly affected by the Clinton Administration's stated goal of encouraging investment in the national information infrastructure. The President's recently-announced technology policy specifically notes the importance to the U.S. economy of developing a broadband, interactive telecommunications network -- an "information superhighway" -- linking the nation's businesses, schools, libraries, hospitals, governments, and other users. Funding is planned for the Department of Commerce to make grants to States, local governments, universities, school systems and other non-profit organizations to "jumpstart, the development of information networks.

The Nature of Work

A national economy that was once based on agriculture and then manufacturing is now dominated by service industries. Almost all business activity, including agriculture and manufacturing, is permeated by the creation, use, and distribution of information. As a result, more than half of the national workforce can be described as information workers, and many others spend significant portions of their time with "paperwork" and its modem electronic equivalents. Indeed, more and more of the documents and data that underlie business activities exist first and foremost as computer files, easily transmitted wherever they might be needed. The technology advances described above have made possible a high degree of geographic decentralization of work, characterized by an almost continual flow of telephone conversations, faxes, and overnight express packages on a national and international scale. Customers, colleagues, and suppliers are increasingly likely to be physically distant, linked by modem telecommunications and other services. One result of these changes is that more and more of the work to be done is of a type that can be performed in places where even modest telecommunications capabilities exist.

The Workers

As business has become more information-based, workers have found themselves spending more of their time interacting with computers and other information technologies. A substantial portion of the workforce is now relatively comfortable with these technologies, even in the home. It is estimated that in the United States about 57.6 million workers (45 percent of the labor force) are potential telecommuters. No longer is the computer programmer the only employee spending long hours at a keyboard in front of a screen. But other, more important changes have also been occurring. Quality of life, at home and at work, has become more and more of a national concern, in part a result of the complexities of modem living. The size, shape, and nature of American families are changing; the number of two-parent families continues to decrease. For single-parent homes and families with both parents employed (there is a growing number of women in the workplace), child-care issues can greatly complicate daily schedules. Finding a satisfactory home at an affordable price may force a long and sometimes stressful daily commute, leaving little time for family or other leisure activities. In fact, many people are either unwilling or unable to relocate to where jobs are available.

Further, the image of the normal worklife as 40 years in the same job followed by a gold watch, however inaccurate originally, is gone. A change in values has occurred regarding work and leisure time. This, together with mobility, changing occupations, and family characteristics is changing the workplace. Most workers consider themselves mobile and expect periodic change in employers -- as likely through mergers, corporate relocations or bankruptcies as through their own volition. The best employees can be retained only by

providing a good working environment.

One of the important results of these disparate trends is the importance that workers place on flexibility in their worklife, and the impact this consideration has in their accepting and staying in a particular job. The gradual introduction of various forms of flexible working hours has been a universally popular employee benefit. Another recent theme has been the importance of employee empowerment, recognized by the business community as a key element of high productivity and morale, and by the worker as central to job satisfaction and stress reduction.

The Workplace

The global nature of the modem economy has brought with it an intense wave of competition for all businesses, making increased productivity a prime objective. The business world has come to realize the importance of maximizing not just the output of workers, but also their creativity and the level of quality and customer service in their work. Retention of experienced staff is also a necessity in gaining high overall productivity. One of the most effective ways of achieving these results is to respond to the workers' desire for flexibility and empowerment in the workplace. Many full-time employees currently work flexible schedules or compressed work weeks; flex-staffing or lean-staffing is considered a responsible business approach when an organization needs to expand or limit its operations. Rethinking management styles, redesigning the work elements, and even adopting new corporate cultures is a difficult and lengthy process and not always successful. However, it is increasingly recognized as a part of doing business in the 1990s and beyond.

Urban Highway Congestion and Its Consequences

America has always led the world in its use of the private automobile for transportation, and has developed an unmatched infrastructure of streets and highways. It is a mode of travel that maximizes convenience and privacy, but it has its limits. Many urban regions of the country are experiencing rising peak-hour congestion. The daily commute is, for many workers, the most disagreeable part of their day. In addition to the delays and stress this imposes on commuters and others on the highways, emissions from these vehicles result in poor air quality for the entire region, highway accidents are a recurring event which worsens the congestion, and a substantial amount of petroleum-based energy is consumed.

Environmental Legislation

The Clean Air Act Amendments of 1990 (CAAA) reflect a commitment by the American people to achieve higher levels of air quality, particularly in the more heavily polluted urban regions. Deadlines are set for reduction of pollution in over 100 major cities, which in some cases may require actually reducing auto travel. In some localities, employer trip reduction

programs will place part of the burden of improving air quality on businesses in the area. The severe challenge of achieving clean air goals forces close consideration of every possible means, since it is clear that no single measure, such as tighter emission controls, reformulated gasoline, improved transit or high-occupancy-vehicle lanes, can do the job by itself. The **CAAA** is a major motivation for public sector interest in telecommuting in many areas.

The Convergence of Driving Forces

In summary, many of the jobs now being performed are such that with little or no restructuring they could be performed at home at least 1 or 2 days per week. Employees are ready for, and even demanding, more responsibility for themselves and more flexibility in their lives. Technology already available makes it possible for at least some portion of many jobs to be performed anytime, anyplace. Businesses are seeking means to increase productivity and improve staff retention. Congestion worsens and the deadlines for air quality improvement grow near. Greater national attention is being given to energy conservation with particular emphasis on petroleum-based sources.

It is not surprising, therefore, that there is a steady rise in telecommuting with an even more rapid growth of interest in the topic by individuals, businesses, and governments. Telecommuting is not the answer for every worker. Many factors bear on its practicality, benefits, and overall attractiveness in any given situation. However, it is clearly a phenomenon which will be of growing importance to the way America works and to urban transportation. The degree to which telecommuting is likely to be adopted and the benefits which might be obtained thereby are examined in the remainder of this report.

TELEWORK- A TELETAXONOMY

What is Telecommuting?

The term telecommuting is attributed to Jack M. Nilles who first used it in 1973. He defines telecommuting as a subset of teleworking (i.e., all work-related substitutions of telecommunications and related information technologies for travel). Telecommuting is not a technology or collection of technologies. Rather, it is a work option that reduces dependence on transportation by exploiting information and telecommunications technologies. In many cases, telecommuting can be accomplished with equipment no more exotic than a telephone. However, it is likely that most telecommuters in the near future will be using microcomputers and modems as major work tools; and for some workers relatively elaborate and sophisticated equipment and services may be the norm. In most cases, workers telecommute only a portion of the time, often as little as 1 or 2 days per week. Telecommuting does not require the active use of telecommunications technology in order to be practical, since workers can carry their information with them when they travel

to their employer's office. Nevertheless, telecommunications and computer technologies both greatly broaden the scope and variety of tasks amenable to telecommuting.

In this report the term "telecommuting" will generally be used to refer to company employees in any occupational group working part- or full-time during normal business hours, for whom the commute is eliminated, shifted out of the rush-hour period, or shortened through the performance of the work role at home or at an alternative remote location, and who communicate with the usual place of work using electronic or other means instead of traveling there.

This definition excludes several categories of telework-based substitutions for transportation, some of which could also have significant impacts on transportation:

- Self-employed, home-based workers, private consultants, contract workers;
- Overtime work performed at home;
- Field workers who travel in the course of work;
- Other forms of telework such as teleconferencing, etc.; and
- Geographical or functional decentralization of businesses.

Telecommuting Freauency, Locations and Forms

Full-time / Part-time

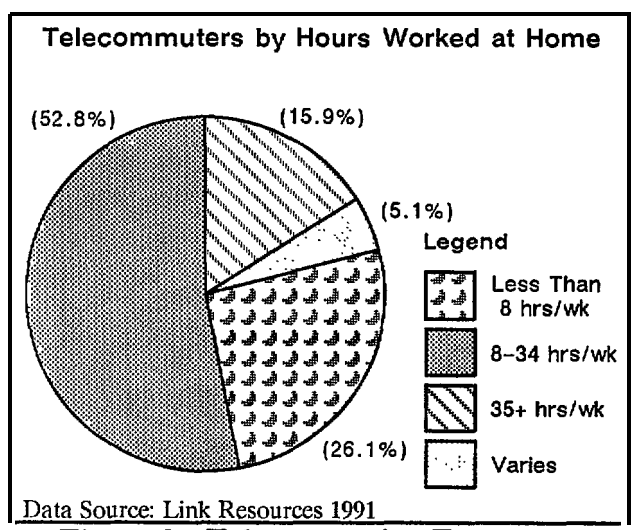


Figure 2. Telecommuting Frequency

In the popular press, telecommuting is often described as full-time home-based work where the worker is almost never in the office. However, current experience, supported by the findings and views of leading experts, suggests that most home-based telecommuting is only partial with time split between home and company offices, including creative scheduling of clusters of meetings for the office, and solo work for home as shown in Figure 2. Over half of all telecommuters work at home l-3 days per week; the average total time worked at home is 18.6 hours per week. Of the 1991 total, 79 percent of all telecommuters worked part-time (less than 35 hours per week) at home Monday through Friday. About 26 percent worked at home less than 8 hours per week. This profile

could change eventually, but appears likely to characterize telecommuting for the next 5 to 10 years.

Locations

There are a number of feasible alternative work arrangements that provide some flexibility in the locational and temporal definition of work. They differ in scope and structure: some require a major reorganization of a number of jobs and people, while others, such as the home-based form, can be implemented on an individual basis depending on the situation. Current telecommuting is predominantly home-based, but many observers see telework centers as playing a much larger role in the future.

Home-Based

In home-based telecommuting, the employee works at home, keeping in touch with the main office by telephone or other telecommunications technologies. It is anticipated that most home-based telecommuters will work at home part-time (l-3 days per week) spending the rest of their work time in the main office or at other facilities. However, some people could be at home virtually full-time. The original sole site of telework was Alvin Toffler's electronic cottage or, under the opposing paradigm, the 'electronic sweatshop' (the home, pure and simple, and full time or close to it). This option is heavily dependent on remote supervision. It does not provide the social interaction that a work center offers. On the other hand, work at home can give employees extreme flexibility in schedule and life style. Child care may be accommodated more easily; for many people with primary child care responsibility work-at-home may be the only employment option. It also offers employment opportunities to the elderly and handicapped. Work-at-home can easily be used as an option on an individual basis to accommodate a particular situation or need either temporarily or permanently.

Regional Centers

An important alternative form of telecommuting consists of working not at home but rather at a special-purpose telework center located relatively close to home. As usually conceived, the centers are equipped with sufficient office automation and communications facilities that they can serve as true extensions of the normal workplace. This approach is particularly attractive for workers who have long commutes. While telework centers do not eliminate travel, they can substantially reduce it. Centers are best located in uncongested areas or near public transit. These centers can take a variety of forms such as the satellite center, regional/local center, and neighborhood center. Their financial feasibility in various circumstances remains to be determined There is also the possibility that regional center telecommuters may move even further away from their place of work when they are no longer commuting to the central business district, thereby negating many of the quantifiable benefits

of telecommuting. Further, if they are not convenient to public transit they could increase total automobile trips.

There are three basic variants of the telework center concept: satellite, local or regional centers, and neighborhood centers. For all of these, the common criterion is that they are close to where the telecommuters live, and the telecommuters work there instead of or in addition to working at home.

Satellite Centers

Satellite centers are facilities established by an organization to serve its telecommuting staff. Note that some of the staff may still have to commute several miles to get to the center as contrasted with travelling tens of miles otherwise.

There has been some confusion as to what constitutes a satellite office. Mokhtarian sees a critical need to include in the definition of telecommuting part-time travel to closer-to-home satellite centers, given the political reality that definitions drive whether large employers are "given credit" under air quality trip reduction ordinances. Guidelines submitted by the Los Angeles based Telecommuting Advisory Council (TAC) to the South Coast Air Quality Management District for determining whether a situation is a telecommuting center are as follows:

- It is part of a monitored Transportation Demand Management (TDM) program.
- The Center is closer to employee's home than central work site.
- Activity must be linked to central office work, results transmitted to central office.
- Employees must be from different companies or different units of same company.
- Employees may be at center full or part time, regularly, or occasionally.
- Supervisors' presence or absence not a criterion.
- No separate employee count or average vehicle ridership is required for the center (except for any nontelecommuting staff stationed there).

Mokhtarian suggests two additional guidelines: location independence (the work can be done anywhere) and organizational structure (absence of a regular self-contained pyramid).

Local Centers

Local center facilities house any number of telecommuters from different organizations. Employees would share space and equipment in the work center closest to their homes. Thus, densely populated areas could have centers financially supported by all of the organizations whose employees use them. Such an option is complicated to implement on a large scale because it requires a great deal of cooperation among different organizations. The state of Hawaii is currently experimenting with a local center, as did Sweden in the mid 1980s.

Neighborhood Centers

Another variation is the neighborhood center: "minicenters, "existing in large numbers, each serving a relatively small number of workers and located within walking distance of their residences.

Jobs with Telecommuting Potential

The most visible classes of work performed by full-time telecommuters are knowledge functions, sales, and marketing. The "knowledge function" or "information worker" category includes reading, writing, customer service, research (in books, databases or by telephone, along with analytic functions of many sorts, while sales functions would comprise calling, planning, and record keeping. Large-scale telemarketing (as opposed to order taking) is most often performed from "boiler rooms" and not homes, both in order to make the most intensive use of the voice-over data lines and to maximize motivation.[5] Parts of many jobs, the totality of which cannot be removed from their normal setting, can be isolated successfully in space and time and performed elsewhere.

LINK Resources conducts a yearly national survey from a random sample of 2,500 households, addressing work-at-home topics. This survey provided the data for all charts in this section characterizing telecommuting and telecommuters. The LINK statistics on Leading Telecommuting Occupations show a very high proportion of telecommuters to be in professions, with only 1 percent listed as clerical workers. Sales and professional specialty occupations constitute the leading telecommuter occupations. The list in Table 1 is not exhaustive but suggests the broad range of jobs that could be suited to telecommuting:

Table 1. Information Worker Jobs

accountant	broker	graphic artist	school administrator
actuary	CEO	journalist	software engineer
administrative assistant	clerk/clerk typist	industrial engineer	statistician
advertising executive	consultant	lawyer	stock analyst
agent	contract monitor	manager	stockbroker
analyst	computer scientist	market analyst	surveyor
architect	data entry clerk	professor/teacher	systems analyst
appraiser	data search specialist	programmer	telemarketer
artist (commercial)	economist	purchaser	telephone operator
auditor	employment	receptionist (sending /	training designer
bankers	engineer interviewer	receiving electronic	word processor
bookkeeper	financial analyst	mail)	writer
		realtor	
		researcher	

Figure 3 categorizes these jobs and presents approximations of the percentages of teleworkers in each category. Certain job characteristics across all job types are suitable to telecommuting:

Minimum physical requirements;
Individual control over work pace;
Defined deliverables;
Need for concentration;
Defined milestones; and
Relatively low need for face-to-face communications.

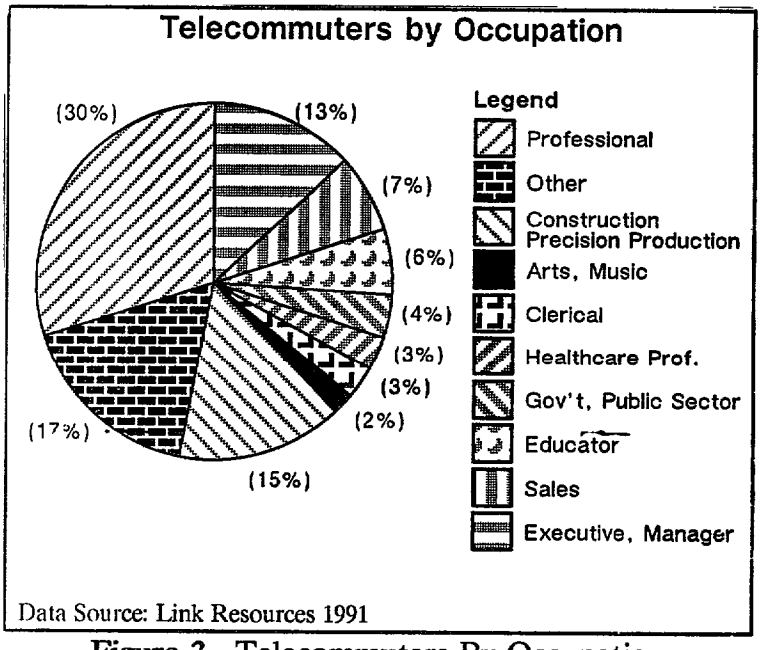


Figure 3. Telecommuters By Occupation

Telecommuter characteristics suitable to telecommuting include: Self-motivation, Self-discipline, Specialized skills, and Ability to work independently.

Note that characteristics of the successful teleworker and job characteristics are relatively independent of the technology involved.[6]

Industry/Company Demographics

Telecommuting Industries

Business Services, Retailing/Wholesaling, and Banking/Finance stand out as the leading industries. Manufacturing, Telecommunications, and Healthcare also rank high in this regard for telecommuting as shown in Figure 4.

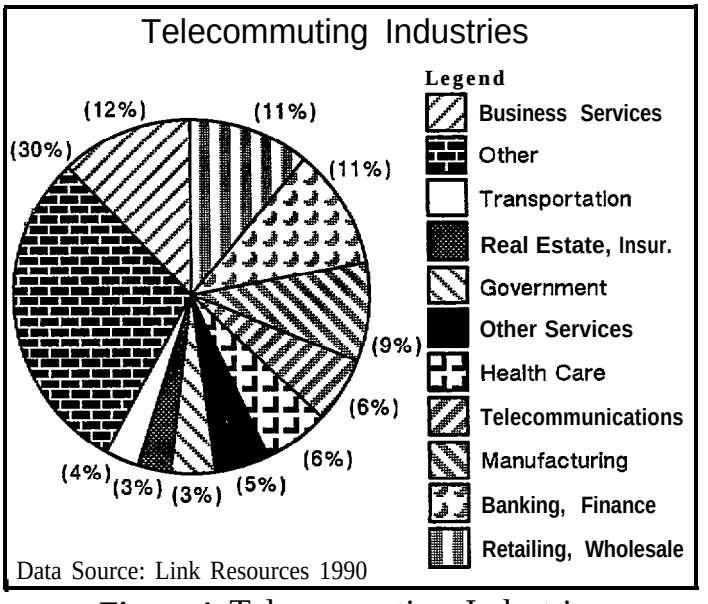


Figure 4. Telecomrnuting Industries

Company Size

Since approximately half of the U.S. workforce work for companies with less than 500 employees, it is no surprise that the majority of telecommuters are associated with smaller companies. As shown in Figure 5, only 4 percent of telecommuters (45 percent of the labor force) work for companies with more than 1,000 employees, while 77 percent are employed by organizations with under 100 employees. Telecommuting in the United States has grown primarily from the bottom up, through individual innovation rather than from the top down, through large-scale organizational innovation.[7] Large, full-time, formal telecommuting programs operated by large well known companies are in the minority. Most telecommuting is strongly associated with smaller companies and organizations for the following reasons:

- Organizational culture is less formal in smaller organizations than in larger ones.
- Innovation is easier and more common in smaller organizations.

- Standard operating procedures are less rigid in smaller organizations.
- Staff flexibility is likely to be equally useful for the company as for the employee in small companies.

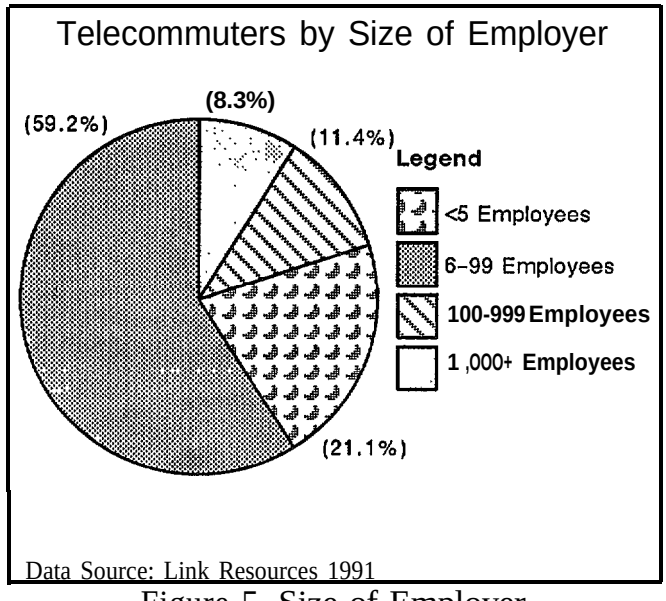


Figure 5. Size of Employer

Formal/Informal Telecommuting

Formal versus informal Telecommuting is illustrated in Figure **6.** The LINK Resources survey indicates that:

- 21 percent of all medium / large businesses (lOO+ employees) support some level of informal telecommuting. This covers 470,000 telecommuters.
- **14** percent of all medium / large businesses (lOO+ employees) support some level of formal telecommuting . This covers 240,000 telecommuters.

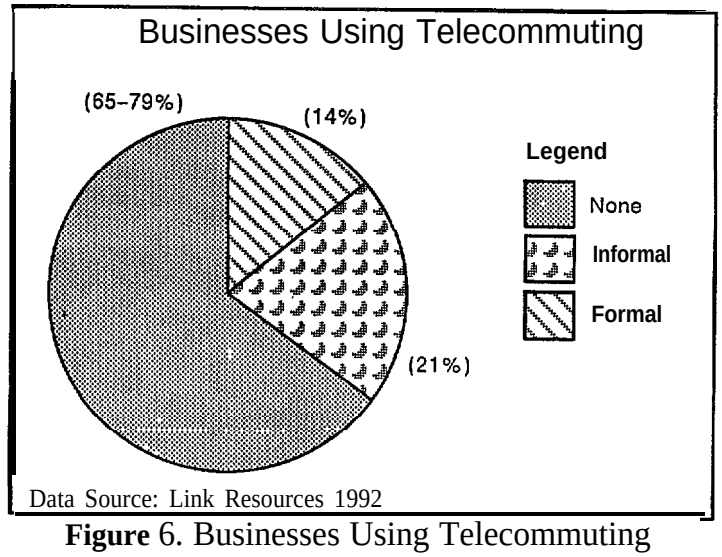


Figure 6. Businesses Using Telecommuting

- 65 percent do not support any telecommuting.

Table 2. Formal / Informal Telecommuting

	Formal			Informal	
	# Telecommuters	% of Companies Using	# Companies	# Telecommuters	% of Companies Using
Small	2.9 million (92%)	13%	819,000 (98%)	1.9 million	
Medium / Large	240,000 (8%)	14%	17,200 (2%)	470,000	21%
Total	3.1 million		836,200	2.4 million	

LINK's data listed in Table 2, shows that telecommuting is growing rapidly among large organizations with over 1,000 employees and small organizations with under 10 employees. Informal telecommuting programs are easy to start and stop, especially if the proponent for telecommuting within the organization leaves.

Technology Used by Telecommuters

Figure 7 shows the technologies used by telecommuters. Personal Computers (PCs) are owned by 36 percent of telecommuters households, over twice the average for U.S. households. Other tools include:

- Telephone Answering Machine – 70.4 percent (3.59 million)
- Modems – 16.2 percent (.83 million)
- Fax Machine – 7.4 percent (.38 million)

The one thing that almost all (95 percent or more) telecommuters rely on is basic residential telephone service; 26 percent use more than one phone line; 46 percent of telecommuters are reimbursed by their employer for long distance phone calls. The use of multiple phone lines and other telephone services and devices has accelerated much faster among telecommuters than in the overall labor force.

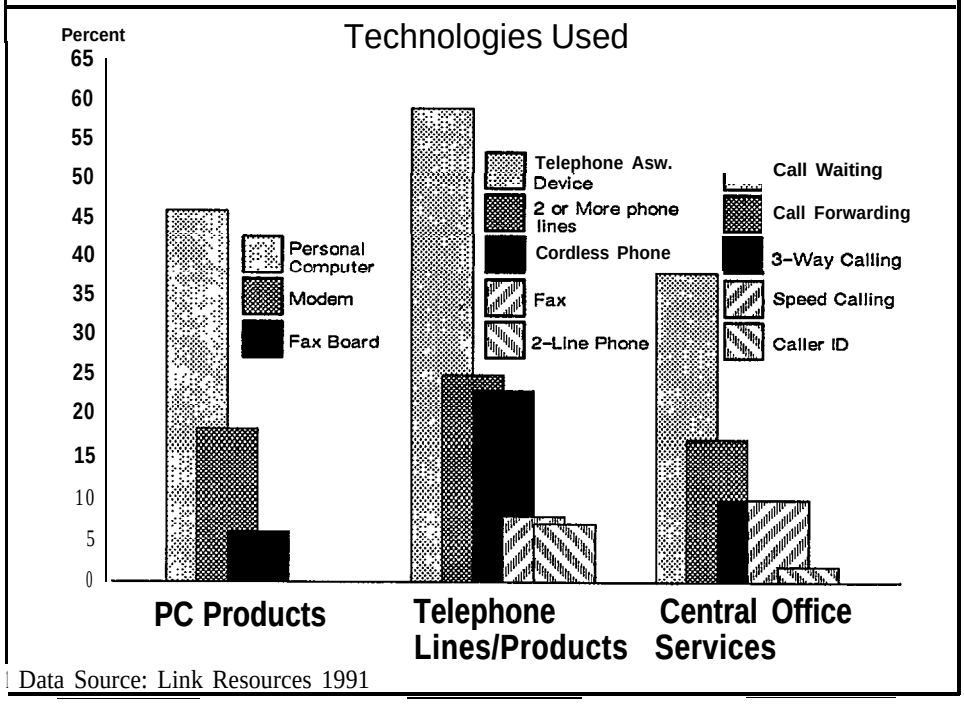


Figure 7. Technologies Used

SCOPE AND NATURE OF CURRENT TELECOMMUTING

The 1992 LINK resources survey estimates the number of conventional employees currently telecommuting at 4.2 million, up 27 percent from 3.3 million in 199 1. Sampling error for the survey is reported to be plus or minus 9 percent.[8] This figure represents 3.3 percent of the total U.S. workforce. However, LINK further estimates that 1.8 million of those employees are working at home on contract or on self-employment activities rather than as part of their basic job. This leaves 2.4 million people telecommuting as part of their regular work. Based on prior LINK surveys, this has grown from .4 million in 1990 and 1.4 million in 1991.

A second estimate of potential telecommuters, provided by Jack Nilles, is based on a 1985-1986 survey, using the Blackman version of the technological substitution curve (Linstone and Sahal (eds.), 1976). This estimate predicts between 2.0 million (nominal case) and 4.4 million (high acceptance case) telecommuters in 1992 increasing to between 15.0 and 30.4 million in 2002.

Telecommuter Demographics

Figures 8 and 9 illustrate the 1991 data compiled by LINK Research's National Work-at-'home Survey which show a fairly even distribution of men (53 percent) and women (47 percent). The typical telecommuter is between the ages of 35-37, and 76 percent are part of a dual career household, with a median income of 40K. About half have children under 18 at home, and just under one-fourth have children under 6 years old.

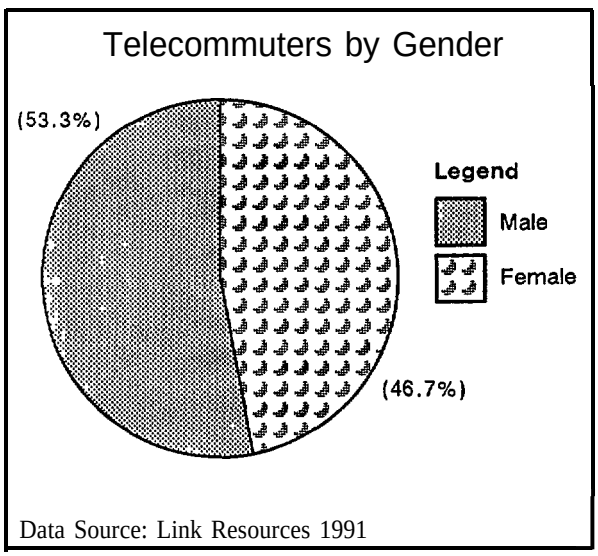


Figure 8. Telecommuters By Gender

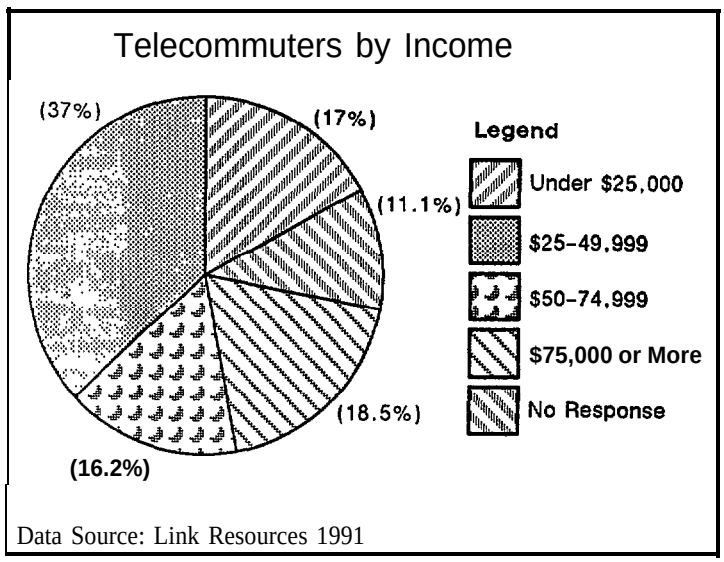


Figure 9. Telecommuter Income

Telecommuting Arrangements

Telecommuting is increasingly accepted by employers, often on an informal "off-the-books" basis, to enable continued workforce contributions in a range of personal circumstances necessitating temporary part- or full-time absence from work. These temporary and transitional applications include maternity leave, temporary care of children or elderly parents, injuries and illnesses, temporary relocations, and phased retirements. While increasingly accepted, these are basically seen as concessions to valued and privileged professional staff. More permanent programs are centered around sales, telemarketing, customer service, and data/forms entry staff.

For employers, telecommuting arrangements are also found helpful to make at least partial use of personnel away at special training and education activities, and to fill needs for peak part time and seasonal work. Also many companies are encouraging telecommuting as one aspect of the adoption by senior staff and executives of high tech/high performance workstyle.

Physically Challenged

Telecommuting would seem to be a natural approach to increasing employment possibilities for disabled or functionally challenged individuals.[1] However, there is relatively little discussion of this topic in the literature. Only small numbers of handicapped persons seem to be employed, despite government programs designed to promote activity. LINK Resources' case studies mention some instances of handicapped workers, but it appears that many of these initiatives have been phased out. The literature mentions placement programs for disabled workers, many of which showed good results.[9] On the other hand, there are also reports of cases of disabled workers who found long hours at a terminal very difficult physically and socially isolating.[10] Many of the efforts for the disabled were discontinued in funding cuts that were due in part to the current preference of vocational rehabilitation specialists for mainstreaming. Huws et al. suggest that disabled workers need sociability as much as income and indicate that satellite or neighborhood centers would be more appropriate venues than homework. [11]

Control Data Corporation ran a very productive program for disabled workers in which the only major problem stemmed from inexperienced or otherwise inadequate managers. A state of California project involving approximately 150 mostly professional level workers, which included mentally disabled workers, did find that telecommuting reduced commuting stress for these workers.

OTHER RELATED TELESUBSTITUTION

Incarcerated Workers

Prison populations are becoming a regular element of certain telework schemes. Inmates at Arizona correctional facilities are employed as reservation agents for Best Western. They receive the same wages and benefits as non-prison workers and part of their pay goes to victim restitution as well as part to the state to pay for room and board. This can also be a valuable job training tool, as the company has hired 50 women after their release." In an arrangement with the California Youth Authority, TWA routes calls from around the country to Camarillo, California, and provides training and geography classes to the students. Their compensation is the same as agents in TWA's Los Angeles office.

Teletransactions

Teletransactions include the many instances where orders are placed within and between businesses (or between individuals and companies, as in computerized stock trading) by computers over private networks or public telephone lines or, as in telebanking, by means

of touchtone lines. As money and stocks are basically "moved" electronically, consumer transactions are also transformed. Teleinvesting combines access via personnel computer to stock quotation services with computerized order placement. The faxed transaction, whether used to settle insurance claims, provide documents, or buy lunch, is a more and more common replacement for mail, phone calls, or personal delivery of documents, depending on the time and space constraints of the particular transaction. "Teletaxes," a subspecies of teletransactions, were quickly democratized as microcomputers and modems entered the home and small office, a situation mutually advantageous to the IRS and the taxpayer as data entry is shifted out of the IRS and the taxpayer gets a speedier refund check.

Other Telesubstitutions

In addition to telecommuting, a growing number of situations are occurring in which telecommunications are substituted for in-person acquisition or performance of services. In the near term they are not likely to have a strong impact on transportation, but the cumulative effect could eventually be significant -- it could affect transportation directly, and also indirectly through its impact on land use, which affects public transportation. Moreover, increasing public acceptance of services that generate a broader market for sophisticated telecommunications services will contribute to the availability of these services for telecommuting. These other telesubstitutions include:

- Teleeducation
- Teleshopping
- Telebanking
- Telemedicine
- Telejustice
- Teletaxes
- Televoting

Teleeducation; Telelearning

Teleeducation, or distance learning, involves the use of satellite, microwave or cable television systems to transmit classroom instructions to one or more remote locations (classrooms, homes, etc.). This could involve receipt of assignments and exams, submission of homework via screen or computer keyboard, access to electronic libraries, face-to-face counselling, and even participation in class discussions. Teleeducation minimizes commuting by students and professors and can serve students in remote locations and those physically unable to appear on campus. More modestly, efforts have been reported in congested areas like New York to replace some class meetings and in person conferences with telephone conferences and video presentations. Elements of teleeducation have entered the university generally as students increasingly collect and

submit assignments and search library catalogues and databases from their home computers.

Teleshopping

Teleshopping is the use of computer or television-based services to purchase a full range of goods, including food, fashion goods, housewares, gift items, etc. Consumers view goods, have products delivered, make payment by direct debit or credit card, etc. While typically performed using television receiver and telephone, it could be accomplished in a direct interactive mode. Teleshopping is quite different from the premall variety of calling up the local grocer to deliver an order. It is typically a long-distance, 24-hour activity. Home shopping services using television and 800 numbers have penetrated certain parts of the market. Extensive computer shopping networks that allow price comparisons of electronics, appliances and other major goods have achieved limited market penetration so far, but that penetration is among an affluent and influential market segment. Local teleshopping services for supermarket staples are becoming common in Europe but have not become usual here -- these are variations of catalogue ordering services.

Telebanking

Telebanking involves the use of a computer and modem and/or touch-tone phone to perform financial transactions such as making direct electronic deposits, obtaining instant access to balance, electronic checkbook balancing, obtaining automated financial services, etc. Telebanking is now seriously supplementing the automated teller machine, and certain of these functions are now offered automatically by many banks. Transfer of funds between accounts, bill payment, and account information are now available as totally automated functions from touch-tone phones to ATM card holders, and other information and loan qualification services are partially teleautomated, with touch-tone routing to the human-provided portions of these services.

Telemedicine and Telediagnosis

Examples of telecommunications substitution include: medical consultation and monitoring; telemetric devices that monitor heart rate and other vital signs, and transmit the patient's information to a doctor at another location; direct transmission of data to the medical computer for automatic analysis; sophisticated imaging (MRI, CAT, x-ray) transmittable over phone line or from emergency vehicles via cellular radio; and face-to-face counselling from the doctor at a remote location. Doctors and other health care professionals can gain instant access to patients' medical histories and visual records, simultaneously viewing information on screen and discussing it.

Telejustice

Depositions and arraignments can be handled through video conferencing links between the courthouse and prison, thus avoiding the need to transfer prisoners.

Televotiug

Tele-voting in the sense of casting a ballot for a candidate for office has not yet become a political reality. For years, however, cable television and talk radio stations have used push-button calling to do extensive electronic polling on every conceivable subject to directly ascertain popular agreement or disagreement with government policies.

Bulletin Board Services

Computer bulletin boards have been characterized as “the 1990s answer to those mythical general stores of a century ago where you could find a congenial group of people gabbing around a blazing wood stove."[13] Some 44,000 public bulletin boards serve functions as diverse as publishing fiction and matchmaking. Many families are already using online computer services at home like CompuServe, formed in 1969, which now has more than a million users. Prodigy, a partnership of IBM and Sears, has 1.75 million subscribers who can shop, bank, make travel reservations, get stock market quotes, get updates on news, weather, sports and much more without leaving their homes.

Information/Entertainment

Examples of news/information services include the sale of news wire, stock information, databases, etc., as well as general or specialty news content. Entertainment services include pay-per-view movies, special sports programs, cultural events, pay-per-listen radios, and video games. Many special information services are available: opinion or market research surveys, association proceedings and records, minutes from club meetings, etc.

TELECOMMUTING DEMONSTRATIONS

Examples of Existing Programs

Worldwide, telecommuting programs may be found in the public and private sectors. At least hundreds of organizations have tried or currently possess telecommuting programs. A selected number of examples have been presented to give a flavor of the range and type of existing programs. Details regarding the kinds of jobs and workers best suited to telecommuting, tradeoffs for employers and employees, and other aspects of telecommuting which have been learned from these and other demonstrations, are also discussed.

Appendix C contains basic descriptions of telecommuting projects. These pilot projects or programs represent a sample and cross-section of U.S. organizations with employees who telecommute one or more days per week. The selected projects (one a pilot program which has since ceased) represent only a small portion of telecommuting demonstrations and programs. The projects were included based on their different aspects (as defined below) and the availability of published information concerning the project or the provision of information from project advocates. Great care must be used in interpreting the results of these and similar projects, since they are typically limited in size, duration, and nature, and involve carefully selected groups of employees.

The material presented in the appendix represents public- and private-sector telecommuting projects. Government plays a dual role by creating telecommuting options for Federal-, state- and county-level employees, as well as fostering the concept in the private sector (see Puget Sound and California-based projects). Telecommuting, while often conceived and implemented by individual businesses, is also fostered by state governments seeking to reduce transportation problems, create new business and economic opportunities, or simply offer employees greater flexibility in managing daily schedules. For example, the Washington State Energy Office (WSEO) is working with other state government offices and private businesses to establish telecommuting opportunities for state and commercial employees as a means of reducing energy consumption and vehicular congestion on Seattle's highways. For information on traffic congestion, management, and planning, see projects based in California and Oregon.

The telecommuting pilots and programs described in Appendix C were formally implemented. In most cases, participants consist of information workers, such as managers, administrators, and customer service representatives, who perform much of their work using telephone communications or computer systems personnel involved in programming, systems management, or other forms of data processing. Participants were volunteers, thoroughly screened and approved by management for participation.

One of the richest sources of actual data on telecommuting is the California Telecommuting

Pilot Project, which ran from July **1977,** to June 1990. Actual telecommuting and travel behavior of over 150 state employees was monitored for two years, beginning in January, 1989. Many of the preliminary conclusions in this report concerning telecommuting and its travel impacts were derived from analyses associated with this project.

Allowing employees to work at home or at neighborhood satellite operations, such as telework centers, are two basic options for telecommuters. WSEO established a telework center in Seattle where employees from various state offices could conduct business one or more days each week (see Washington State Telework Center). Other telework centers, providing an office environment, technological tools, and support, are being implemented in California (see Los Angeles County Telecommuting Project), Kentucky, and New York City.

The reasons organizations pursue telecommuting vary. Sears instituted telecommuting to retain valued employees following a relocation of the work place. Some programs were implemented to reduce employees' costs in terms of fuel, time, and stress, while also decreasing the number of employees in crowded facilities. Other projects were implemented and maintained because telecommuting increased productivity and profitability.

All the telecommuting projects sampled indicate qualitative improvements in employee work and home life. Productivity gains have also been studied and documented (see Sears "Over the Rainbow" and the Los Angeles County Telecommuting projects), as well as other benefits such as decreased sick leave and absenteeism. In most cases, determination of the level of productivity gains and other benefits to employers has been based on subjective surveys of employee opinion.

Implementation / Practical Telecommuting

Effective implementation of a telecommuting program involves more than just providing equipment and expecting benefits. Implementation can be a complex process requiring careful management to succeed. There are many practical and management considerations in implementing a telecommuting program, including planning, selecting jobs, selecting and training employees and managers, linking telecommuters to the office, liability concerns, and technical details. In the past, many such programs have failed because of inadequate planning and/or poor management.

Telecommuting pilot programs have enabled organizations to assess the economic reality of telecommuting, to determine the benefits that can be expected from participants, and to review manager-employee interaction. The results of such projects have eased concerns by showing that potential problems can be addressed satisfactorily with proper planning. Pilot projects have shown that:

- Labor concerns can be allayed by ensuring participation early on.
- Effective management can be maintained.
- Security risks need not be any greater than those on-site.
- Insurance issues can be handled through telecommuting agreements.
- Telecommuting need not affect a worker's employment status.

Chapter 2 - Factors Affecting the Future Degree and Impacts of Telecommuting

INTRODUCTION

The objective of this chapter is to identify and assess issues which will determine the level of adoption of telecommuting. As with the introduction of any broad societal innovation, there are a variety of potential barriers to implementation. These barriers can be technological, institutional, legal, or societal in nature. This chapter outlines the major factors affecting implementation of telecommuting. Specific emphasis will be placed on topics that appear to be the greatest impediments, involve a government role, and are least understood.

Whether an individual telecommutes and how often are results of the decisions of employer and employee, made within the constraints of the existing technical and legal environment. Many separate and often complex considerations can affect these decisions, making estimation of the future level of telecommuting an uncertain task at best. Many projections in the technical as well as popular literature are based on relatively arbitrary assumptions that the workforce can be divided into "information workers" and all others, and that some percentage of the information workers will telecommute. Since telecommuting is still at an early stage, with no large-scale, long-term experiences to draw on, it is difficult to go beyond this very approximate approach. However, explicit consideration of the principal factors bearing on employer and employee decisions is necessary if the assumptions are to be reasonable and credible.

The definition of "information worker" -- someone who is primarily concerned with the creation, distribution and use of information -- is very broad, covering a great variety of activities. The implied notion that telecommuting is not relevant to people who operate equipment (truck driver, farmer, autoworker) or interact constantly with other people (salesperson, receptionist, doctor) is a reasonable starting point, supported by the fact that estimates exist for the number of information workers -- generally assumed to be somewhat more than half of the working population.

However, the limitations of this assumption should be kept in mind. Many jobs, whether or not they are classed as information-related, are a mix of various attributes, which may be quite separable. Telecommutina is not an all-or-nothing activity. It can easilv be practiced onlv 1 day per week or less, and therefore, may be well suited to dealing with accumulated paperwork, writing reports, reading, planning, and thinking, regardless of the basic nature of the job. On the other hand, some "information" jobs may be so closely integrated with other activities and people that telecommuting is not a viable option.

The more critical question, often overlooked in the popular literature, is the frequency of telccommuting. It is not uncommon for writers on the subject to assume full-time telecommuting, whereas current experience suggests an average of between 1 and 2 days per week at home for most telecommuters. Hence, estimates of the impact on transportation of telecommuting can vary widely.

The purpose of this chapter is to describe the factors that bear on the telecommuting decisions of employers and employees and the degree to which technical and legal barriers may impede telecommuting. With this foundation, a baseline estimate is developed of the near-term degree of telecommuting. This baseline also assesses the timeframe in which the projected level might be achieved by taking into account typical rates of adoption of technical and managerial innovations.

PERSPECTIVES ON TELECOMMUTING

The future will not simply be determined by information technology and its potential for transforming the nature and location of information processing work. The technology is a tool with many possible applications. And these applications will, in turn, only be adopted and implemented by individuals and organizations which can see how to facilitate the achievement of their own current aims. Telework will be adopted only by those managers who see it as a solution to their problems and workers who see it as a solution to their nceds.[14]

An understanding of the potential advantages and disadvantages for employers and employees is critical to the credibility of estimates of the number of telecommuters. The principal advantages, disadvantages, concerns, and issues associated with telecommuting, from a variety of perspectives, are summarized in Table 3.

Telecommuting provides compelling economic and family benefits to both employers and employees. Experience with telecommuting projects confirms the benefits that telecommuting brings to employer, employee, and society.

Table 3. Perspectives of Telecommuting

From the point of view of the:		
Employer	Advantages	* Increased productivity * Reduced facility space and expenses * Labor economies, possibly via lower pay, benefits for workers * Difficult shifts covered * Retention of valued employees and access to wider (even multinational) labor pool; reduced retraining * Lower sick leave utilization; reduced health care costs * Telework can be used as a casual pool to protect against downswings in demand * Savings in relocation expenses * Off-hour utiliition of mainframe computers * Savings on shiftwork, overtime * Improved motivation of employees
	Disadvantages	* Change in basic organizational practices required * Competition from offshore and out-of-market labor * Possible increase the need for computer resources
	Issues/Concerns	* Decreased productivity * Loss of corporate culture, deterioration of office environment quality * Trust and control of employees, including how to monitor * Worker accessibility * Lack of organizational experience in remote supervision and management by objectives * Union opposition / organized labor concerns * Security, confidentiality of property and ideas * Insurance issues * Health and safety issues
Employee	Advantages	* Reduction or avoidance of commuting time, expense (gas, transit fees, depreciation), travel stress * Cost savings on wardrobe, parking costs, meals * Proximity to family and community * Autonomy and control over work conditions, schedules * Relaxation of time-space constraints of formal workplace * Improved quality of life
	Disadvantages	* Speedups and/or electronic monitoring in some cases * Forced subcontracting * Lack of support
	Issues/Concerns	* Exacerbation of existing family problems ** Isolation from colleagues * Tendency to overwork * Pressure to work harder to justify telecommuting * Career sidetracking * Possible lower wages, benefit losses * Widening of money and autonomy gaps between sexes and classes of workers

Table 3, continued - Perspectives of Telecommuting

From the point of view of the:		
Transportation Planner	Advantages	* Reduced total and peak hour vehicle miles travelled, energy consumption * Leveling out of peak hour transit use * Reduced infrastructure maintenance; need for expansion * Possible mitigation of land use pressures * Mitigation of congestion and air pollution * Reduced traffic accidents and attendant economic and social costs * Possibly decreased local infrastructure maintenance * Possible positive mode change effects from - e.g.,walking, biking for errands
	Disadvantages	* Not under the direct control of public agencies
	Issues/Concerns	* Uncertainty as to the magnitude of transportation benefits * Uncertainty as to whether congestion will actually be reduced * Unknown impact on car and van pooling and transit use * Possible residential relocation farther out
Telecommunications Industry	Advantages	* Enhanced demand for telecommunications products and services
	Disadvantages	
	Issues/Concerns	* Increased pressures on capacity and capability of existing networks * Multinational opportunities and connectivity, political problems * Extent of government interest, infrastructure assistance, regulation unclear * Degree of technology that is necessary * Compatibility of technologies
Society in general	Advantages	* Increased energy conservation * Control of infrastructure costs for construction and maintenance * Cleaner air * Less highway congestion * Improved highway safety * Contribution to healthy business climate * Stronger connections of workers to families (Quality of Iife) * Greater sense of community for employees and neighborhood residents * Positive impact on local businesses
	Disadvantages	
	Issues/Concerns	* Possible acceleration of downtown abandonments * Land-use / sprawl

EMPLOYER BENEFITS AND CONCERNS

Potential Employer Benefits

The following potential employer benefits are often cited as reasons, motivations, or justifications for implementation of telecommuting programs.

Improved Quality of Work Output

Work quality can improve through faster customer processing, fewer errors, shorter response times for communications, and faster and more accurate responses to production failures. In particular, performance of creative work can benefit from the person's having greater flexibility in the work situation and scheduling. Quality of a Workgroup's performance can also be affected by improved (often electronic) access to specific people on the team with special expertise.

Reduced Overhead

The potential for reducing the need for expensive central business district office space, greater use of computer resources, and fewer parking space requirements is very attractive to businesses. Office space savings amounting to between 30 and 40 percent of currently leased space is not uncommon. Another author suggests that office space savings amounting to from $1500 to $6000 per person per year is a possibility [Gordon 1987].[15]

Public Relations Value

Hiring the otherwise unemployed or underemployed worker with limited mobility or access to reliable transportation has public relations value and also contributes to general societal goals such as reduced pollution, congestion, and gasoline consumption.

Increased Productivity

Productivity increases reported from various studies average around 10 percent to 20 percent [Miller 1986][16], although some reports are as high as 40 percent. The literature reports productivity gains ranging from 15-25 percent found in a wide variety of telecommuting situations, **even** where researchers (or workers or managers) had not expected them, and better quality work was also reported throughout.[17] Indeed, it is hard to find a report or study that does not report these. On the other hand, Hartman et al. found that the hypothesis that greater amounts of time spent at home would mean greater productivity was not supported. Care must be used in interpreting the results of these projects, since they are typically limited in size, duration, and nature, and involve carefully selected groups of employees. See Table 4 for possible factors contributing to increased productivity.

Table 4. Possible Factors Contributing to Increased Productivity

Productivity Improvement
More Hours Worked per Day • Some employees may work some of the time they would have been commuting • Less nonproductive socializing • No decompression time • Facilitates evening, weekend work
More Work Done per Hour • No interruptions/distractions (assuming appropriate telecommuting setting) • Work done at times which are suited to individuals internal clock • Moving tasks off mainframes, or shifting to off peak hours, increases productivity for those left on-line • Group norms not followed
Less Time Missed from Work • Less incidental absence • Less sick leave

Handling of Work Overflow and Scheduling Fluctuations

Use of home-based workers can ease the difficulty of hiring, retaining, and mobilizing on-call workers in some areas. JC Penney finds home-based telecommuters the answer to fast on-call operations. The part-time workers, recruited in-house from experienced telemarketers, receive the same pay and benefits as on-site workers and are managed by phone or electronic mail and by twice-monthly visits."

Coverage of Difficult Shifts

Similarly, unpopular shifts may be more easily filled if no travel is involved, i.e., work from home is possible and/or a wider labor pool is available.

Meet Temporary Ad Hoc Needs

The potential for meeting temporary needs using existing workforce can be maximized by allowing existing staff to do extra work at home.

Cost Savings

Cost savings could be achieved through reductions in office space and energy, and parking spaces. Credits may be earned under air quality and congestion reduction plans. However, workspace-related benefits may not be achieved for part-time telecommuters unless some form of office-sharing is established.

Improved Employee Recruiting

The option to divide time between in-house and remote work can be an important recruiting option where lifestyle, family, or other similar issues are vital to a valuable prospect. Telecommuting provides access to a larger and possibly lower-cost labor pool, including handicapped, elderly, incarcerated, and geographically remote persons.

Improved Employee Retention / Decreased Turnover

Many telecommuting programs have been initiated in an effort to attract and retain specialized talent regardless of location. Telecommuting can be a selling point for technical talent whose lifestyle or family needs are incompatible with daily commuting.

It is claimed that organizations can expect to have less turnover with a telecommuting program. This can save a great deal; some estimate the cost of training a new employee at between $20,000 and $25,000. Pacific Bell has determined that recruiting and training a skilled programmer can typically cost $100,000 [Miller 1986][19].

Eased Facility Moves and Avoidance of Employee Relocation

When a business location is changed, the cost of relocating workers can be quite large. This component has been valued at an average cost of about $32,00Ofor home owners and $9000 for renters [Miller 1986][20]. Others put these relocation costs at between $30,000 and $50,000. Telecommuting may make it feasible to move a corporate facility with minimum of relocation or loss of employees.

Reduced Absenteeism and Sick Leave

Pacific Bell reports that telecommuters exhibit 25 percent less absenteeism than do employees who work in their Central Business District offices [Pacific Bell 1988]. Telecommuters in the state of California Telecommuting Pilot Project reported an average annual decrease in sick leave of 1.1 days. Several telecommuters reported that they would otherwise have been on even more extended leave because of illness, maternity or parental leave. Similarly, many telecommuters report that doctor and dentist visits now do not require taking sick leave since they can be fit into the regular telecommuting schedule without reducing work time. There is a further possible gain in sick workers staying home and telecommuting rather than infecting others at the office. Also, telecommuting may allow employees with illnesses or injuries that limit their mobility to do some work in a comfortable home setting and to more readily "work around" personal appointments, deliveries, etc.

Extended Computing Capability

Telecommuting could allow a company to delay the lease or purchase of computers by shifting more of the workload to off-hours if telecommuting results in spreading of the workload over a longer day.

Labor Cost Savings

Cost savings can be achieved by removing work from metropolitan locations (for example, by JC Penney, who set up home teleordering operations in the Far West) in 24-hour operations. Also, savings in overtime labor may result when additional at-home shifts can thus be arranged.

Continued Operations in Special or Emergency Situations

Telecommuting can be used as a tool in disaster management -- the workforce can remain productive while lessening the impact on the transportation system -- or when access to the normal worksite is impossible or impractical. Telecommuting could diminish work stoppages in emergency situations, earthquakes, storms, etc. Examples include the 1984 Los Angeles Olympics and San Francisco earthquake. Pacific Bell's policy, set after the Loma Prieta earthquake, demonstrated the value of telecommuting in emergencies. It defines ground rules for what is generally part-time voluntary telecommuting, guarantees workers their basic salary and benefits, and the right to be evaluated on results.[21]

Clean-Air Mandates

Telecommuting may help business to achieve trip-reduction mandates imposed by local or regional agencies to bring air quality improvements.

Emplover Concerns

Organization-level Institutional Barriers

Lack of organizational and institutional experience of remote work constitutes a considerable barrier to be overcome. [22] Organizational disadvantages frequently mentioned in the literature include concerns that telecommuting employees will not be working; that employees will use proprietary information or company equipment while working part-time for another company; and that employees might farm out work to somebody else, further reducing organizational control over sensitive corporate information and work procedures. In addition, there are security risks inherent in allowing outside computer terminal access to company databases and need for maintenance and control of company equipment placed in employees' homes (not only the potential damage or abuse to equipment but also the

additional insurance problems that arise when equipment is off-site). Other problems include determining who is responsible for repairing and transporting such equipment and how the employee should be compensated when the equipment is down.[23]

Management Attitudinal Issues

Many commentators believe that present organizational structures and managerial attitudes form a major barrier to the rapid spread of telework. Olsen states that resistance from managers and the strength of organizational culture are the main reasons why telework is still a comparative rarity (Olsen, 1981,1982,1983,1988). The prevailing philosophy in large corporations is one of encouraging close identification with the company by its employees.[24] Managers worry that company loyalty will wane among telecommuters.

Remote Supervision and Management

Management of remote workers may be beyond the capabilities of managers who rely on frequent visual contact to reassure themselves that their staff are really working. The successful management of teleworkers requires trust and the development of new supervisory methods which are contrary to the management style currently practiced in most organizations. A Phillips Business Systems survey found fewer than 10 percent of managers in favor of telework, while 60 percent were opposed, saying that they needed the interaction of individuals in offices to work effectively. In a University of Minnesota study, 53 percent of the managers said they thought that telework was difficult to manage. This was perceived as the greatest problem posed by telework to organizations.[25]

A major deterrent to telecommuting is resistance to change on the part of managers. Of particular importance is the attitude that effective management requires large amounts of direct visual observation and/or frequent face-to-face contact. Because of the loss of ready visual cues managers must move from a process to a product orientation when dealing with their subordinates; they must be significantly more concerned with identifying and negotiating for specific results than monitoring work activities. It appears that management apprehensions about loss of control and unrewarded effort are currently the pacing factors in the adoption of telecommuting.[26]

On the other hand, Niles states that none of these "resistance factors" appear sufficient in itself to act as an absolute barrier, although the combination of factors can be, and has been, a significant deterrent to telecommuting. Many of the resistance factors appear to be steadily diminishing in effect as more experience (hence confidence) both with personal computers and with telecommuting is accumulated.[27]

Based on studies conducted in California, the potential negative effects of managerial resistance have been demonstrated to be real and of concern. Telecommuting can highlight

both the strengths and weaknesses of existing management practices, and more specifically managers. Good workers and managers thrive, poor workers and ineffective managers resist change and stand in the way of implementation.[28] Training for both employees and managers can help overcome these issues.

Organizations wishing to institutionalize telework are required to find innovative solutions to completely new organizational problems, such as the supervision, coordination, and motivation of a dispersed workforce; challenges to traditional hierarchical functions and to the principle of authority; finding ways to bypass the role of middle management; and other problems of communication, dialogue, feedback, and loyalty to the company. Improved technology and an advanced network infrastructure can help this transition. For example, affordable and readily accessible video conferencing capability would enable employers and employees to interact in relatively traditional ways, wherever the worker might be. Nevertheless, telework requires a management system that supervises the output (results of work) rather than the input (ways of working, working time, etc.), concentrating on decentralization and involvement rather than centralization and control. Assuring motivation and accountability will be more difficult.[29]

Potential Employer Disadvantages

There are also costs and potential disadvantages to the employer in supporting a telecommuting program. Principal possible disadvantages discussed in the literature are identified below.

Security Issues

Security and confidentiality issues present many challenges: lack of institutional control over the workplace and the greater use of technology will increase the risks of theft, forgery, and untimely disclosures.[30]

Data security has been cited as a major problem for some firms, while other business people deny that it is a problem. As recent "computer virus outbreaks" illustrate, a lapse in computer security is like an illness; once it happens, it can be a serious problem. Otherwise, one doesn't think much about it. Security systems, which include passwords and other techniques, are improving rapidly and much can be done (at a price) to solve this problem.

Reduced control over sensitive corporate information, work procedures, and security risks are frequently mentioned as barriers to telecommuting.[31] This can be dealt with by taking steps to assess and upgrade the current security program; identify incremental risks; and improve monitoring and control. Security is based on four main principles: 1) adequate hardware and software controls; 2) sound employee selection criteria; 3) management control and audit; and 4) password control (including the use of a hierarchy of passwords to limit access).[32] Implementing these controls will greatly reduce the risks. Legal sanctions to make unauthorized

access a crime are also important.

It is unknown to what extent security concerns may have prevented the adoption of telecommuting in some quarters. In theory, stealing, corrupting, or destroying confidential information in computerized form ought not to be much easier from home than from the office. A double password implemented in software, and a host-to-remote terminal callback procedure satisfied the concerns of IBM executives about placing terminals in remote locations and was adopted by most of their Information Services departments; the capability was enhanced during the experiment: a handshaking system to identify the remote terminal and requester, and encryption were added.[33] Although this was not a telework study, most programmer and information system user comments addressed not having to make extra trips to work to take care of problems occurring off-shift.

Security techniques require a review and evaluation of each specific situation -- who uses the computer, what software systems are in operation, and so forth -- in order to select appropriate techniques. These may involve a hierarchy of passwords, procedures for changing and assigning passwords, formulating company policy, and increasing user awareness of the need for precautions.

Currently, computer crime legislation is focused on information that is accessed, stolen, or manipulated. The Data Processing Management Association (DPMA) adopted a model computer crime act in 1987 to guide state legislators in developing new laws.

Startup and Operations Costs

The cost of implementing telecommuting can include (1) equipment purchase or lease, particularly telephone lines and terminals or personal computers, and sometimes office furniture; (2) satellite or neighborhood work center setup; and (3) manager and employee preparation and adjustment, such as training programs and installation of enhanced communication facilities. Overall, costs per telecommuter can range from a high of $6000 or more in initial one-time setup costs and $200 per month for administrative overhead and services [Miller 1986][34] to as low as $100 to $200 in setup costs and $50 to $100 monthly for other costs.

Less Employee Loyalty

Some managers are concerned that the telecommuter will have less company loyalty and be more like a freelancer.

The Business Fii Might Look Less Credible

The company "uniform," the corporate headquarters, and other symbols of the company's stature may be important for business. Telecommuters working at home or at a satellite center may not

enhance that aspect of the company's image.

A Change in Managerial Style May Be Required

While some supervisors feel that managing telecommuters is no different from managing in-office employees, others report that it is more difficult, for example, in the areas of assessing job performance, communicating, and maintaining a sense of teamwork.

Numerous writers on the subject of telecommuting have pointed out that the resistance of managers (especially midlevel managers) to telecommuting is one of the chief obstacles to its implementation.

EMPLOYEE BENEFITS AND CONCERNS

Potential Employee Benefits

The following potential employee benefits are often cited as reasons, motivations, or justifications for employee participation in telecommuting programs.

Decreased Commuting Time, Work Expenses and Stress

Some telecommuters may work fewer days, while others use telecommuting to enable them to commute at times when the highways are less crowded. Gas, transit taxes, and depreciation decrease, while cost savings are likely for wardrobe, parking costs, and meals.

Increased Flexibility of Schedules

Telecommuters are better able to coordinate their work schedules to accommodate family responsibilities, although telecommuting is not a substitution for child care. People are able to work more often when at their peak hours of mental alertness.

Improved Work Environment

Workers experience fewer distractions, less environmental noise, and less job-related stress. They are able to avoid office politics and exert control over their physical environment, e.g., adjusting the temperature to their liking.

Greater Job Responsibility and Autonomy

Workers may be more in control, with a feeling of being "their own boss."

Increased Employment Opportunities

Telecommuting may be the only means of acquiring a job for the mobility-limited or handicapped. A number of programs have been aimed at these groups.

Stronger Family Ties

Telecommuters may experience increased satisfaction with home life, enjoy more time with their families, and feel in closer touch with the world outside work. Many may prefer to work at home because they need to care for a child or old person.

Employee concerns

Isolation

The social aspects of work can be major inducements to go to the office. Several writers have dismissed home-based telecommuting on the basis of this consideration alone, making the unwarranted assumption that telecommuting is an "either/or" proposition. Nonetheless, home-based work is solitary work, and not every employee can cope with the reduction of personal interaction.[35] Social and professional isolation of teleworkers has frequently surfaced as a potential problem.

- A Diebold survey found that 56 percent of teleworkers surveyed mentioned social isolation as a disadvantage, a proportion that rose to 70 percent among women in the survey (Diebold Group, 1981).[36]

- A survey in the United Kingdom in 1983 reported that 60 percent of teleworkers named isolation as the greatest disadvantage. 22 percent found it such a problem that they would prefer to work in a satellite office or neighborhood center.

- An extensive 1987 Hudson Bay survey found that the majority of interviewees would miss the stimulation of exchanging ideas with colleagues.

Isolation is not a necessary by-product of home-based telecommuting. Employers can minimize or overcome this problem by developing schemes that enable teleworkers to maintain contact with the parent company, by means of frequent meetings, briefings, social functions, etc. A certain amount of social interaction is facilitated by a computer network. Neighborhood centers and satellite offices can offer a high level of interaction.

It should be noted that most of the negative evaluations of this nature, and others that report social isolation for single people, the handicapped, etc., typically are from studies of full-time, home-based telecommuters rather than split week or satellite office telecommuters.

Career Advancement

"Out of sight, out of mind" is a serious concern of many workers. Telecommuters often fear a loss of workplace visibility, and a threat to personal and professional advancement through missed opportunities.[37] Employees are also apt to feel that if they spend too much time out of the office, it causes resentment among fellow employees.[38] Another possible disadvantage for the individual employee is the reduced opportunity to become involved with coworkers and the informal communication network at the office.[39] Indeed, being "out of the loop" can be a real problem in a work culture which draws strongly on informal contact.

A related concern is that the telecommuter may be handicapped in developing knowledge and skills in the job that lead to wider responsibilities for work and the management of others.

Performance Appraisals

Just as managers must come to terms with new and more complicated performance appraisal situations, employees may fear that their supervisor will not meet that challenge fully so that their evaluations will suffer. It is a reasonable fear that if the supervisor is more distant from performance of the work, he or she may be less able to appreciate the obstacles or complications which impede progress or limit quality.

Support Services

Many information workers make frequent use of various technical support services -- documentation, graphics, clerical, library, etc. In principle, careful scheduling of telecommuting days, good planning, and exploitation of facsimile transmission, voice mail, and electronic mail, and linkage to computer networks should prevent significant diminution of support. However, for workers accustomed to having these services constantly at hand, the adjustment can be difficult and even threatening. Lack of clerical support or equipment maintenance may cause uneasiness about equipment or software failure.

Job Satisfaction

Whether the consequences of telecommuting are positive or negative depends upon the worker, what type of telework is involved, where it is performed, and under what contractual agreement. Autonomous professionals have their autonomy reinforced by working at home, while clerical employees regulated by control measures can find their autonomy reduced still further vis full-time permanent employees.

Evidence for increased or decreased job satisfaction, quality of life, promotion potential, and supervisory support is ambiguous, and the various worker satisfaction measures do not correlate

significantly with productivity.[40] Studies of homework and family relationships have found that these linkages are important but not easy to analyze and in need of further study. The literature suggests that telecommuters from government agencies report greater satisfaction and productivity gains than those of private employers. No significant correlation was found between gender, age, or educational level and telecommuting satisfaction or productivity, and their studies showed that the evaluation system and level of supervisory support (emotional and technical, including equipment, software, etc.) were important to satisfaction.

Kathleen Christensen, director of the National Project on Home-Based Work at the Graduate Center of CUNY, notes that the home work environment can turn employees into lonely contract workers, without fringe benefits and job protection, and speeded up past endurance.[41] She feels that disabled workers, elderly and rural residents, and other classes of people without options can be caught in traps that belie the favorable popular images of telework.

Lotte Bailynn cites earlier work by Pratt, Olson and Ramsower in support of the "segmented nature of the work-at-home option" insofar as it involved the vulnerability of women doing clerical work as an alternative to no work, in contrast to part-time male telecommuters who were usually men with scarce skills[42]. Bailynn also studied (1987) 55 workers in a largely female formalized home-based workforce in the United Kingdom, and compared them with 55 office-based systems developers from a different unit of the same company. The design of this analysis allowed for differences in gender, in roles, technical or managerial, and in family status. Less difference between managerial and technical roles was found in the home-based group, and less compartmentalization of tasks; but even in this relatively privileged population, with full benefits and high skill levels, the women assessed their situations as much better than not working at all, but as a conscious sacrifice of money and power for family values. Male telecommuters have reported improvements in their family and leisure lives, while women clerical workers have often experienced greater stress and less leisure.

Overworking

Telecommuters have complained of working too many hours and of "not knowing when to quit." Anecdotal accounts also describe many telecommuters as "workaholics." Workers say this is a factor that they could control if they chose to. However, it is possible that pressure from their organization, perhaps in the form of competition with peers for promotion, is the cause of "working too much." Related to the problem of working too much are telecommuters' reports of "less time to myself" and "less time with my family." Many telecommuters found it "hard to separate personal and work life."

Work Style

The notion of telework has absorbed a great deal of societal anxiety about changing work and family roles, so that it is not surprising to find polarized views of effects on workers.[43] Both

information and relationships change with distributed work settings, e.g., E-mail conveys information with a different tone and disseminates it more quickly than face-to-face or phone contact.

Workers may find it difficult to abandon a "familiar" working environment to face the challenge of new social and personnel arrangements.[44] Some individuals are much more comfortable dealing with others on a face-to-face basis, perhaps emphasizing casual or informal contacts, than in the more structured style imposed by telephones and messages. While concerns based on matters of personality can often be alleviated with time and experience, there will be workers for whom these characteristics determine whether telecommuting is appropriate, and if it is, what form and frequency it should have.

Work/Life Boundaries

Blurring of the boundaries between work and personal life is a concern for many telecommuters. According to U.S. TeleCenters (a Boston-based distributor of telecommunication equipment), telecommuters often work 7 not just 5 days a week from "9 to 5". Some telecommuters work too much; they become unable to walk away from the home office in the evenings and on weekends, which eventually can lead to burnout.[45] This effect can be intensified by a desire to justify telecommuter status be achieving higher productivity. An A&T Bell Laboratories test also identified the lack of clear separation between work and home life, and the loss of casual office interactions as problems.[46]

POLICIES OF GOVERNMENT AGENCIES

Governmental entities are initiating policies to reduce transportation social costs and inducing organizations to adopt programs to decrease the number of trips made by their employees. In some areas, these policies include an extra bonus for trip reductions obtained by telecommuting. By using these types of regulatory devices, government can exert some influence on the level of adoption of telecommuting by individuals. However, the language of legislation can operate as a barrier to the development of useful telecommuting schemes that do not fit its definitions since companies are constrained from attempting innovations that do not meet the law.[47]

TECHNOLOGY AVAILABILITY

Potential Technology Barriers to Telecommuting Growth

Until recently, the technology required for effective telecommuting was limited in capacity.[48] However, it appears that few telecommuting applications today are hampered by the lack of suitable technology, although in some cases it may not be cost-effective to use.[49] For example, videoconferencing systems are available but high cost, bulkiness and technical limitations hamper use in remote work. An on-site meeting with employees would be more cost-effective.

The reduction in the costs of electronic equipment has not been matched by a reduction in the cost of telecommunication charges, which are still often based on volume, thus discouraging the diffusion of telework.[50] The most significant lags at present are in telecommunications software and network interconnectivity.[51] Different networks are not always compatible and their integration is difficult to achieve.[52] The National Telecommunications and Information Administration (NTIA) of the Department of Commerce has determined that a key pacing factor in the deployment of broadband communications and other technologies that will expand opportunities for telecommuting in the years ahead is the adoption of standards that all manufacturers and service providers can follow.[53] The Clinton Administration's strong support for advancing the nation's information infrastructure will inevitably strengthen the technical foundation for telecommuting and focus attention on a wide variety of tele-substitutions.

Views differ as to whether the current telecommunications infrastructure can support broad-base telecommuting. In his testimony before the Subcommittee on Telecommunications & Finance in July 1992, Dr. Charles E. Grantham, University of San Francisco, stated technology is not the barrier. The technological base necessary to support the emergence of the electronically distributed work place is largely in place. Appearing before the same Subcommittee, Mr. Charles Oliver, Senior Policy Advisor, NTIA, U.S. Department Of Commerce, presented an opposing view. Mr Oliver testified that the telecommunications infrastructure is not always available to support telecommuting . In his testimony, he stated that the practicality of telecommuting is heavily dependent on the kind of telecommunication infrastructure that is locally available. Clerical work and routine conversations can be accommodated over existing networks, provided that adequate switching capabilities are provided. But even so fundamental a service as switching does not meet every employer's needs. For example, Blue Cross/Blue Shield was unable to locate a 150-person claims processing office in Willows, CA, because the local telephone company's switch was incapable of handling high-speed data communication from desk-top computers. For Blue Cross/Blue Shield and many other employers, remote work sites are practical only if linked with efficient communications. Although this example does not involve telecommuting, the situation is basically analogous to that of a telework center.

Mr. Oliver also stated that some companies preferred face-to-face conversations. Videophones could provide a medium for many such interactions; however, the existing telephone network is not able to support ubiquitous, high-quality videophone service at an affordable price.

Also appearing before the Subcommittee on Telecommunications & Finance was Mr. E.M. Risse, Coprincipal, Synergy/Planning, Inc. Mr Risse testified that the telecommunications infrastructure, while of critical importance, is the easiest and the cheapest type of infrastructure to place in the urban region. He commented that the growth of telework and telecommuting is primarily an organization, culture, and perception issue, not a technology or telecommunications issue. In over 20 years of working with these concepts, Mr. Risse has not encountered a significant technological limitation of telework/telecommuting.

The cost of telecommunications services has not declined to the extent that equipment cost has, and network incompatibilities and the difficulty of setting up wide-area networks are still barriers.[54] As yet, no truly global and transparent data network exists, while at the low (small company) end, cost, pricing, and features incompatibility are still factors.[55] The 1990 LINK case studies report suggests that the cost of technology is rarely a factor. LINK found that dirty or overloaded lines have been a problem in some geographic areas.

The slow pace of technology standards agreement and adoption could be a deterrent to the growth of telecommuting. Electronic mail is one example of a technology that comes in many "flavors," mostly proprietary by vendor. The only international standard is the CCITT X.400 messaging system that is very slowly gaining acceptance and being integrated, in many cases by fiat, in large companies and governmental organizations. Many other not-yet-standardized technologies, such as forms, database query, and distributed transaction processing, constrain telecommuting because of the lack of standardized, low-bandwidth, reasonably priced services.

As suggested by the above discussion, the question of whether limited telecommunications services currently are a serious impediment to telecommuting is approached from widely divergent viewpoints. Some individuals in the telecommunications community, acutely aware of the high level of functionality potentially available in a home office using today's sophisticated technology, see inadequate telecommunication services as a serious impediment to telecommuting now and in the near future.

On the other hand, those in the telecommuting world looking at the tools needed to implement realistic programs often have a different view. They tend to see the technology as largely satisfactory, with the real barriers residing primarily in the guarded response of employers and workers to a major change in the way work is done, and to legitimate concerns over potential disadvantages and uncertain benefits. While desktop computers now pervade much of the business community, the great majority of office applications are relatively "low-tech," primarily word processing. Even effective electronic mail and networks for document sharing are far from ubiquitous in American business. Thus, it is not clear that large numbers of people are prevented from telecommuting merely by telecommunications limitations other than in localized situations. Indeed, the LINK Resources study indicates that many telecommuters do not even have computers at home. For many workers one of the advantages of telecommuting occasionally is to work undisturbed. As advanced telecommunications and computer applications become more fully integrated into corporate America, similar capabilities will be needed to support a growing portion of home workers. The near-term (5- to lo-year) importance of video is not clear. From a longer time perspective, it is likely that high-bandwidth video service will be of great importance to the entire economy, and telecommuting and telework generally will be a modest but important element of a much larger and very demanding telecommunications market.

Regardless of whether one believes that the current telecommunications infrastructure is

sufficient at present, two points are clear. First, current technology allows many people to telecommute successfully today. Second, the deployment of a nationwide broadband network would make it easier to telecommute in the future.

REGULATORY, LEGAL, TAX, AND OTHER INSTITUTIONAL ENVIRONMENT

Legal and Regulatory Issues

Telecommuting touches on many different areas of the law, some of which are extremely complex and will require test cases to be brought before they can be unambiguously clarified.[56] It is possible that a general lack of clarity about the legal status of teleworkers may have acted as a deterrent to setting up telework schemes in some cases.[57] However, it seems unlikely that legal prohibitions will be brought into effect which will restrict the growth of home-based telework.[58]

Zoning Restrictions and Planning Regulations

There are several potential regulatory barriers to home-based telecommuting, the most important of which are local zoning codes that prohibit home-based work. The city of Los Angeles is modifying zoning laws to promote telecommuting. Los Angeles also specifically includes telecommuting as a congestion reduction option for prospective developers of large office buildings. Other regulatory options being proposed to encourage telecommuting are mandatory parking fees for workers and preferential business telephone rates for telecommuters and/or their employers. [59]

Zoning laws and regional development regulations can influence the nature of telework development. Some cities have laws prohibiting home-based work of any type.[60] Zoning restrictions in most counties limit the use of the home as a work place, but telework might easily go undectected.[61]

The deterrent effect of zoning regulations on telework is difficult to quantify. Planning regulations tend to be extremely complex, varying considerably from one locality to another both in their content and in the degree to which they are enforced (Holden, 1984; Bureau of National Affairs, 1986; Gordon & Kelly, 1986).[62]

Only one example was found of a situation where zoning rules have posed problems for teleworkers. A particularly strict Chicago zoning ordinance was invoked to stop a teacher and his wife from writing a textbook or developing software programs on the home computer (Rubins, 1984).[63] Should telework become widespread, changes in zoning laws will undoubtedly be required. In the meanwhile, these cannot be regarded as a major constraint on its development.[64]

Tax Implications

Current tax laws and regulations are not conducive to telecommuting and may need to be changed to encourage the widespread adoption of telecommuting. By narrowly defining a "home business, " income tax regulations discourage using the home as a workplace. Individuals may deduct expenses for a home office only under very restrictive circumstances. According to IRS guidelines, "regular" work is allowed but "occasional" work is not.

Existing state tax laws are also a barrier to cross-state telecommuting. A telecommuters' work may subject an employer to state corporate franchise taxes. Ohio's corporate franchise tax was applied to an Indiana-based employer on the basis of one telecommuting employee who lived in Ohio.[65] Although the telecommuter was the only employee working in Ohio, the corporate franchise tax was assessed on the percent of total corporate sales made to Ohio addresses.

State income tax laws also create potential problems. For example, New Jersey and New York state income taxes are based on where the work is actually performed, requiring employers to modify payrolls systems to record where the telecommuter worked each day and withhold New York and New Jersey income taxes accordingly.

New Jersey also requires New York firms employing New Jersey residents as telecommuters to register with New Jersey to perform business in the state when the work being performed would not normally require registration.

Liability/Insurance

The question of insurance is closely connected with that of contractual status. Employees can expect their health insurance contributions to be paid by their employers, who are also responsible for employee liability, personal injury, and other types of insurance. In cases of self-employment, these become the responsibility of the individual teleworker.[66] The responsibility is less clear-cut in other cases, and much depends on individual contracts and the small print of particular insurance policies. Some questions which need to be asked are: who should be responsible for the loss or damage of data or equipment used in telework? Who should be responsible for injury to third parties caused on the teleworker's premises? Who is insured for delivery and pickup of work? (Gordon & Kelly, 1986) There is no case-law in these areas so the answers must be speculative, In only one case, involving telework for the US Army, have insurance problems appeared sufficiently adverse to affect the outcome of the scheme. Here, government liability, protection of government property, and workmen's compensation were all perceived as problems. Along with security difficulties, these led to the discontinuation of the project, despite the development of a "hold harmless" agreement absolving the government of responsibility, which all teleworkers were required to sign (McDavid, 1985).[67]

Health and Safety

As with insurance, legal responsibility for health and safety of teleworkers will vary according to their employment status. Telecommuters, if true employees of the company, are covered by the Occupational Safety and Health Act (OSHA), but in practice, effective implementation is virtually impossible (Bureau of National Affairs, 1986). Telework contracts/collective agreements sometimes have provisions requiring inspections and covering all aspects of homework, including safe and comfortable working conditions in the home, and realistic work standards. However, adequate levels of safety and health protection for teleworkers may be jeopardized by the difficulties in carrying out inspection.[68] There is no evidence that the fear of becoming liable for industrial injuries or diseases is currently a deterrent to the employment of teleworkers. However, in the United States, there is a fear that the enactment of legislation to regulate the use of Video Display Terminals to minimize health hazards would restrict the development of telework. It would become very difficult for employers to ensure compliance at remote sites (Gordon and Kelly, 1986).[69]

Protection of Workers' Rights / Union Opposition

Telework at home has generally been regarded negatively by trade unions. Telework was initially perceived as a modern form of industrial homework, which is traditionally associated with low wages **and** substandard working conditions. Trade unions fear the fragmentation of the workforce with the consequent isolation of teleworkers, making them particularly vulnerable to exploitation and at the same time difficult to organize. This apprehension resulted in the adoption of positions opposing telework, with some unions calling for its prohibition. However, given the attractiveness of telecommuting for many workers, it appears that this issue can generally be resolved by good-faith efforts to address the real concerns.

Regulation / Banning of Homework

There are no current Federal restrictions on work at home except for a few garment occupations under the Fair Labor Standards Act (FLSA). However, in some states there exists partial or total bans on employment of home-based workers to carry out certain types of work (frequently garment making or other forms of manufacture associated with the traditional sweat shop trades). Even where these are not prohibited, they may be governed by regulations concerning minimum wages, leave provisions, and health and safety practices.[70]

Protective legislation concerning the length of working time is very difficult to enforce for teleworkers, who may have difficulties trying to combine family and work duties. There may be pressure to work at night or on the weekend or for prolonged periods in order to met deadlines. Overtime, perhaps without compensation, may be habitual and may take the form of individual, quite substantial work just to complete the "extra bit" which is required. At the same time, teleworkers may be asked to be on standby or work overtime during peak periods,

while being paid only for the hours actually worked.[71]

In recent years, a highly polarized debate has grown concerning the question of deregulation. On the one hand, the AFL-CIO has called for a total ban on electronic homework for clerical-level workers (National Research Council, 1985; Peles, 1985). In 1983, the AFL-CIO and the Service Employees International Union called for "an early ban on computer home work by the Department of Labor as a measure of protection for those workers entering the fastest-growing occupation in the United States. " It argued that "homework has historically led to worker exploitation, " and that "the piecework nature of computer work increases the risk of employee exploitation. " It claimed that "leaving the home computer industry unregulated will have a devastating impact on the well-being, wages, hours, and working conditions of homeworkers. Moreover, the enforcement of wage, hour, and safety standards in the home is absolutely impossible. "[72] On the other hand, there have been various attempts to repeal what legal restriction currently exists. Particular controversy surrounded the celebrated "Vermont Knitters" case, when a group of would-be home-knitters who had successfully applied to the Labor Department to have the proscription on home work lifted found themselves opposed by the International Ladies' Garment Workers Union, supported by unions and some state officials (Beck, 1984). In 1986, the Department of Labor proposed lifting the ban on homework, a proposal which was opposed by the garment industry unions. In the same year, New York moved in the opposite direction by instituting a new law designed to crack down on sweat shops and illegal industrial homework. White collar homework, however, would be unaffected. (Bureau of National Affairs, 1986)[73]

Contractual Relationships / Compensation and Benefits Issues

The fear of loss of employee status occupied a central place in trade union arguments against telework. Some companies have identified their teleworkers as independent contractors to reduce expenses and avoid the costs of employee benefits. These contractual relationships between a company and its employees stating whether the teleworker is an employee or independent contractor can create legal problems. U.S. case law suggests that the critical factor in deciding whether or not a worker is an employee is the degree of dependence on the supplier of the work. The criteria used for assessing this can be summarized as:

- The degree of control over the work;
- Opportunities for profit and loss;
- Whether risk capital is supplied;
- The degree of permanence of the relationship; and
- The amount of skill and initiative contributed by the worker (Elisburg, 1985).

To date, there have been only two reported cases of teleworkers taking legal action in an attempt to establish employee status. In one case, eight home-based claims examiners sued California Western States Life Insurance Company, charging that the company's claim that they were independent contractors was incorrect. The case has not been resolved. In the second case, the Department of Labor brought suit against Dial America Marketing. The U.S. Court of Appeals for the Third Circuit found that the home-based telephone number researchers were not independent contractors but employees subject to the minimum wage and record-keeping requirements of the Fair Labor Standards Act (Bureau of National Affairs, 1986).[74]

On the whole, this is an important factor affecting the income of teleworkers since companies tend to provide the necessary equipment for teleworkers. However, some teleworkers, often freelance workers, have to purchase or hire their equipment.[75] Overtime compensation, an important consideration in the computer industry, is also an issue.

The greatest problem for management is that they do not want to acknowledge that the relationships fostered are more like customer to contractor than boss to employee. The reverse side of this coin is that companies switch workers to independent contractor status, or contract out otherwise to keep costs down by denying benefits.[76] On the other hand, companies like Pacific Bell and JC Penney have adopted policies by which workers and companies both win.

More recently, however, the moderate rate of telework and the involvement of various categories of workers (from highly qualified and highly paid to semiskilled and poorly paid) have led trade unions, while still critical, to take a more moderate and watchful approach. In the past few years, the actions of a number of trade unions has consisted largely of producing discussion papers or documents examining the nature and extent of telework and listing its advantages and disadvantages.

There is evidence that unions are softening their stand towards telecommuting. One union (the Communications Workers of America) has, at least on the local level, taken a different position. The union has developed guidelines to be followed by pilot project participants. These are as follows:

- Equal pay and benefits for telecommuters and other employees performing the same work.
- Requirements that telecommuters work from the office a minimum of 2 days each week.
- Limiting visits by managers to a telecommuter's home to no more than twice a month with a minimum of 24 hours notice.
- Corn any-furnished equipment and supplies (including telephone equipment) and reimbursement for additional utilities and insurance costs paid by the employee. The union also should have the right to inspect equipment at home to ensure that it is safe and ergonomically sound.

- Routine advertisement to telecommuters of job openings and advancement opportunities. The union also calls for a message from the union to appear on the home computer screen when telecommuters log on, and for assurance that telecommuters will be given time to consult regularly with union stewards.
- Prohibitions against excessive monitoring of remote workplaces and notice of monitoring to employees.
- No preferential scheduling for telecommuters.
- Training to be provided to telecommuters to keep them up to date with new technologies.
- Assurance that employees will not be hired directly into telecommuting jobs, and that any employee participating in a home-based work program should have the option to terminate the agreement.[77]

SUMMARY OF RELEVANT FACTORS

This study has not identified any insurmountable barriers to telecommuting.

While legal issues may pose problems for companies and would-be telecommuters, very few actual test cases exist to conclude that legal issues present a significant barrier to telecommuting. In more than a year of investigation by members of the Virginia Governor's Task Force on Telework and Telecommuting, the only example of a potential legal, governmental or technological barrier to telecommuting has to do with a possible tax liability under some state statutes of an employer not doing business in the state where the employee lives.[78]

Although employer liability is frequently cited as a major concern for telecommuting,[79] Pacific Bell, which has one of the largest telecommuting programs in the country and has been involved in telecommuting for over 8 years, has yet to show a Workman's Compensation or other employer liability case arising from telecommuting. In general, organizations that have been successful in adopting telecommuting also adopt a set of guidelines that clearly state the responsibilities of both the organization and the home-based telecommuters in these areas. These guidelines should also cover contingency plans for down time resulting from equipment malfunction, family crises, etc.[80]

Overall, technological limitations have not proven to be a significant barrier to telecommuting; however, development of an advanced communications network could only serve to facilitate and encourage telecommuting in the future.

BASELINE ESTIMATE-S OF POTENTIAL TELECOMMUTERS

Current and Potential Numbers of Telecommuters

The determination of the number of potential telecommuters requires definition of the telecommuting universe (as shown in Figure 10) - actual telecommuters as a subset of potential telecommuters, potential telecommuters as a subset of information workers, information workers as a subset of the total labor force. At each level there occurs a filtering out of workers as telecommuters for various reasons - inappropriate jobs, individuals, and/or circumstances.

Estimates of the amount of existing and projected telecommuting vary widely, often because they are based on different definitions of the term. Researchers use a variety of definitions depending on the purpose of their survey. Another problem in enumerating telecommuters is that most contemporary telecommuters are employees of organizations that have no formal telecommuting policies/programs, so it is difficult to identify them.

The variety of definitions of telecommuting have resulted in wide variations of estimated impacts, present and future, of telecommuting and its transportation impacts.

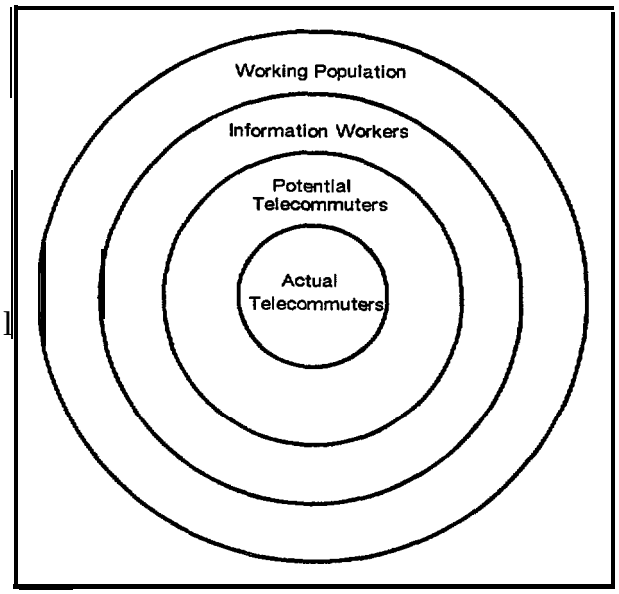


Figure 10. Telecommuting Universe

Population/Labor Force

According to projections by the Bureau of Labor Statistics, the growth of the U.S. labor force is expected to slow perceptibly between 1988 and 2000. The overall labor force, which was 83 million in 1970, is projected to be 70 percent larger in 2000 -- the effect of increased population and increased labor force participation. But growth has been decelerating: between 1970 and 1980, the labor force grew by 2.6 percent annually and between 1980 and 1988 by 1.6 percent. The rate of increase is projected to slow to 1.2 percent over the 1988-2000 period. Labor force figures for this analysis were obtained by increasing the 1988 base year by 1.2 percent annually.

Information Workers

Information occupations play a large role in today's economy, accounting for over 50 percent of the labor force. As fewer workers are involved in physical production, more information related jobs are evolving. Porat's ***The Information*** Economy divided the work force into 4 sectors, Agriculture, Industry (manufacturing), Service, and Information. The relative size of each sector is shown in Figure 11.

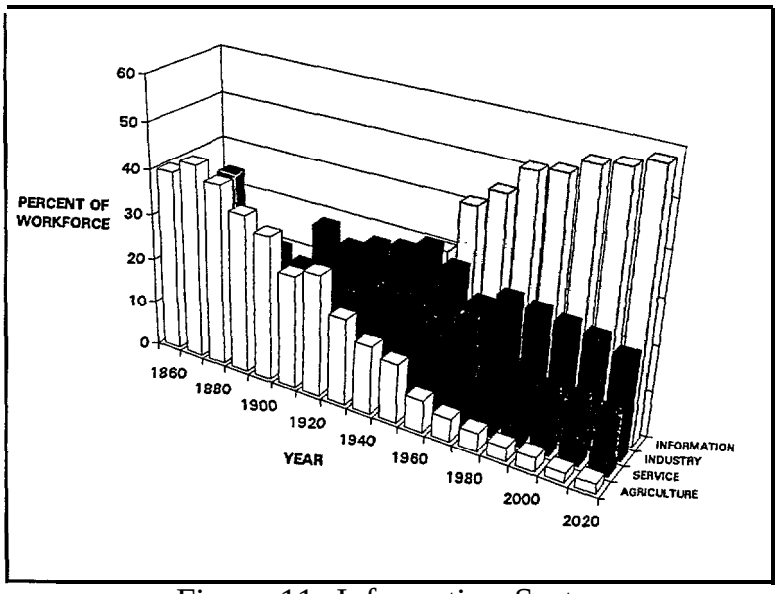


Figure 11. Information Sector

The information sector is the one of primary interest. "Information work" should not be seen as involving only information technology, advanced computer systems, etc. Information workers are simply individuals whose primary economic activity involves the creation, processing, manipulation or distribution of information. It is generally agreed that most information workers, because of the nature of their job functions, could potentially telecommute at least on a part-time basis. However, the counting of information workers, and thus of potential telecommuters, is not straightforward. This is due to the gross nature of census occupational data and the fact that there are many job functions, not typically categorized in the information sector, which deal with information to such an extent that telecommuting is possible at least part time. The ultimate fraction of the total labor force that will be involved with information work is not clear.

The analysis in this report is based on the assumption that information workers currently constitute about 56 percent of the U.S. workforce, and will gradually increase to around 59 percent in 2002, as shown in Table 5.

Table 5. Population/Information Worker Projections

Year	U.S. Population* (millions)	Labor Force** (millions)	Information Workers	
			Number(millions)	Pct. of Labor Force
1992	253.3	127.6	72.1	56.5%
1993	255.2	129.1	73.3	56.8%
1994	256.9	130.7	75.6	57.1%
1995	258.7	132.3	75.7	57.2%
1996	260.5	133.9	76.8	57.4%
1997	262.3	135.5	78.2	57.7%
1998	264.1	137.1	79.6	58.1%
1999	266.0	138.7	81.0	58.4%
2000	267.8	140.4	82.5	58.8%
2001	269.7	142.1	84.0	59.1%
2002	271.6	143.8	85.5	59.5%

* 0.7% increase annually ** 1.2 % increase annually

Rate of Adoption of Telecommuting

Telecommuting represents a fundamental change in the way companies and employees view work. This kind of innovation would inherently require a substantial number of years for widespread adoption even for jobs and individuals perfectly suited to remote work, with supportive managers and sophisticated technologies. The uncertainties about costs and benefits and the need for individuals and firms to work out appropriate telecommuting programs are matters which will take time to resolve. In some areas particularly afflicted with congestion and air quality problems, these impediments will be confronted by public sector requirements to reduce travel, and those situations can be expected to be among the first to experience relatively widespread telecommuting; the Los Angeles area is the leading example.

The high initial rate at which innovation can occur is suggested by the example of introduction of the personal computer in the workplace. While not directly comparable to the broader changes associated with telecommuting, desktop computing also involves significant changes in the way work is performed and organized, and has been affected by growing technological capabilities. The number of personnel computers in the workplace increased 16-fold -- from slightly over 1 million to 20 million -- between 1981 and 1988, with the annual growth rate at the end of that period still almost 30 percent. Similarly, in only 2 years (from 1985 to 1987) telecommunications revenues for both cellular mobile radio and local area network connections tripled. Internet, a network linking many university, corporate, and government computers, experienced a five-fold traffic increase between 1990 and 1992.

Thus, it is clearly possible for an innovation such as teleeommuting to spread rapidly once a cost-effective technological foundation is in place, given that the innovation is truly useful to a large portion of the population. To a significant and rapidly increasing degree, communications services and electronic technologies are making it possible for many people to work almost anywhere. For telecommuting, a favorable environment -- the transition to a service economy consisting to a large degree of information workers, coupled with steadily growing reliance on information technology -- has been established and itself is still increasing at a high rate. The near-term rate of expansion of telecommuting thus, will depend largely on the benefits it offers firms and individuals, moderated by the rate at which all people and organizations can incorporate changed work styles. Only when a large portion of potential telecommuters have become practitioners would the growth rate be expected to taper off.

The very high rate of growth possible in the very early stages of innovation is consistent with the findings of the LINK Resources work-at-home survey. In just 2 years, that survey indicated a doubling of telecommuting by employees from 2 million to 4.2 million. If restricted only to that subset of workers whose telecommuting is associated with their regular job, and not with after-hours work for other firms or personal customers, the growth is more than five-fold: from 0.44 million in 1990 to 2.36 million in 1992.

Exogenous factors which could influence growth rates include:

- Increased government and market pressures for telecommuting implementation.
- The level of telecommunications technology and network enhancements.
- Faster-than-projected implementation of enhanced technologies (such as ISDN and continuing expansion of personal computer technology).
- The widespread enactment of regulatory incentives such as increased gas taxes, mandatory parking fees, elimination of parking subsidies, and Central Business District parking surcharges.
- Enactment of direct incentives such as tax rebates and/or deductions for employers of telecommuters or for telecommuting employees.

Potential Number of Telecommuters

Given a projection of the number of information workers and a sense of the rate at which telecommuting could be adopted, it remains necessary to assess the degree to which information workers can and will become telecommuters. Many conditions must be met for a person to become an active home-based telecommuter. Dominant considerations are as follows:

- The job must be suited, at least in part, to performance at a remote location.
- The capabilities and personal characteristics of the employee must be appropriate to working with little or no direct supervision.
- The employing firm must accept telecommuting as a legitimate and desirable activity, provide necessary support, and must have appropriate information technology applications.
- The supervisor or manager of the employee must accept the concept and practice of telecommuting.
- The employee must feel comfortable with telecommuting in terms of its suitability to his or her personal work habits and style, its reduction of social interaction, and its relationship to advancement and career.
- The employee must have a suitable workplace and working time free of distractions (such as child care responsibilities).
- Available technolo y, particularly telecommunications services, must be adequate and cost-effective for the work to be performed at home.

Even if all of these conditions are met, it is still necessary that the business and the worker be motivated toward teleeommuting. The local transportation environment will be critical in this. Severe congestion, stringent transportation demand management practices, and lack of public transit will typically be a powerful incentive for telecommuting.

While all of these conditions can clearly be met in many cases, it is also apparent that each will filter out a portion of the potential telecommuting population. Their cumulative effect is likely to be substantial. As telecommuting becomes more established and experience accumulates on this new way of working, it may turn out that the factors listed previously shrink to a low level of importance. However, without evidence to the contrary, all must be considered as significant constraints on the speed and ultimate level of implementation of telecommuting.

Some of the factors listed above lose much of their importance in the case of telecommuting centers close to the home. Although the work is performed remotely, it will still be in a relatively conventional workplace environment and is likely to provide significantly better telecommunications services and other supporting functions. On the other hand, it will typically represent a significantly greater investment for the employer. Most importantly from the perspective of this report, remote work centers will typically only shorten, rather than replace, the daily commute. Their impact will thus depend on the whether they proliferate to the degree that they are very close to the workers they serve. A compensating factor is the likelihood that people working at a center are likely to teleeommute more often, perhaps nearly full time. When this occurs, the expense of providing the facility may be balanced to some degree by not having to provide an office at the regular workplace.

Several studies have attempted to arrive at quantitative estimates of the upper bound of substitutable transportation behavior. Most center around the idea that certain work roles with certain job functions may be susceptible to performance from remote locations. Figures between 10 and 20 percent are most often quoted. These are based on assumptions about the location and mix of work roles in the future economy and conjectures about the susceptibility of those work roles to substitution.

In this way Nilles has developed forecasts based on a relatively detailed examination of the subject, and his values are used as a starting point for the analysis presented in this report. He foresees an exponential growth during the early 199Os, followed by an approximately linear increase from 1995 to about 2010 at a rate of approximately 10% per year, nearing saturation in 2030 at 60 percent to 70 percent of the information worker population. These projections are explicitly speculative; Nilles notes "Since we are still at the relative beginning of the major growth curve of telecommuting it is not possible to make definitive forecasts. In fact, there is a growing literature supporting the allegation that definitive forecasts of complex, chaotic phenomena are impossible for other than very short periods into the future. That does not diminish the importance of understanding the major forces at work so that the scope of alternative outcomes can be suitably restrained. "

During the period 1992-2002, the timeframe chosen for this report, these projections yield an increase from 2 million telecommuters (1.6 percent of the labor force) to 15 million (10.4 percent), an average annual growth rate of 22 percent. Graphs showing both the short-term and long-term projections are presented in Figure 12. While not unprecedented, the assumption of sustained growth at these rates could be unrealistic, particularly given the behavioral, societal, and institutional changes involved. Thus, in order to reflect the uncertainty of the analysis, this report also calculates potential transportation impacts based on a lower bound scenario for which only half as much telecommuting occurs. Figure 13 shows the upper and lower bound scenarios used for subsequent analysis, and, for reference, a curve representing 20 percent of the population of information workers. The data for both cases is shown in Table 6, along with the percentages of information workers and total labor force telecommuting.

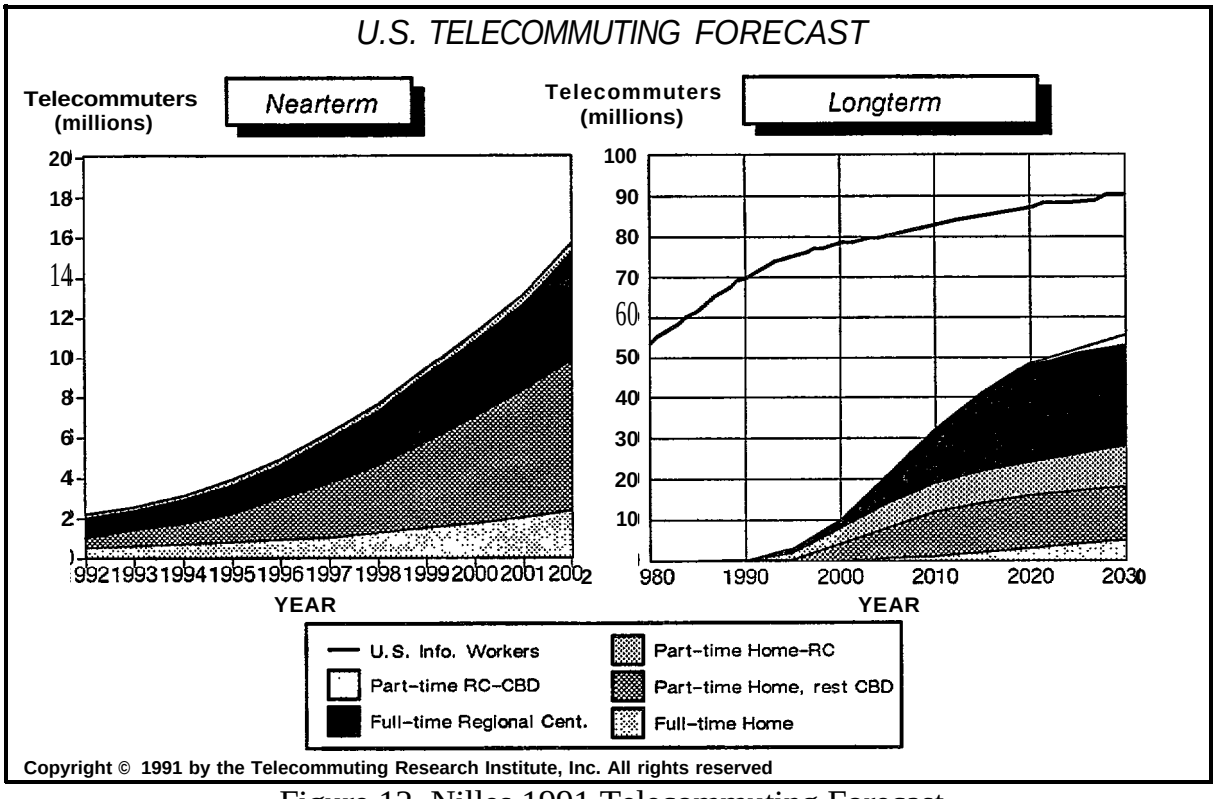


Figure 12. Nilles 1991 Telecommuting Forecast

Table 6. Telecommuter Projections

Year	Projected Telecommuters					
	Upper Bound			Lower Bound		
	Number (millions)	*Pct. of Labor Force*	*Pct. of Information Workers*	*Number (millions)*	*Pct. of Labor Force*	*Pct. of Information Workers*
1992	2.0	1.6%	2.8%	2.0	1.6%	2.8%
1993	2.5	2.0%	3.5%	2.5	2.0%	3.5%
1994	3.2	2.5%	4.3%	3.1	2.4%	4.2%
1995	4.0	3.0%	5.3%	3.7	2.8%	4.8%
1996	5.0	3.7%	6.5%	4.2	3.1%	5.5%
1997	6.2	4.6%	7.9%	4.8	3.5%	6.1%
1998	7.6	5.5%	9.5%	5.3	3.9%	6.7%
1999	9.2	6.7%	11.4%	5.8	4.2%	7.2%
2000	10.9	7.8%	13.3%	6.4	4.6%	7.8%
2001	12.9	9.1%	15.4%	6.9	4.9%	8.3%
2002	15.0	10.4%	17.5%	7.5	5.2%	8.8%

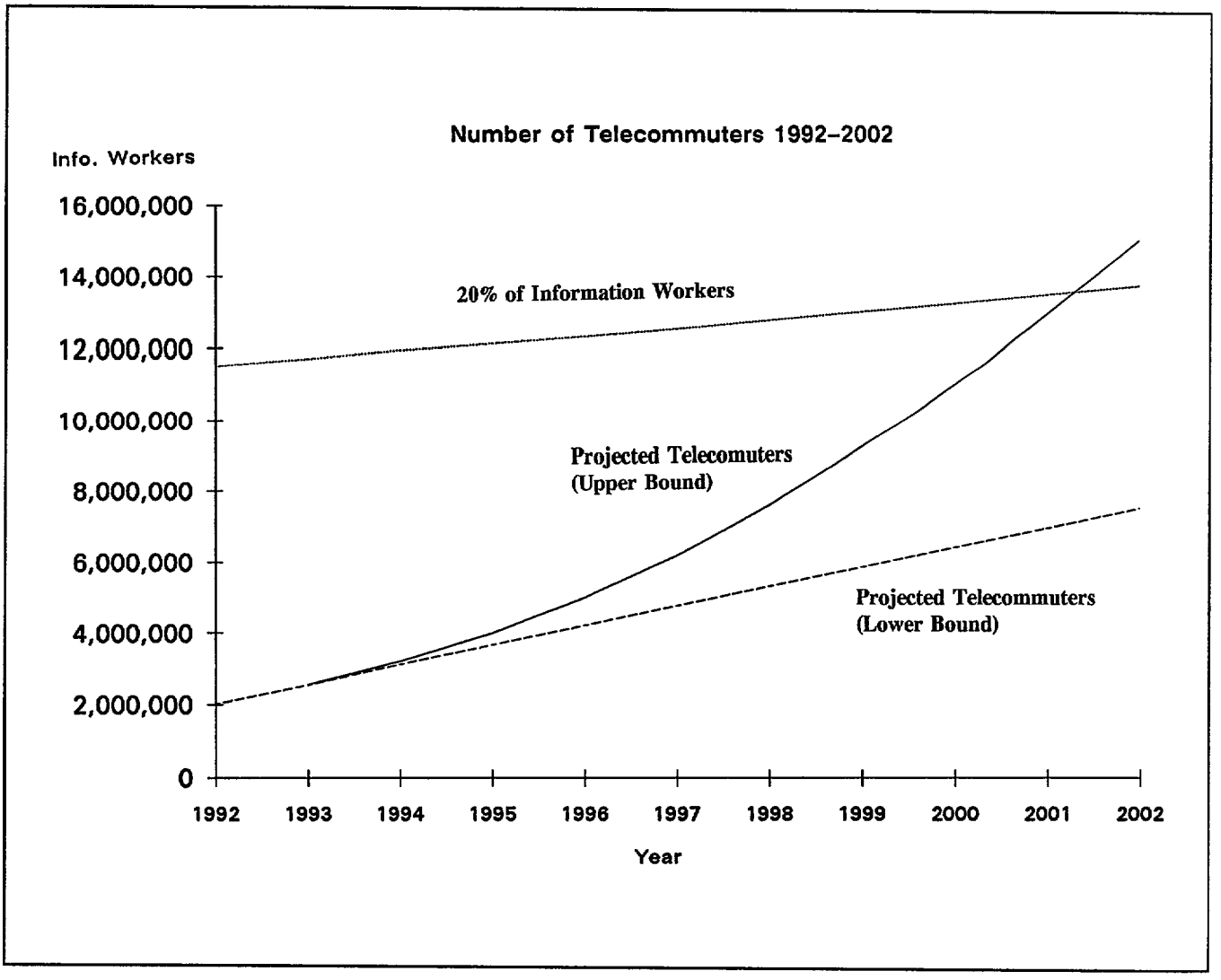


Figure 13. Telecommuting Forecast

Allocation of Telecommuters Over Various Forms of Telecommuting

Each of the forms of telecommuting has the first-order effect of reducing work-related travel to some extent. The trip, energy, accident, and pollution reduction implications are different for non-home-based (satellite, regional, local) telecommuting than for home-based telecommuting. Therefore, it is necessary to subdivide telecommuters into these five categories. Varying growth rate and saturation parameters for the following 5 main telecommuting options as defined by Nilles, are used. Table 7 shows the estimated percent of telecommuters in each of the categories from 1992 through 2002. 1992 numbers were generated from actual current telecommuter numbers from LINK Resources. 2002 numbers

are Nilles' estimate of telecommuters for the year 2002. 1993-2001 numbers are a straight line estimation between these 2 points.

Telecommuting Frequency

For determining the transportation impacts of telecommuting, how often people telecommute is as important as how far they avoid driving.

Telecommuting frequencies for the lo-year period range from:

2 - 3.1 days/week for home/CBD
2 - 4.1 days/week for regional/CBD
1 - 1.5 days/week (home) for home/regional
4 - 3.8 days/week (regional) for home/regional
5 days/week for full-time home and full-time regional

Table 7. Home / Regional Center Telecommuter Mix - As % of Total Telecommuters

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Part Time **Home/CBD**	84.00	80.31	76.61	72.92	69.22	65.53	61.84	58.14	54.45	50.75	47.06
Part Time **Regional/CBD**	0.06	0.17	0.28	0.40	0.51	0.62	0.73	0.84	0.96	1.07	1.18
Part Time **Home/Regional**	0.37	1.86	3.36	4.85	6.34	7.84	9.33	10.82	12.31	13.81	15.30
Full Time Home	15.00	13.76	12.53	11.29	10.05	8.82	7.58	6.34	5.10	3.87	2.63
Full Time Regional	0.57	3.90	7.22	10.55	13.87	17.20	20.53	23.85	27.18	30.50	33.83
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Chapter 3 - Potential Transportation-related Impacts of Telecommuting

INTRODUCTION

Telecommuting and other forms of remote work are becoming more and more widespread in the United States. Advantages often experienced by employers and workers alike assure that this trend will continue, ultimately affecting a substantial percentage of the national labor force. This chapter assesses the nature and magnitude of the impact this innovation can have on transportation and on transportation-related lost time, energy use, air pollution, and safety. It also explores other social impacts associated with working at home or other remote locations.

The starting point for this assessment is the estimate of total telecommuting population presented in Chapter 2. Based on available data concerning average trip distance for commuters, the total reduction in vehicle miles traveled is readily calculated. Average values for fuel use, vehicle emissions, and accidents are then used to establish direct estimates of time, energy, environmental, and accident savings associated with telecommuting. The results of this process are presented below. It must be emphasized that in addition to the uncertainty of the estimates of telecommuting behavior, the use of average values for other factors may be quite inaccurate in some specific situations. Thus, estimates are considered highly approximate at best, and may have only limited relevance to particular regions where parameter values differ substantially from the national averages.

Further, there are many secondary factors to be considered that can modify the results obtained in this direct manner. These and other transportation-related impacts of telecommuting are discussed in the following pages.

Changes in Travel Behavior

The approach described above implicitly assumes that the only effect of telecommuting is to eliminate work trips and associated vehicle miles travelled. This assumption clearly is not strictly true, since total travel behavior of the telecommuters is likely to change in response to their new situation and flexibility. In some cases these effects could potentially be comparable in magnitude to the direct results of telecommuting.

As Sissine puts it: "Telecommuting entails a certain amount of change in the lifestyle of a person. The telecommuter now works at home and can allocate time to various tasks with increased flexibility. Telecommuting releases some of the work-related constraints such as the commute to and from work and the lunch hour which usually take place according to a fixed

schedule. This added flexibility in a telecommuter's life, as a result of the relaxation of time-space constraints, may lead to changes in the travel behavior of not only telecommuters but also their household members."[81]

The key question is whether the reduction in work trips might be balanced by new trips made possible or necessary by telecommuting. Examples of possible new or longer trips include:

- Shopping trips normally made while en route to or from work.
- Dropoff and pickup at a child care facility that otherwise would have been part of the work trip.
- Trips by other household members made possible by availability of the vehicle.
- Trips made possible by the time saving or more flexible work schedule associated with telecommuting.
- Trips necessitated by working at home -- such as to the post office or to obtain supplies.
- Relocation of residence, yielding a longer commute on office days, and possibly more driving for shopping and services.

Full understanding of the impact of these effects will come only as telecommuting becomes more widespread and further research is conducted. However, initial findings from pilot telecommuting programs suggest that their impact may be small. Hartman and colleagues report: "It has only been within the past five years that a variety of telecommuting programs, mainly in the public sector, have offered the opportunity to test some of these hypotheses empirically. Transportation evaluations have been completed or are in progress for programs involving the Southern California Association of Governments, the state of California, the Hawaii Telework Center, the Netherlands Ministry of Transport, Puget Sound multi-employer program, Los Angeles County, and several other employers in Southern California. From these programs, several findings are beginning to emerge:

- Commute travel is reduced;
- Non-commute trips do not increase;
- Telecommuters make proportionally fewer linked trips;
- Telecommuters tend to shift activities to destinations closer to home;
- Proportionally fewer peak period trips are made when telecommuting; and
- Evidence regarding the impact of telecommuting on residential relocation is mixed."[82]

The results of an analysis of the State of California Telecommuting Pilot Project, which was performed to determine the impacts on telecommuting on household travel behavior, confirm that

the pilot project home-based telecommuters substantially reduced travel and were not offset noticeably by the generation of new trips. On telecommuting days, the telecommuters made virtually no commute trips, reduced peak-period trips by 60 percent, reduced total distance traveled by 75 percent, and reduced freeway miles by 90 percent. Telecommuters chose nonwork destinations that are closer to home; they exhibited contracted action spaces after the introduction of telecommuting (on both telecommuting and nontelecommuting days). The telecommuters distributed their trips over the day and avoided peak-period travel on telecommuting days. Nonwork trips, however, show similar patterns of temporal distribution on telecommuting days and commuting days. Nonwork trips continued to be made during the lunch period, late afternoon and evening hours. [83]

Collins asserts: "Telecommuters tend to shift activities to destinations closer to home. Interestingly, telecommuters as well as members of telecommuter households show a contracted activity space (on both telecommuting and nontelecommuting days), indicating that they are not making the longer-distance trips formerly engaged in by the telecommuter."[84] This suggests a learning process by which new destinations, closer to home, are discovered and (more or less) permanently adopted.

Based **on** these and other findings from pilot and demonstration programs, no adjustment for changes in travel behavior is used in this assessment. However, extensive research will be needed to determine their true impact in specific circumstances, particularly as telecommuting becomes integrated into people's lives.

In addition to Vehicle Miles Traveled (VMT) effects, impacts could occur on air quality, congestion, and fuel usage as a result of other changes:

- Extended retention of vehicles, less fuel-efficient and with poorer emission characteristics;
- Shift of driving to nonpeak periods; and
- Shift of driving to noncongested (less-urban) roads.

Impacts on Location

Historically, transportation improvements leading to reductions in commute times have facilitated decentralization to lower-density or less expensive housing on the urban fringe (Muller 1986). Jobs tend to remain concentrated at centers or develop in other suburbs, while associated commuting distances and commuting time tend to increase. Although telecommuting appears to bring great improvements in transportation, 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 VMT than are saved through not commuting to work every day.

Data derived from the California Telecommuting Pilot Project suggests the following:

- In the first 2 years there was no significant difference in household move patterns.
- Availability of telecommuting will influence household move decisions.
- Telecommuting does not as yet exacerbate urban sprawl and does produce net reductions in household travel in proportion to the intensity of telecommuting.
- The proportion of state employees who could telecommute is high; one-half of these employees had job characteristics that suggested telecommuting only to centers. Therefore, the development of regional telework centers is an important factor in future growth.

As Pratt reports: "Evidence regarding the impact of telecommuting on residential relocation is mixed. In the 2-year data collection period of the California Pilot Project, 6 percent of the telecommuters indicated that they had moved, or were considering moving, 45 or more miles farther from work since they began to telecommute. Of all those who moved or were considering moving, 28 percent reported that the ability to telecommute played a significant or decisive role in the choice. It is important to note, however, that no significant difference existed between actual moves of the telecommuters and those of a control group, suggesting that on the whole, the moves that did occur would have taken place anyway. In this particular study, any net increases in VMT traveled because of long-distance moves were more than compensated for by travel savings on the part of others. However, these are only short-term results (for a relatively small sample); long-term residential relocation trends are likely to be more pronounced. "[85]

These factors are not incorporated in the estimates that follow. However, they represent an important area of future research.

Changes in Modal Choice

Some mode choice changes resulting from telecommuting are probable:

- Telecommuting schedules may make it easy or even necessary for some telecommuters to drop out of carpools and vanpools (which may or may not dissolve themselves); they could also switch to driving alone on nontelecommuting days.
- Telecommuters will not be using mass transit on telccommuting days, causing transit revenue losses. [86]
- Household members may change modes if a vehicle is made available on telecommuting days.
- Trips closer to home may shift to nonmotorized modes such as bicycle or walking.

Mokhtarian and her colleagues summarize the situation as follows: "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. In conducting such an analysis it is important to realize that lower vehicle occupancies alone do increase congestion. As long as telecommuting simply removes a passenger from an existing carp001 or vanpool, VMT will not increase - and will actually decrease (as a result of reduced pick-up and drop-off portions of the trip) unless the members of the carpool/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 already have some built-in flexibility (e.g., a vanpool where it is possible to pay by the ride or car-pooling only a few days a week to allow individual activities to be conducted on the way to or from work on remaining days). The impact of telecommuting in these situations could be minimal. "[87] For this analysis, it is assumed that telecommuters will be pulled from the commuting ranks in the same percentages that previously existed. This is considered to be reasonable in view of the similarity of the demographics of telecommuters and solo drivers.

Congestion Mitigation and Latent Travel Demand

Traffic congestion can have direct and indirect cost impacts on business activities. The direct costs of congestion that affect production costs include additional labor costs associated with longer trips made by employees during business hours, higher vehicle operating costs, and suboptimal vehicle use. The trucking industry is both a contributor to and victim of traffic congestion. According to FHWA officials, the annual cost of truck delays on freeways is between $4.2 and $7.6 billion, based on vehicle operating costs and driver time charges. Time losses on urban streets, docking areas, etc. could range between $19.4 and $22.9 billion (excluding costs to industry such as lost sales opportunities in not having products available on time).[88] Indirect costs of traffic congestion include increases in accidents and insurance premiums; the degradation or loss of employee productivity; and increases in delivery costs, employee turnover, and recruitment problems. For example, a recent survey of business leaders in 13 metropolitan areas found that about one-half indicated that traffic conditions affected their businesses in terms of reduced productivity and poor employee punctuality and morale, as well as increased employee stress. In addition about one-third of those responding to this survey indicated that traffic conditions had an influence on plans to develop or expand their operations.

It is often assumed that from the worker's perspective, the most important reason for telccommuting is to avoid the stress, unpleasantness, and lost time associated with a lengthy trip to work on highly congested highways. Mitigation of congestion and associated air quality benefits are at the heart of public sector interest in many areas suffering from clogged roads. However, while the congestion problem is clearly solved for the telecommuter, the broader

impacts are unclear.

One view is that removal of telecommuters' vehicles from the highway will, in the aggregate, reduce overall congestion. Benefits are then substantially larger than the energy, pollution, and safety gains associated directly with the telecommuters' absence, since all vehicles on those now less-congested roads will operate more efficiently, cleanly and safely, and the occupants will suffer less delay. This effect can be large; control measures in Los Angeles during the 1984 Olympic Games reduced congestion by 60 percent, although the drop in traffic was only 7 percent. An ADL study suggests that congestion mitigation benefits are comparable in magnitude to direct benefits associated with the reduced travel of the telecommuters alone.[89]

On the other hand, it is often perceived that attempts to increase capacity through construction of additional roads seems to stimulate traffic growth -- latent demand -- that quickly vitiates any gains. A similar argument could be applied to the telecommuting case: the telecommuters might simply be replaced on the highways by other people, formerly users of transit or members of carpools, who observe that congestion has moderated to a point just below their threshold of pain and return to their automobile. In this case, the telecommuter still saves time, but the net societal benefits (in terms of VMT congestion, energy, pollution, etc.) vanish.

The concept of latent demand absorbing the potential congestion gains is contentious, and the degree to which it occurs, if any, will depend on the particular circumstances. Latent demand might be very limited or absent in the context of stringent transportation demand management measures or where congestion is minimal. Estimation of the quantitative reduction of congestion for each removed telecommuter is uncertain in any case, depending on very local and specific factors. It would be very difficult to generate a convincing overall average for the magnitude of this effect, and that estimate would shed little light on the situation in any particular urban region.

In view of these complexities, any attempt to relate telecommuting to congestion relief in a quantitative manner would be more likely to mislead than to inform. Rather, the approach taken in this report is to develop estimates only for the time, energy, pollution, safety, and cost savings directly associated with trips replaced by telecommuting, for a specified baseline case. No adjustment is made either for compensation due to latent or induced travel demand, or for reduced overall congestion. However, all assumptions are presented explicitly so that the reader may readily assess the values that would be obtained for different assumptions or for any desired congestion adjustment. **These factors are among the largest uncertainties in estimation of the transportation impacts of telecommuting, given a projection of the amount of telecommuting which will occur.**

Specific Assumptions and Limitations in the Analysis

The projection of the total number of telecommuters, as presented at the conclusion of Chapter 2, includes the assumption of gradual growth in the total United States workforce and a rise of the percentage of information workers. The parameters used in converting those projections into vehicle miles travelled (VMT) and related impacts (energy use, emissions, safety, etc.) are all subject to change during the next decade, although experience in recent years suggests that such changes will be very modest. However, the magnitude of the more readily predicted changes is small compared to the uncertainty in the prevalence and frequency of telecommuting, and in comparison to their variability from urban area to urban area.

The use of current national averages limits accuracy even for parameters which are not currently changing, since telecommuters will not necessarily be "average" in their travel behavior. For example, the trip distance for telecommuters might well be greater than the national average used in this analysis, since those with longer commutes could be expected to show a greater preference for telecommuting .

Table 8. Values of Factors Used to Compute Transportation Impacts

Factor	Value
Commute Distance (one-way, Home-based)	10.7 mi.
Commute Distance (one-way, Center-based)	9 mi.
Commute Time (one-way, Home-based)	22.4 mi.
Commute Time (one-way, Center-based)	11.2 mi.
Commute Speed (urban)	19.6 mph
Commute Speed (rural)	45 mph
Fuel efficiency	20.9 mpg
Fuel cost	$1.14/gallon
State Gasoline Excise Tax	$0.158
Annual Highway Fatality Rate	0.0232 per million miles
Urban/Rural Mileage Split	75.2%/24.8%

As a result, current values are generally used for factors such as vehicle fuel mileage and emission characteristics, average trip distance, average commute time, etc. However, the estimates presented in the following pages can easily be adjusted for other values wherever available. Given the total number of telecommuters, subdivided into home-based and center-based, and their frequency of telecommuting, results are typically proportional to each factor. The values used are shown in Table 8; sources or rationale are presented in Appendix B.

In order to put the results that follow into perspective, projected impacts are shown not only as absolute values, but also as a percentage of national totals. However, it is important to note that the relative impact could be much higher in specific regions where motivation to telecommute is strengthened by public perception of serious air quality and congestion problems, and by associated stringent transportation demand management measures.

NET TRANSPORTATION IMPACTS OF TELECOMMUTING

This section presents the net transportation impacts of telecommuting, based on the telecommuting projections asserted in Chapter 2 and the approach and assumptions described previously. Impacts include VMT/trips, energy, air quality, safety, and time. Impacts are estimated for both scenarios (upper and lower bound), as defined in Chapter 2.

Appendix B presents details of the estimates, assumptions, and calculations for the analysis.

Summary of VMT and Trip Reductions

1515,370 million miles were travelled by passenger cars in 1990 (MVMA). Figure 14 shows that 32.1 percent (NTS Table 72) of the total VMT were commuting miles. 26.3 percent (NPTS Table 74) of total trips were commute trips. The increase in VMT averaged 3.7 percent annually between 1988 and 1990; this growth rate was used in this analysis to calculate projected VMT for 1992-2002.

Table 9 and Figure 15 shows telecommuting VMT savings as a percentage of total passenger car VMT and commuting VMT for both the upper and lower bound cases. Total annual commuter round trips were calculated by multiplying potential telecommuters by the number of working days per year. The estimated 1992 vehicle miles saved due to 1.6 percent of work force telecommuting is 3,735 million. This represents 0.23 percent of the total passenger car VMT and 0.70 percent of the commuting VMT, rising to more than 4 percent by 2002.

In the presence of severe congestion and a concerted effort by public agencies to reduce automobile travel, these levels of telecommuting and associated VMT reduction could be substantially greater.

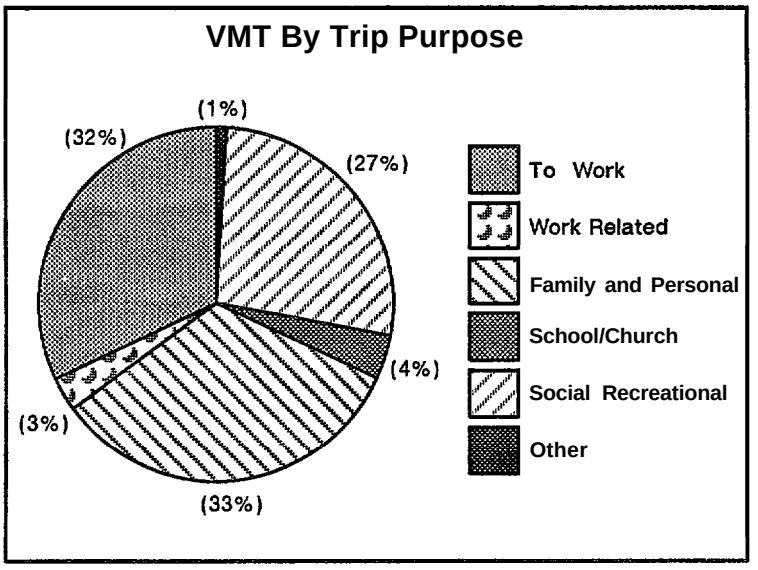


Figure 14. VMT by Trip Purpose

Table 9. VMT/Trip Savings

	1992			1997 - 5 year			2002 - 10 year		
	VMT Saved (Billions of Miles)	% of Total Passenger Car VMT	% of Total Passenger Car Commuting VMT	VMT Saved (Billions of Miles	% of Total Passenger Car VMT	% of Total Passenger Car Commuting VMT	VMT Saved (Billions of Miles)	% of Total Passenger Car VMT	% of Total Passenger Car Commuting VMT
Upper Bound	3.7	0.23%	0.70%	12.9	0.63%	2.0%	35.1	1.4%	4.5%
Lower Bound	3.7	0.23%	0.70%	10.0	0.49%	1.6%	17.6	0.7%	2.3%
	Trips Avoided (millions)		% of Total Potential Round Trips by Commuting Passenger Cars	Trips Avoided (millions)		% of Total Potential Round Trips by Commuting Passenger Cars	Trips Avoided (millons)		% of Total Potential Round Trips by Commuting Passenger Cars
Upper Bound	238		0.17%	882		0.59%	2500		1.54%
Lower Bound	238		0.17%	679		0.45%	1300		0.77%

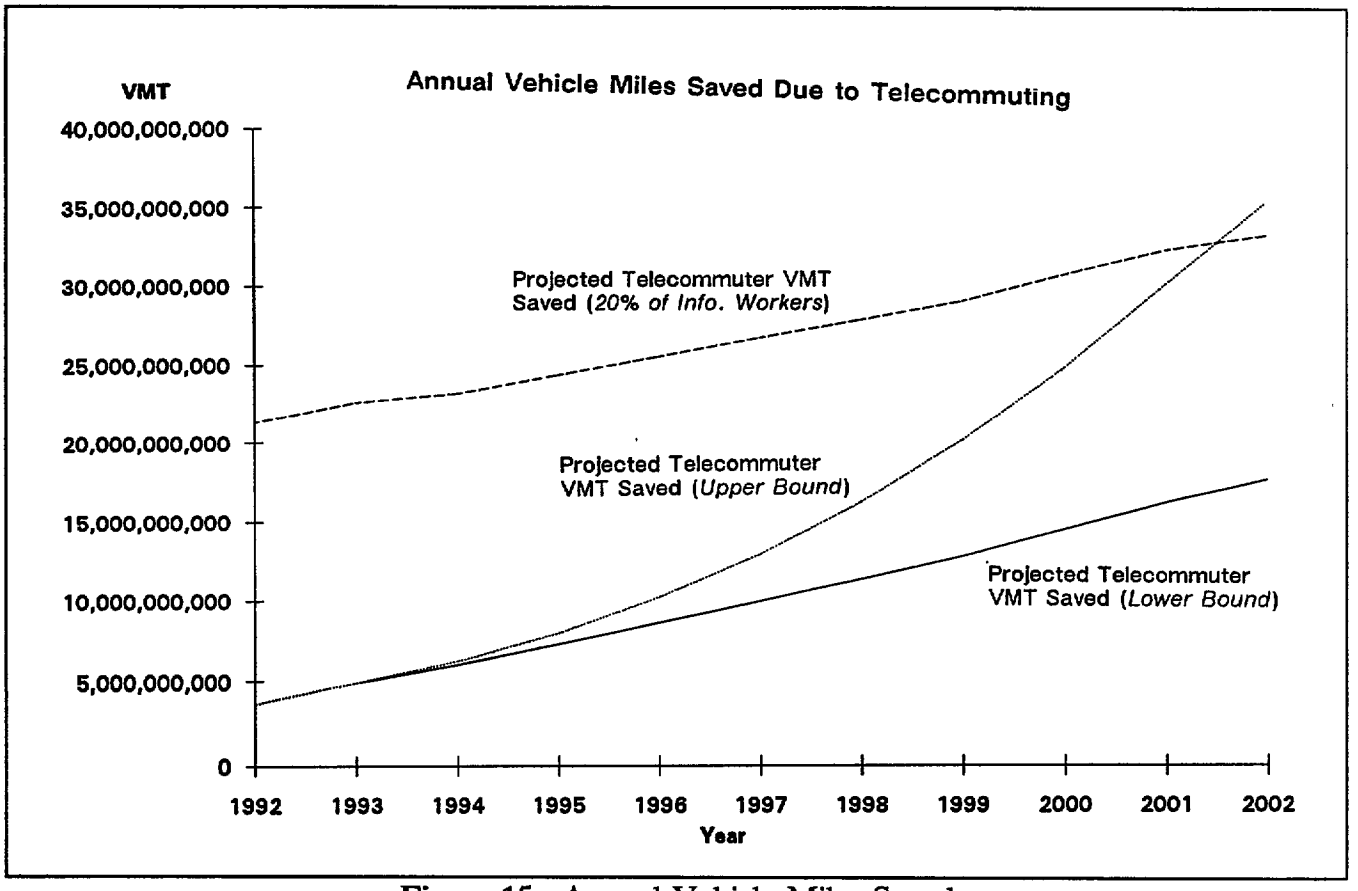


Figure 15. Annual Vehicle Miles Saved

Interactions With Other Demand Management Strategies

"In transportation contexts, telecommuting most often appears on a list of TDM strategies for reducing the demand for peak-period vehicle travel. The interactions among these various strategies are not well understood. Telecommuting could change the effectiveness of other TDM measures (positively or negatively) and vice versa. In particular, strategies intended to shift commuters to higher occupancy vehicles may affect the adoption of telecommuting or the transportation impacts of telecommuting or both. For example, the provision of child-care at the work site is expected to lower a common barrier to ridesharing. However, this strategy could at best discourage some from telecommuting and at worst lead to increased travel. In the Puget Sound project a worker whose child was in the day child center next to the work site had to make two round commute trips on telecommuting days (one in the morning to deliver the child, one in the evening to pick up the child), compared with one round trip on a normal commuting day. On the other hand, such strategies as parking and congestion pricing will stimulate shifts to telecommuting as well as to transit and ridesharing."[90]

ENERGY USE IMPACTS

Table 10 and 11, and Figure 16 illustrate the impact of energy use. In 1991 transportation accounted for 27.3 percent of the total U.S. energy consumption (NTS 1992, Tables 38 & 39) with 3,936.2 million barrels of petroleum used, of which the transportation sector accounted for 10.78 million barrels of petroleum products per day. Transportation thus accounts for about two-thirds of all national oil use. Use for transportation is led by highway vehicle fuel use which, in turn, is dominated by passenger car fuel use.[91] Since commuting constitutes a major portion of automobile travel (32.1 percent), widespread and intensive telecommuting could produce significant savings in national oil use.

Table 10. Petroleum Consumption by Highway Vehicles

U.S. CONSUMPTION OF PETROLEUM AND TOTAL ENERGY BY HIGHWAY VEHICLES (In Quadrillion (10^{15}) BTU)

Consumption	1975	1980	1985	1988	1989	1990	1991
Petroleum Usage by Highway Vehicles							
Gasoline	12.426	12.655	12.958	13.735	13.837	13.781	13.637
Special Fuels	1.336	1.911	2.462	2.783	2.945	2.968	2.892
Total	13.762	14.466	15.420	16.518	16.782	16.749	16.529
Total Petroleum Usage	32.731	34.202	30.922	34.228	34.025	33.553	32.720
Motor Vehicle Percent	42.0%	42.6%	49.9%	48.3%	49.3%	49.9%	50.5%
Total Petroleum Usage	70.546	75.955	73.945	82.200	81.282	81.273	81.497
Motor Vehicle Percent	19.5%	19.2%	20.9%	20.1%	20.7%	20.6%	20.3%

SOURCE: U.S. Department of Energy and U.S. Department of Transportation

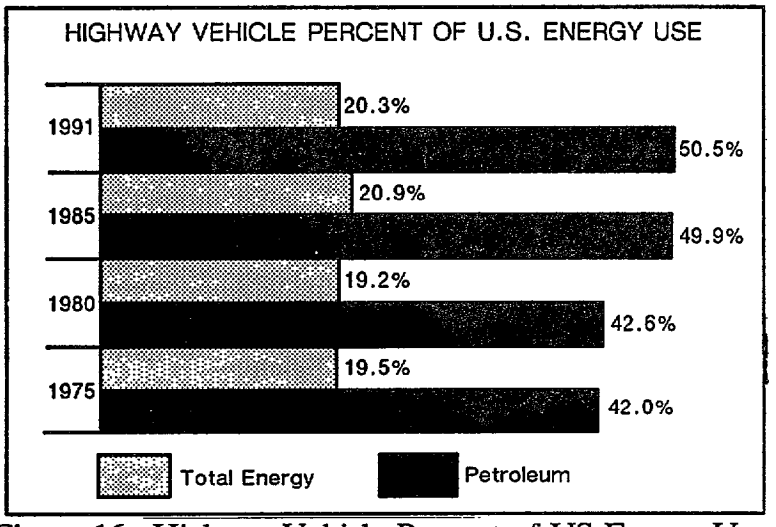


Figure 16. Highway Vehicle Percent of US Energy Use

Transportation usage of motor gasoline for 1991 was 7 million barrels per day. Domestic demand for gasoline in 1990 for highway was 110 billion gallons, 96 percent of the U.S. total (NTS Table 69).

Table 11. Fuel Savings

		1992		1997 - 5 year		2002 - 10 year	
		Saved	% of Total	Saved	% of Total	Saved	% of Total
Upper Bound	Gallons of Gasoline (millions)	178	0.25%	619	0.8%	1,679	2.1%
	Barrels of Gasoline (millions)	4.2		14.7		40	
Lower Bound	Gallons of Gasoline (millions)	178	0.25%	475.9	0.6%	840	1.1%
	Barrels of Gasoline (millions)	4.2		11.3		20	

Using the projected VMT reduction presented in section 2.9, it is estimated that a national total potential savings of 4.2 million barrels per year could be obtained in 1992 and 40 million barrels by 2002 through telecommuting. The total amount of fuel consumed by passenger cars in 1990 was 72.4 billion gallons (U.S. DOT, FHWA, Highway Statistics). The estimated 1992 savings of 178 million gallons represents 0.25 percent of this total, rising to 2.1 percent by 2002. A typical telecommuter who works at home an average of 2 days per week would realize a net fuel savings of about 96.6 gallons, or 2.3 barrels, per year. This is 19 percent of the average yearly per-vehicle fuel consumption.

Reductions in Fuel Tax Revenues

Telecommuting occurring at the projected levels would result in combined Federal and state gas tax revenue losses as shown in Table 12.

Table 12. Gas Tax Revenue Losses

	1992	1997 5 year	2002 10 year
	Foregone Taxes (millions)	Foregone Taxes (millions)	Foregone Taxes (millions)
Upper Bound	**$57.5**	**$199.2**	**$540.8**
Lower Bound	**$57.5**	**$153.2**	**$270.3**

Other Energy Use

Nontransportation energy impacts of telecommuting are also relevant since the net impact will depend on whether energy use increases in home heating and cooling caused by home-based telecommuting are offset by energy consumption decreases in the conventional offices. Lights, heating, ventilation, and air conditioning systems may remain on in the office, as well as in the home. Less energy-efficient incandescent lights may be used in the home, rather than the fluorescent lighting more commonly found in offices. Also, the dominance of part-time telecommuting may lead to heating and lighting empty offices. At present, there is insufficient data available to make a meaningful estimate of this effect.

AIR QUALITY IMPACTS

Emissions Reductions

Transportation is a major contributor to the air pollution problem throughout most urban areas. Despite major strides in mitigating the emissions from industry and transportation, most areas of the country have experienced either a slow rate of improvement or deterioration in air quality is now at the forefront of national policy, and the Clean Air (CAA) as amended in 1990, places particular emphasis on transportation and all quality planning. The 1990 amendments expand on the requirement that federally assisted highway and transit projects conform with State Implementation Plans (SIP) for achieving or maintaining Federal clean air standards.

The U.S. DOT is required to work with EPA and state and local government to ensure that CAAA provisions are being met while ensuring sufficient mobility to the Nation’s population and business. Mobility is a key element in economic growth and competitiveness and must be maintained at acceptable levels. The challenges posed by the CAAA will force all levels of government to rethink traditional policies and actions as will as to develop new thrusts that identify alternative transportation technologies, options, and practices that meet the

multiple goals of safety, mobility, and clean air.

The transportation system is responsible for direct and indirect environmental impacts -- directly by producing emissions from the cars themselves, and indirectly through emissions associated with fuel extraction, refining and distribution, infrastructure construction, and vehicle manufacturing. Figure 17 shows that the direct combustion of fuel (primarily gasoline) in the transportation sector accounts for 27.3 percent of total U.S. air pollutant emissions of hydrocarbons, 28.6 percent nitrogen oxides (the principle ingredients of smog) and 50.4 percent of carbon monoxide emissions (a noxious pollutant as well as one implicated in the formulation of smog). In urban areas, autos account for an estimated 70 percent of smog-precursor emissions and 90 percent of carbon monoxide emissions.

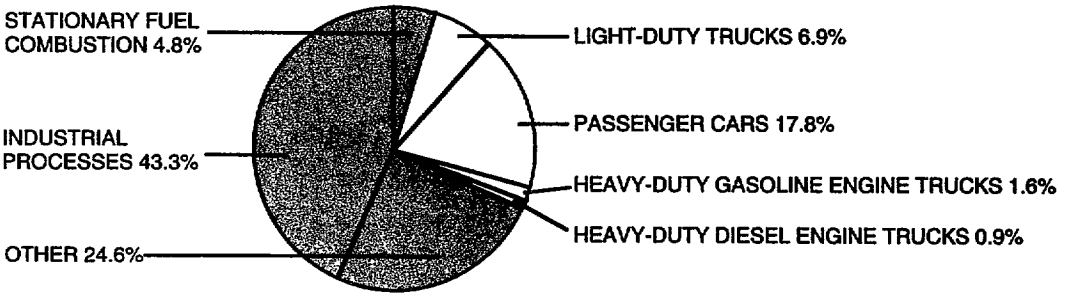
U.S. SOURCES OF AIR POLLUTION, 1990

	Suspended Particulates	Sulfur Oxides	Nitrogen Oxides	Volatile Organic Compounds	Carbon Monoxide	Lead	Fine Particles (PM-10)
Total (Millions of metric tons)	7.5	21.2	19.6	18.7	60.1	7.1(2)	6.4
Percent of total:							
Highway Vehicles	17.3%	2.8%	28.6%	27.3%	50.4%	28.2%	19.0%
Stationary Fuel Combustion	22.7	80.7	57.1	4.8	12.5	7.0	17.0
Industrial Processes	37.3	14.6	3.1	43.3	7.8	31.0	43.0
Other(1)	22.7	1.4	11.7	24.6	29.3	33.8	21.0

(1) Includes air pollutants from other transportation modes, solid waste disposal, forest fires and other burnings.
(2) Gigagrams/year (thousands of metric tons).

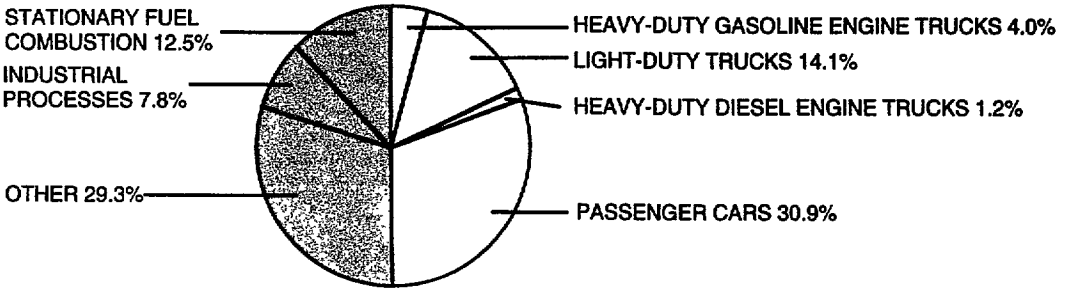
HYDROCARBONS

Hydrocarbons (volatile organic compounds) are not generally considered an air quality problem as they leave the vehicle. Some hydrocarbons react in the atmosphere to promote the formation of photochemical "smog." Ozone concentration is generally used as the measure of the extent of the photochemical reaction. Thus, hydrocarbon emission standards have been set to meet the National Ambient Air Quality Standards for ozone.



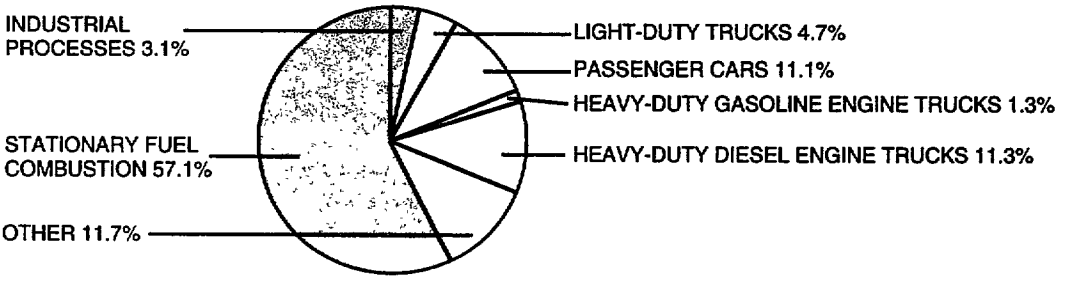
CARBON MONOXIDE

A by-product of incomplete fuel combustion, carbon monoxide is a colorless, tasteless and odorless substance that displaces oxygen in the body. Especially at high concentrations in confined areas, it can be injurious to health. A National Ambient Air Quality Standard and a vehicle emission standard are set for carbon monoxide.



OXIDES OF NITROGEN

Vehicle emission standards are set for NO_x to meet the National Ambient Air Quality Standard for nitrogen dioxide. Vehicle NO_x emissions are a significant, but not major, contributor to the creation of nitrogen dioxide. NO_x emissions are also ingredients in "smog" formation, but their role appears ambiguous. At times they appear to promote, while at other times they seem to inhibit "smog" in urban areas.



NOTE: Columns may not add to 100% due to rounding.
SOURCE: U.S Environmental Protection Agency, *National Air Pollutant Emission Estimates, 1940-1990, November, 1991.*

Figure 17. U.S. Sources of Air Pollution

"In addition to being the leading source of air pollution in the U.S., cars and trucks (as the source of several greenhouse-gas emissions including carbon dioxide, chlorofluorcarbons, and ozone) are major contributors to global climate dioxide (the principle greenhouse gas) into the atmosphere. Overall emissions of pollutants are projected to increase by almost 40 percent by 2010 because we are driving more and under more congested conditions (Walsh, 1990)."[92]

The pollution created by highway vehicles in 1990 was 5.085 million tons of nitrogen oxides, 4.63 million tons of hydrocarbons, and 27.48 million tons of carbon monoxide (U.S. EPA, National Air Pollution Emission Estimates 1940-1990, Nov. 1991). The estimated amount of reduction of these pollutants due to telecommuting is shown in Table 13 below.

Table 13. Emissions Savings

		1992		**1997-5 year**		**2002-10 year**	
	Emissions	Tons Saved	% of Total*	Tons Saved	% of Total*	Tons Saved	% of Total*
Upper Bound	NOx	11,852	0.23%	41,061	0.81%	111,479	2.19%
	HC	14,571	0.31%	50,468	1.09%	137,047	2.70%
	CO	98,753	0.36%	342,118	1.25%	928,836	3.38%
Lower Bound	NOx	11,852	0.23%	31,593	0.62%	55,739	1.10%
	HC	14,571	0.31%	38,839	0.84%	68,524	1.35%
	CO	98,753	0.36%	263,229	0.95%	464,418	1.69%

* percentages based on 1990 levels

Table 13 shows a relatively limited impact of telecommuting on air quality. However, these results could be very misleading when applied to a specific locality. The degree to which telecommuting is adopted depends in part on the overall transportation environment. In areas suffering serious congestion and air quality problems, in which stringent transportation demand and control measures are in force, firms and employees will have much greater incentive to explore and implement telecommuting. The result could be a substantially higher rate of adoption than used in this analysis, particularly for individuals who face the more lengthy or congested commuting trips. Under those circumstances, it is also less likely that latent demand will appear as telecommuters disappear from the highways. The resulting reduction in congestion will result in emission reductions for all traffic—an effect that could be as great in magnitude as that from removal of the telecommuters. With a higher number of telecommuters and reduced congestion for all vehicles, the total reduction in emissions could conceivably be several times that suggested by Table 13.

These estimates are based on emission levels from the EPA's Mobile 4.1 model. Transportation related emissions occur as a result of vehicle trip, VMT, and the vehicle itself. In general, the

lower the VMT, the lower the fuel consumption and emissions. However, even if the number of VMT is reduced, fuel consumption and emissions impacts of telecommuting are affected by a number of factors. These include:

- **Distance traveled by auto.** The distance traveled by auto is important since, other things being equal, the shorter the distance traveled, the shorter the emissions. Thus, if a telecommute results in an overall reduction of distance travelled through the elimination of commute trips, positive impacts on emissions will result. Conversely, if increased work trips or a move to a more distant location leads to a net increase in auto distance travelled, the impact on emissions will be undesirable.

- **Number of cold** starts (related to the number of trips). A high proportion of the emissions for the entire trip are created when a cold engine is started. If telecommuting was to generate new trips, or a higher proportion of unlinked trips, then the number of cold starts could increase, resulting in higher emissions even if total miles travelled decline.

- **Number of hot starts.** The number of stops or links on a given round trip matters, because starting even an already-warm engine generates more emissions than a running engine. Thus, a lo-kilometer trip with four stops emits more pollutants and consumes more fuel than the same 10 kilometer trip with only two stops.

- **Speed.** In general, low speeds and accelerations/decelerations result in higher emissions. A 10 kilometer trip at 20 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, through telecommuting, more travel takes place in the off-peak at higher average speeds, a benefit to air quality will result.

- **Time of** day. Cold start emissions are sensitive to the surrounding (ambient) air temperature. In general, the lower the ambient temperature, the higher the emissions.

- **Vehicle used.** The possibility must be considered that 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. The presence or absence of a catalytic converter affects the emissions from a vehicle. Emissions from diesel engines differ from those of gasoline-powered engines. Thus, since telecommuting might prompt a reassignment of vehicles within households, a complete study of transportation-related energy and air quality impacts of telecommuting should account for the use of all vehicles in the household.[93]

If telecommuting reduces trips in the early morning and late evening hours, and induces trips to be made later in the daytime, it may have a significant positive effect on air quality. Note that the situation is highly uncertain for satellite centers. If they are not located near public transit, they could conceivably increase VMT and cold starts.

Another currently-unquantifiable factor is the possibility of increased release of hydrocarbons as a result of the buildup of gasoline vapors in the fuel system of vehicles not driven on a daily basis.

Figure 18 reflects the distribution of hydrocarbon emissions by trip phase. In general there is a U-shaped relationship between speed and emissions. That is, emissions per mile decline as speed increases, up to about 80-96 kilometers per hour (50-60 miles per hour), then increase with higher speeds. If telecommuting reduces congestion, leading to fewer accelerations and decelerations and higher (but not too high) average speeds, it can be beneficial for air quality. The importance of speed on automobile emissions is illustrated in Figure 19.

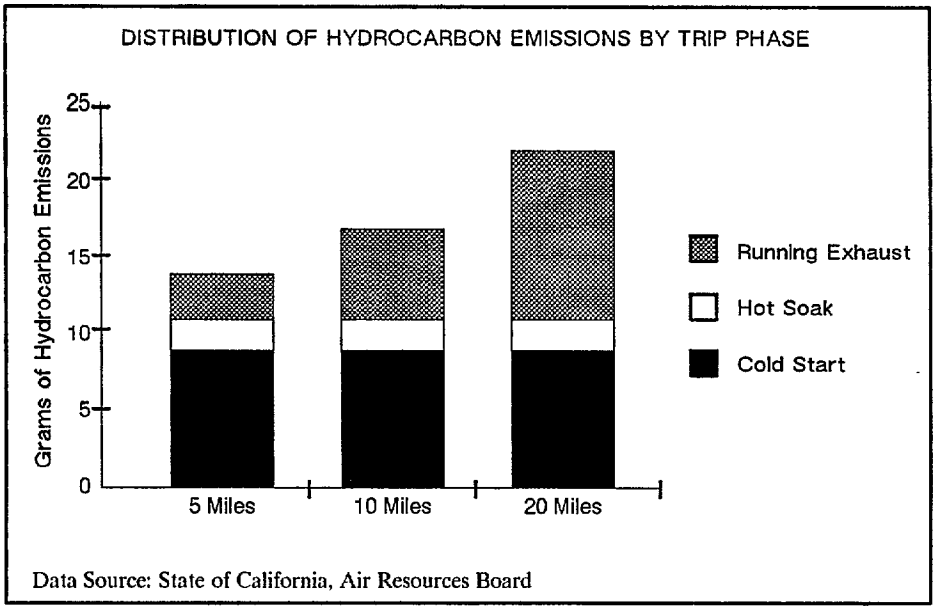


Figure 18. Distribution of Hydrocarbon Emissions by Trip Phase

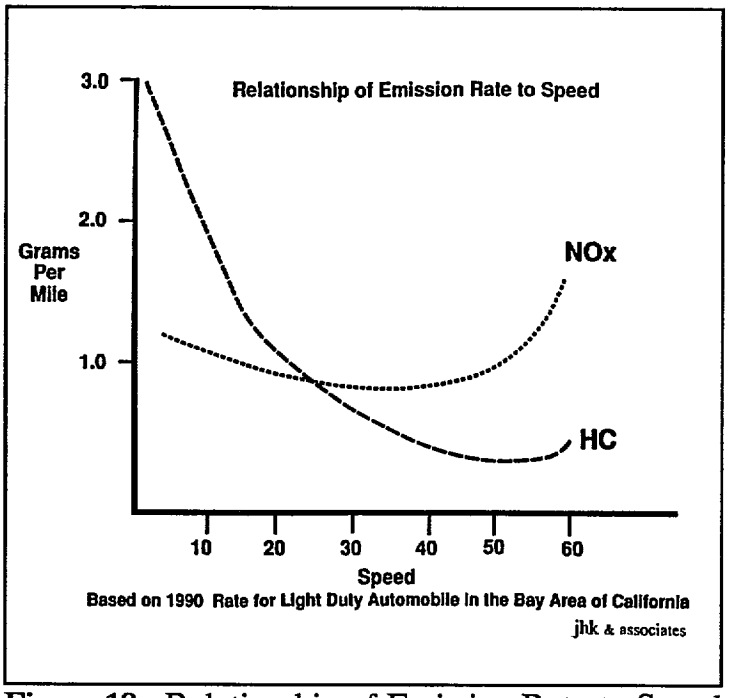


Figure 19. Relationship of Emission Rate to Speed

SAFETY IMPLICATIONS

Highway accidents cost 43,500 lives in 1991. The telecommuters reduce their risk of injury and death by reducing the amount of time they spend in rush-hour traffic. Table 14 below contains estimates of annual fatalities and accidents avoided due to a decrease in VMT from telecommuting.

Figure 20 and Table 15 show a downward trend of both the annual motor vehicle deaths and accident rates for 1980-1990 over 10 years. The savings due to telecommuting were calculated against total motor vehicle deaths and accidents, and would be substantially higher if calculated against only passenger vehicle deaths and accidents for commuters. Future accident rate and death totals were based on future VMT totals; this rate was then applied to VMT savings accrued as a result of telecommuting to arrive at projected death and accident totals. There is a very high degree of uncertainty in these estimates; safety impacts can be expected to be highly sensitive to specific circumstances.

Table 14. Safety Implications

		1992		1997 - 5 year		2002 - 10 year	
		Number	% of Total	Number	% of Total	Number	% of Total
Upper Bound	Lives Saved	87	0.19%	300	0.69%	815	1.97%
	Accidents Avoided	28,520	0.23%	65,770	0.63%	117,700	1.43%
Lower Bound	Lives Saved	87	0.19%	231	0.54%	408	0.99%
	Accidents Avoided	28,520	0.23%	50,355	0.49%	58,850	0.72%

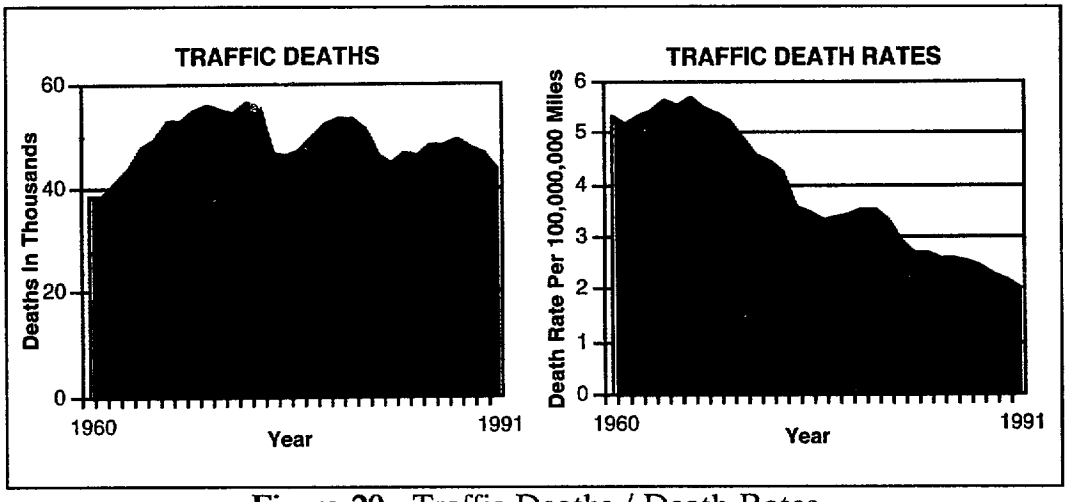


Figure 20. Traffic Deaths / Death Rates

Table 15. Motor Vehicle Deaths / Death Rates

MOTOR VEHICLE DEATHS BY TYPE OF ACCIDENT AND DEATH RATES

	Total Motor Vehicle Deaths	DEATHS FROM COLLISION WITH							Deaths from Non-collision accidents	Per 10,000 Motor Vehicles	Per 100,000,000 Vehicle Miles	Per 100,000 Population
		Pedestrians	Other Motor Vehicles	Rail-Road Trains	Street Cars	Pedal-Cycles	Animal-drawn Veh. or Animal	Fixed Objects				
1991	43,500	7,000	18,500	500		800	100	12.100	4.500	2.23	2.01	17.2
1990	46.800	7,600	19,800	500		800	100	13,200	4,800	2.43	2.18	
1969	47,575	7,800	20,300	720	2	900	100	12,900	4,900	2.48	2.26	19.2
1988	49,078	7,700	20,900	638	2	1.000	100	13,400	5,300	2.60	2.42	20.1
1987	48.290	7,500	20,700	554	1	1,000	100	13,200	5,200	2.63	2.51	19.8
1986	47; 86.5	a, 900	20,800	574	2	1,100	100	3,300	13,100	2.63	2.60	19.9
1985	45,901	8,500	19,900	538	2	1,100	100	3,200	12,600	2.59	2.59	19.2
1984	46,263	8,500	20,000	630	0	1,100	100	3.200	12,700	2.69	2.69	19.6
1983	44,452	8,200	19,200	520	1	1,100	100	3,100	12,200	2.62	2.68	19.0
1982	45,779	8,400	19,800	554	1	1,100	100	3,200	12,600	2.77	2.88	19.7
1981	51,385	9,400	22,200	668		1,200	100	3,600	14,200	3.13	3.30	22.4
1980	53,172	9,700	23,000	739		1.200	100	3,700	14,700	3.29	3.50	23.4

SOURCE: National Safety Council, Accident Facts; 1991.

TIME SAVINGS

The annual commute time savings were calculated assuming a 44.8-minute round-trip by the urban commuter (75.2 percent) and a 22.4 minute round trip commute by the rural commuter (24.8 percent). This averages 77.3 hours/year/telecommuter for 1992 up to 110.3 hours/year for 2002 as shown in Table 16.

Table 16. Time Savings

	1992		1997 - 5 year		2002 - 10 year	
	Hours Saved (millions)	% of Telecommuter's Regular Commute Tie	Hours Saved (millions)	% of Total	Hours Saved (millions)	% of Total
Upper Bound	156	49.2%	577	59.5%	1,652	70.2%
Lower Bound	156	49.2%	444	59.5%	826	70.2%

Economic Benefits of Reduced Commuting Time

A substantial literature exists concerning the value travellers place on their time. Typically, studies suggest that commuters behave on average as though the time spent on their trip has

a value of about $7 per hour. Thus, time savings are often multiplied by some such value and the results presented as a specific economic benefit arising from telccommuting. That calculation is not made here, since in this context such a number adds little to understanding and can be misleading. The meaning of a worker's saving an hour of commuting time is readily comprehended, but the meaning of a dollar-equivalent of that time is much less clear. The "saving" does not directly generate wealth that shows up as national income or gross domestic product, or in any other indicator. In fact, the net effect is exactly the same as if the employee simply moved to a new home adjacent to the location of his or her employment. If the worker should choose to labor at home for an additional hour, the result would be reflected in productivity figures. Were the employer able, perhaps over time, to negotiate comparably lower pay scales in exchange for the opportunity to telecommute, there would again be a direct productivity gain, but this is not generally expected to happen.

Thus, while a dollar value can be imputed to the telecommuter's time savings, the degree to which the Nation has benefitted is more meaningfully stated simply in terms of reduction in personal commuting hours, rather than as a somewhat artificial dollar amount of uncertain real meaning. It is important to note that this issue, which relates purely to the dollar value of saved commuting time, is not related to the unquestioned real economic benefits to an employer arising from the possible higher productivity of telecommuters -- a gain often reported for pilot programs.

OTHER EFFECTS

Health Care Effects

Telecommuting may improve the overall health of the worker and result in reduced medical costs. Studies of automobile drivers have shown significant relationships between exposure to traffic congestion and a variety of adverse physiological reactions. For example, researchers have reported a significant and positive correlation between high traffic volumes and increased heart rates, blood pressure, and electrocardiogram irregularities. Studies also show that chronic exposure to traffic congestion, especially over long distances, long waits, and frequent trips, increases negative mood states, lowers tolerance for frustration, and can even lead to more impatient driving habits.[94] The State of California Telecommuting Pilot Project survey data and interviews revealed telecommuters experienced reduced levels of stress.

Other related factors that would improve worker health and also therefore reduce medical costs are reduced exposure to individuals with contagious conditions and benefits associated with walking instead of travelling by car.

Economic Development

The development of an extensive telecommunications infrastructure may provide economic growth opportunities in both urban and rural areas. Many authors have argued that advanced telecommunications systems will make all locations attractive and, therefore, tend to reduce existing inter-regional economic and social inequalities. However, reduced telecommunications costs do not seem to have had a major impact on changing the relative weights of location factors and many of the current disadvantages of distance will persist into the future. Outlying locations are chosen by employers based on a long list of factors that together represent the costs and benefits of the alternatives available to them. Only when the benefits of outlying locations significantly outweigh their costs in relation to central locations will they be selected.

Overall, studies in this area do not yield any concrete conclusions as to the effect of advances in telecommuting and telecommunications technologies on the decision making process of firms and individuals with regard to location or relocation. However, many authors think that the main effect will be to accelerate the movement of jobs out of central areas to suburban fringe or rural locations. Growth and redevelopment of cities and towns in rural areas is considered a viable alternative to urban sprawl. If telecommunications reinforce the trend to move from major cities to rural cities, then urban sprawl may be reduced in favor of rural city/town growth. However, this could have serious consequences since small cities may be unprepared for the new growth and large cities may be hurt by the erosion in quality of the tax base.

Rural Area Development

Twenty years ago, "access" in economic development terms meant roads, highways, concrete, and air and rail transportation. Today, access refers to information and data and fiber optics. Telecommunications may mitigate the factor of geography from the economic development equation and make rural areas very accessible and attractive to expanding businesses. Unique applications of telecommunications may ensure that jobs are available in all areas, especially rural areas, and stop serious tendencies towards emigration.

Telecommuting is being viewed as a means to provide a new way of establishing an economic base in rural areas by providing a mechanism to funnel work into areas of high unemployment. To the extent that telecommuting makes more jobs more accessible to economically depressed regions, it may help reduce the social tensions of poverty and unemployment.

A prospectus for the Kentucky Science and Technology Council (Kentucky Rural Telecommuting Centers, June 1991) lays out an optimistic case for bringing jobs and prosperity into rural areas via investment in a superior communications network and

education. The Kentucky program uses telecommuting as a means to encourage economic development in rural areas.

A study by Arthur D. Little, Inc., Can Telecommunications Help Solve America's Transportation Problems? Cambridge, MA, 1991, estimates the potential societal benefits to rural areas at about 6.5 percent of the national benefits, or about $1.5 billion in 1988 dollars; 61 percent of this is in the form of productivity savings and the rest is attributed to energy savings. (This model focuses on the time savings from trip elimination as the largest factor and assumes rural commuters are less likely to substitute telecommunications for auto trips than urban commuters; reduction of congestion and pollution is a very minor benefit in rural areas and rural residents do not save plane miles or truck miles for business trips or information transport).

The U.S. Congress Office of Technology Assessment reports Rural America: Networking for the Future (1991) goes into great detail about the opportunities, challenges, and pitfalls implicit in the telecommunications revolution as they may affect rural areas, including extensive and detailed information about the possible implications of the pricing of telecommunications goods and services.

While most authors are optimistic, constraints are likely to result from the lack of suitable skills in remote areas and the lack of appropriate support services, many of which require a critical mass of customers to be viable. It is unlikely that telework will lead to regional development without active intervention by national or local government to make up for such deficiencies and provide fiscal resources.[95]

Telecommuting/Urban Sprawl

Telecommuting is sometimes portrayed as a means of increasing the jobs-housing balance in urban and suburban areas by enhancing the ability to move work to, or closer to, the workers' residences rather than requiring workers to commute to work daily. This has the immediate side effect of decreasing automobile congestion and associated energy consumption and air pollution. However, there is a possible long-term adverse impact of telecommuting resulting from its ability to decrease constraints on household location, thereby enhancing the rate of spread of suburbia. Nilles reviews evidence concerning the possible effects of telecommuting on urban sprawl, the continuing urbanization of formerly rural areas. One consequence of urban sprawl is jobs-housing imbalance, the locations of employee residences change while work-site locations either do not change or follow the housing trends slowly.

One of the reasons for studying the potential for telecommuting is to determine whether, as some feel, it would produce even more "urban sprawl" than is currently expected. Already there is an explosion in farm and village home prices in upstate New York, rural

Maine, the Sierra Nevada, and other attractive locales that were once too distant from urban areas to be practical locations for home-based work [Portable.. ." 1988,162]. For these reasons, even more careful land-use planning will be needed to protect areas of scenic beauty as well as promote optimal land use patterns in rural and small town areas if telecommuting is widely adopted. "[96]

Nilles suggests that this will depend strongly on the form that telecommuting takes. If it is primarily on a part-time basis, people who move further out into rural areas will still press for improvements in transportation infrastructure, thereby encouraging sprawl. If, on the other hand, telecommuting is full-time, which is more likely for telework centers, transportation infrastructure is less likely to be expanded. Thus, the more-rural locations will still be relatively unattractive for commuters, and sprawl will be discouraged. In addition, the telecommuters' constant presence will encourage development of neighborhood stores and services, diminishing the motivation to travel to larger urban locations.

Job Creation

The establishment of telecommuting centers in economically disadvantaged areas may revitalize commercial districts, and potentially, new employment opportunities. Increased employment will come from new jobs created at the center, as well as other jobs which the development and support services will create. Aside from these aspects, the existence of such centers will lure other employers, both public and private, to the region.

Chapter 4 - Conclusions

- **Telecommuting is now practiced on a substantial and rapidly growing scale**

Telecommuting, now practiced by about two million people (2 percent of the U.S. labor force), is already a fact of life for many businesses and individuals. Employee gains in flexibility and quality of life can often be matched by corporate benefits of higher productivity and a more loyal and motivated work force. As a result, this phenomenon is currently growing at about 20 percent annually and the rate could increase as it becomes a more conventional element in providing workplace flexibility in coming years. It seems likely, that by early in the next decade 10 percent of office-based workers will have become telecommuters, averaging more than three days per week working at home or at a local telecommuting center. Table 17 lists Projected Future Telecommuting.

Table 17. Projected Future Telecommuting

PROJECTED FUTURE TELECOMMUTING	1992	1997	2002
Number of Telecommuters (millions)	2.0	3.1 - 6.2	7.5 - 15.0
Percent of Labor Force	1.6%	2.3% - 4.6%	5.2% - 10.4%
Percent of Telecommuters Working at Home	99.0%	74.3%	49.7%
Percent of Telecommuters Working at Telework Centers	1.0%	25.7%	50.3%
Average Days per Week	1-2	2-3	3-4

- **Estimates of the future level and impacts of telecommuting are highly uncertain**

Telecommuting is still in an early stage and an accurate prediction of its rate of growth and of transportation impacts is difficult. Many factors contribute to the uncertainty in the estimates in the table shown above. The actual degree to which jobs, individuals and employers ultimately will be suitable to telecommuting is not clear. Most large-scale experiments are of recent origin and involve carefully selected workers and managers. Data specifically for the telecommuting subset of the driving population is lacking with regard to key parameters such as travel behavior (e.g., trip length and duration), and information concerning emissions and fuel use is not generally available. Direct and indirect costs to employers and the magnitude of business benefits also are not well established.

Achievement of the full potential of telecommuting, as well as that of many other uses of telecommunications services to provide access or replace transportation, depends on having a regulatory and investment environment that yields a sophisticated, efficient, high-capacity,

broad-bandwidth telecommunications infrastructure. Many complex and contentious regulatory and legislative issues arise in addressing that need.

- **Telecommuting has the potential to provide significant transportation-related public benefits**

Although the uncertainties are very large, experience to date indicates that, under favorable circumstances, telecommuting can provide significant reduction in highway congestion and associated lost time, fewer accidents, reduced emission of pollutants, and savings in energy and petroleum consumption. Telecommuting is already widely seen as an important travel **demand management measure to reduce congestion and meet existing ambitious** national air quality goals. Among the parties most interested in telecommuting are public agencies concerned with congestion and pollution.

Estimates based on the technical literature and current travel statistics suggest that significant transportation benefits could be attainable, as indicated in the table below. These projections make clear that telecommuting could eventually play a significant role in addressing problems of urban congestion, air quality, and energy use, but it is by no means a near-term or complete solution. Its impact in any particular region will depend importantly on travel demand management measures and other aspects of the local transportation environment and could, in some cases, be substantially larger than shown in Table 18 that follows.

Table 18. Transportation Impacts

TRANSPORTATION IMPACTS	1992	1997	2002
Saving in Vehicle Miles Travelled (VMT) (billions)	3.7	10.0 - 12.9	17.6 - 35.1
Percentage Saving in Total Passenger VMT	0.23%	0.49% - 0.63%	0.7% - 1.4%
Percentage Saving in Commuting VMT	0.7%	1.6% - 2.0%	2.3% - 4.5%
Saving in Gallons of Gasoline (millions)	178	475.9 - 619	840 - 1,679
Percentage Saving in Gasoline	0.25%	0.6% - 0.8%	1.1% - 2.1%
Value of Gasoline Saved (millions)	$203	$543 - $706	$958 - $1,914
Percentage Saving in Emissions			
NOx	0.23%	0.6% - 0.8%	1.1%- 2.2%
CHC	0.31%	0.8% - 1.1%	1.4% - 2.7%
CO	0.36%	1.0% - 1.3%	1.7% - 3.4%
Annual Hours Saved for Average Telecommuter	77	93	110.3
Total Annual Hours Saved (millions)	156	444 - 577	826 - 1,652

- **Emergence of latent travel demand could substantially diminish the congestion and air quality improvements attainable through telecommuting**

The figures shown above reflect only the direct impact associated with individual telecommuters. The place of telecommuters might be taken by people who previously commuted in car-pools or by public transportation but, because of the reduced congestion, now choose to drive single-occupant automobiles. To the degree that this latent demand appears, the net change in congestion would be reduced, and transportation benefits associated with the telecommuter would be partially nullified. The importance of this effect will vary from place to place; its magnitude is likely to be strongly affected by the stringency of regional travel demand management measures and the local public perception of congestion and air quality problems. No generalization as to the net result is possible. The benefit estimates shown above do not include adjustment for this effect.

- **Direct energy, air quality, safety, and time benefits of telecommuting will be multiplied to the degree that congestion is reduced**

To the degree that telecommuters removed from traffic are not replaced by other motorists drawn by the reduced traffic, the resulting reduction in congestion will improve traffic flow and yield additional benefits in time saved, energy, and emissions for all remaining commuters. The magnitude of these benefits can be comparable to the direct benefits for the telecommuters; multiplier effects are not reflected in the table shown above.

- **Telecommuting could stimulate urban sprawl and other adverse impacts on land use and public transportation**

A potential negative impact of telecommuting and telework generally (including self-employed people working at home) is the possibility that people freed from a daily commute will tend to migrate further from urban areas, exacerbating decline of central cities, suburban sprawl, and development pressure on rural areas prized for their natural beauty and resources. Similarly, the overall pattern and density of land use in urban areas could be affected, with direct impact on the design of public transportation systems. However, at this very early stage, no conclusions can be reached as to the degree to which telecommuting might change residential choices, contribute to decline of the city center, or raise other land-use issues.

- **Critical limits on the near-term rate of growth of telecommuting include uncertainty of benefits for employers and the considerable time and effort inherently required to bring about major changes in workstyles and ways of doing business**

The rate at which telecommuting is adopted will be constrained primarily by the still uncertain cost-benefit implications for businesses and the pace at which employers and

workers become familiar and comfortable with this new way of working. In most cases, it represents a substantial change for employees and their supervisors, and it is not suitable to every job, person, or situation. The penetration of telecommuting will also be affected by the rate at which firms and agencies become more nearly "paperless," with most documents and working materials existing primarily on electronic media and employees fully linked by networks. A rapid expansion of advanced telecommunications services supplied to homes could also serve to stimulate telecommuting. Establishment of remote telecommuting centers is a complex undertaking that may require several years to come to fruition. Although there appear to be no major or insurmountable institutional impediments to telecommuting, a variety of legal, tax, zoning, and labor-management issues can require resolution in specific cases.

- **Telecommunications services and equipment are adequate for most current telecommuting, but high-bandwidth capabilities will be needed in the future, and would be beneficial now**

Telecommunication services and the often necessary electronic and computer equipment are generally adequate for most current telecommuting, although advances, particularly in high-bandwidth communications capability in homes, would be beneficial even now for telecommuters and many other individuals who work at home. Improvements will increasingly be necessary for some telecommuting situations in the future, just as they will be needed for many business and other applications in which telecommunications capabilities are substituted for physical transportation. Market forces, stimulated by the Clinton Administration's "information superhighway" goals, may be expected to yield the necessary infrastructure. However, this result could be impeded to the degree to which evolution of the regulatory and legal framework for telecommunications services lags the growth of technical capabilities. The steady decline in the cost of computers and peripheral equipment, facsimile machines, and other devices has already reduced cost to a minor consideration for home-based telecommuting, particularly as more and more homes are already so equipped. Cost does appear to be a significant factor in establishment of telework centers.

- **Government agencies can play a significant role in facilitating and encouraging telecommuting**

Government agencies can encourage and facilitate the application of telecommuting as a travel demand management measure. The 1991 Intermodal Surface Transportation Act (ISTEA) authorizes Federal funding to be used to support planning, development, and marketing of telecommuting programs designed to improve air quality and reduce congestion. Research and other studies to clarify employer benefits and transportation and air quality impacts will be important in assuring that businesses and planning agencies have a sound basis for telecommuting decisions.

As telecommuting becomes more widespread, issues such as tax codes, liability, and labor laws could become more intrusive. Those issues will have to be addressed in a responsive and fully-informed manner by the responsible Federal, state and local agencies if telecommuting is **to** achieve its full potential.

- **Telecommuting can be an effective tool for travel demand management, but cannot be forced**

The potential transportation impacts of telecommuting are sufficient to make it appropriate for serious consideration as a travel demand management measure. However, the suitability of telecommuting to a specific situation depends on the particulars of job, person, supervisor, and corporate culture. It can be promoted, encouraged and facilitated by public authorities, but cannot be mandated externally. In general, to require that individual businesses or public agencies achieve a specific level of telecommuting would be inappropriate and ineffective.

- **Continuing research will be needed to clarify the costs, benefits, and impacts of telecommuting**

As noted above, the projections of telecommuting and its transportation impacts presented in this report and elsewhere are inherently highly uncertain. Very little firm data is available to resolve these uncertainties. Telecommuting is a diffuse activity, not well captured in current statistics, and transportation impacts are unlikely to be directly measurable. Even as telecommuting becomes more widespread, needed information, particularly that involving travel behavior and land-use impacts, will not be acquired without special efforts in collection, analysis, and dissemination of data. Research will be needed concerning virtually all facets of this subject.

As state and local authorities struggle with formulation of programs to combat congestion and air pollution, they will need reliable information as to the likely characteristics and effectiveness of each travel demand management measure under consideration, including telecommuting. Similarly, businesses and other organizations considering establishment of a telecommuting program can generate reasonable estimates of the costs, but have relatively little firm information as to the overall benefits that can be expected from large-scale implementation. The price and value of establishing telework centers is particularly uncertain. Businesses and other organizations need credible data concerning implementation and administration costs for telecommuting programs, as well as good estimates of productivity improvements and employee hiring and retention.

Although it is likely to be at least several years before telecommuting reaches the level at which land-use impacts become of real concern, the long lead time needed to deal with such issues necessitates that the nature and magnitude of these effects be characterized as early

as possible.

Some of the more important questions which need to be answered include:

Amount and Nature of Telecommuting. How many workers will telecommute in the near term? At what rate will telecommuting increase? What percentage of the U.S. work force will telecommuters make when this activity has reached saturation within the workforce? For what jobs, individuals and businesses will widespread telecommuting be truly feasible and advantageous? How well will telecommuting work for businesses and government agencies? Will telecommuters be preferentially those who have the longest commuting trips? What will prove to be the relative attractiveness of home-based telecommuting as compared to telework centers?

Direct Costs and Benefits. What are the productivity impacts of large-scale telecommuting? How significant are the capital, management and administrative costs of conducting a major program? To what degree does telecommuting affect employee recruiting and retention?

Transportation Impacts. How does total travel behavior change for telecommuters and members of their households? How are these changes affected by various travel demand management measures? How does telecommuting affect such measures, such as car-and-van pooling and compressed (4-day) work weeks? What are the average driving scenarios for telecommuters? What are the emission and energy implications of their telecommuting?

Land Use. In the long term, to what degree will telecommuters tend to relocate to less urban localities? Will telecommuting lead to land-use patterns that aggravate urban sprawl? Can telecommuting play a significant role in reinvigorating rural areas?

Barriers to Telecommuting. Are there significant regulatory, legal, tax, or institutional barriers to implementation of telecommuting programs? What is their nature and what governmental and private actions can eliminate or reduce them? To what degree is telecommuting impeded, currently or in the future, by the inadequacies of telecommunications infrastructure? How much is the adoption of telecommuting linked to continuing advances in the cost and performance of telecommunications services and information and communications technology?

Transportation Planning. How is telecommuting best incorporated in travel demand forecasting and transportation planning? Can it be considered a "mode"? How does it affect existing modes? To what degree is its "mode share" affected by other modes?

Telework Centers. What are the costs of various types of telework centers? What is

their transportation impact? What role will they play in telecommuting? How will they affect land-use issues? How can they be accommodated in transportation and land-use planning?

The Department of Transportation will work with other Federal agencies, states, local governments, and the private sector to monitor and assess telecommuting activities, conduct research and disseminate relevant information concerning its spread and consequences for transportation and land use. Insofar as is practical, organizations implementing telecommuting will be encouraged to develop as much information as possible concerning changes in the travel behavior of their telecommuters, and to disseminate that information for integration with other data and subsequent analysis and dissemination.

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Appendix A - Telecommuting Technologies and Services

1.0 Primary Telecommuting Technologies and Services

1.1 Technologies and Services Classification

It is difficult to differentiate between "technologies" and "services" used by telecommuters. For example, fax service requires a set of technologies (e.g., computer, software, scanner, teleconununications, etc.) to make it work between two sites. It is perhaps better to categorize telecommuting services then discuss technological trends, potentials, and risks associated with the realization of telecommuting services.

Studies of telecommuters, conducted since 1983, have consistently yielded two findings concerning the technology of telecommuting:

> "Telecommuters vary widely in their preferences and use of high-tech equipment such as computers, fax machines and advanced phone applications. The one thing they most all generally rely on is basic residential telephone service."[1]

Products and services used by telecommuters:

PC Products: personal computer, modem, fax board for PC.

Telephone Lines/Products: telephone answering device, two or more phone lines, cordless phone, fax, two-line phone.

Central Office Services: call waiting, call forwarding, three-way calling, speed calling, caller ID.

[1]Telecommuting Case Studies, LINK Research Report.

Telecommuting services may be classified as follows:

Messaging: electronic mail, computer bulletin boards, paging, voice mail, mobile radio, cellular mobile telephone, personal communication networks (PCNs), etc.

Text Processing: word processing, desktop publishing, etc.

Image Processing: the capture, enhancement, manipulation, storage, display, and management of images for animation, 3-D modeling, fax, videoconferencing, scanning, etc.

Utilities: spreadsheet, text and graphical retrieval from databases, file transfer, etc.

"Number Crunching:" computer simulation, statistical packages, mathematical packages, etc.

Symbolic Reasoning: artificial intelligence support for logical and qualitative reasoning.

The above services are being combined into multimedia systems over local and wide area networks.

1.2 Telecommuting Services

1.2.1 Mobile Radio

Mobile radio enables people without access to a fixed, stable communications system to communicate with each other and/or a central dispatcher. Advances in wireless transmission technology have made available myriad techniques and devices for mobile voice and data communications. Among the most effective of these are private network services such as mobile satellite communications, Automatic Vehicle Monitoring (AVM), Radio Determination Satellite Service (RDSS), and Specialized Mobile Radio (SMR) systems. Many of these systems are restricted to the 8OOMHz to 900MHz frequency ranges, although the FCC has considered allowing trunked mobile systems at frequencies below 800MHz.

1.2.2 Paging

Paging systems range from the office intercom system to complex wireless systems of interconnection which allow one to receive messages in the field, the latter being obviously more useful to telecommuters. Wireless paging systems offer several signaling options, including tone only, tone-voice, digital, alphanumeric, and computer interface.

1.2.3 Cellular Mobile Telephone

Cellular mobile service operates much like the wireless telephone service in homes and offices - it uses full-duplex mode, permitting two-way simultaneous transmission, with each mobile unit assigned its own private telephone number. In general, cellular telephones are not designed for data transmission. The IS-41 standard defines signaling and handoff rules among dissimilar systems to create a seamless network. This standard is very important in the movement toward enhancing cellular service and providing a seamless nationwide network.

1.2.4 Personal Communication Networks (PCNs)

PCNs are relatively new in mobile communications. Like cellular telephony, a PCN relates telephone numbers to persons rather than fixed locations. The PCNs planned over the next 5 years will provide the first truly personal, portable communications with a lightweight, wallet-sized handset. The PCN will feature more capacity than exists in today's mobile communications network and will make more efficient use of the spectrum.

PCN services are a multibillion dollar undertaking; for them to be successful there will have to be major competitors in the marketplace. Cable TV companies may be the only ones financially able to handle the high startup cost associated with quality PCN services. In addition, PCN represents a value-added service to complement the position already enjoyed by cable TV companies in the marketplace.

1.2.5 Audio/Audiographic Teleconferencing

Audio teleconferencing allows participants in geographically dispersed locations to converse simultaneously over telephone lines using various bridge, microphone, and loudspeaker combinations; audiographic teleconferencing adds visual support capability. Because of recent developments, hundreds of callers can now hold a common meeting by phone; but the average is seven callers per teleconference.

Advances in computer communications and voice/data/image workstations will greatly affect the traditional audiographic market and could enable convergence between office automation systems and teleconferencing systems.

1.2.6 Videoconferencing Systems

Videoconferencing provides users with a fuller sense of participation than is given by a telephone conversation or audioconference. Videoconferencing's rapid growth in the last

decade is largely a result of technical advances. The basic components, coder/decoders (codecs), cameras, audio systems, and displays, have all been radically improved. Moreover, telecommunications carriers have improved their transmission facilities while dropping their prices.

While users still hold some analog videoconferences, the cost of the necessary bandwidth (approximately 90M bps) has converted most users to digital videoconferencing techniques. To complement the improved hardware, standards efforts are now beginning to produce results. With the adoption of the CCITT H.261 (P X 64) video compression standard, customers can look forward to the double benefit of greater choice and lower equipment costs as vendors introduce mass-produced, standard-compatible equipment.

The impact of videoconferencing on broadband networks is dependent on a number of interrelated factors: system costs, transmission costs, transmission availability and variety, digital compression, multipoint videoconferencing , cost of videoconferencing rooms, standards, and network type (LAN, MAN, or WAN). Eventually, the demands of video and voice will be accommodated on LANs. This, coupled with cell relay-type metropolitan and wide area transmission services, will permit videoconferencing to be integrated into corporate, national, and international intemets and could stimulate an explosion in bandwidth consumption. Increased videoconferencing use is due, in part, to current economic conditions that are putting extreme pressure on business people to cut travel costs and time in order to be more efficient.

1.2.7 Business Television

Business television (BTV) is the production and electronic transmission of video programming to targeted user groups in corporations, educational institutions, government agencies, and other organizations. Almost without exception, BTV is transmitted via satellite (primarily Ku-band, these signals being subject to far less terrestrial interference than C-band signals) using an analog signal. Because satellite transmission costs are distance insensitive, programs can include large numbers of locations cost-effectively. Many organizations realize tremendous savings because BTV removes the need for large numbers of employees to travel to particular training locations.

There are four forms of BTV: special event networks, permanent private networks, programming networks, and programming services. Examples of four customized programming networks are: Automotive Satellite Television Network (ASTN), which is used to train sales and service staff of 4500 automobile dealerships; Hospital Satellite Network (HSN)/Health Information International, which provides about 730 hours of educational programs to health care professionals per month, National Technological University (NTU), which offers graduate level courses to almost 300 sites in the country; and Law Enforcement

Television Network (LETN), which provides programming to about 2500 law enforcement agencies nationwide.

1.2.8 Imaging

Although many workers depend on computers today, not all business information is computer-created. Much is still generated on paper -- typewritten material, notes, photographs, drawings, etc. Optical scanning allows computer systems to capture and store bit-mapped images representing physical documents. Image systems consist of a scanning element that converts a document to a bit-mapped data representation, a storage element on which representations are stored, and a display element used to access and view stored images. Image capture and access involves the exchange of bit-mapped files. A high-contrast image of a printed page, scanned at 30 dots per inch, results in a file ranging from 80,000 to 250,000 characters, even with compression, corresponding to between a quarter-million and two million bits. For grey scale or color images, storage and communications requirements rise sharply.

Users rarely access a given stored image but, when they do, it may be necessary to transmit it some distance. In image processing, however, the greatest problem is normally volume. Image applications do not necessarily require large bandwidths. If a user will tolerate multisecond transmission, image systems can operate with connections at 56K bps or less. Imaging is a proven, leading, broadband application.

12.9 Visualization

Visualization is one of the most exciting applications for high-performance computing systems. Visualization of information relationships, unlike CAD/CAM/CAE (Computer-aided design, manufacturing, and engineering), can be applied to abstract concepts for which no physical models exist. Visualization applications create demands for broadband communications because the data storage and processing units may not be located near the point of display. Most process simulations and data point visualizations generate data rates of between 4M bps and 45M bps, and sometimes higher, requiring broadband LAN and WAN support. A visualization system is supported by a specialized visual display and a high-speed vector computer. The number of such visualization workstations is expected to grow from less than 100,000 in 1991 to nearly a million by year-end 1994, contributing to the demand for broadband services.

1.2.10 Multimedia

Multimedia conferencing systems consist of video and personal computer monitors, remote controls, speakers, computer software, cameras, and microphones. These systems transmit

video, audio, text documents, computer data, and video mail between two or more geographically separated locations. A single screen can be partitioned into windows that display text, graphics, and individual participants. Some systems offer a real-time drawing capability, permitting users to diagram difficult concepts to facilitate communication. Special bridging arrangements with carriers enable three or more locations to interactively participate in a multimedia conference.

Whether implemented on stand-alone or shared systems, multimedia programs' bit-intensity and the real-time nature of multimedia audiovisual data put new performance demands on computer systems and networks. These demands are already accelerating the development of more powerful desktop computers. This, in turn, is hastening the move to broadband networks that can handle a mix of variable-bit-rate and constant-bit-rate traffic over LANs and WANs.

Telecommuting applications that will fuel the growth of networked multimedia include: education and training; personal communications, including electronic mail and desktop videoconferencing; kiosk and business presentations; and information repositories, such as electronic catalogs, libraries, and manuals.

1.2.11 Telecommuting Services Now Used

The telephone companies offer the following services:

- Additional phone lines
- Other add-on services such as Custom Calling & Custom 800
- Voice mail and cellular service
- Automatic Call Distribution (ACD)
- E-mail, data entry, graphics, file transfer through ISDN
- Automated Customer List
- Automatic Callback
- Voice messaging with Out Call notification
- Advanced Call Forwarding
- Advanced Call Waiting with Calling Number Delivery and Take Message
- Automatic Call Routing service
- Professional Sales Assistant (PSA)
- Citywide Centrex
- Remote LAN access
- Video phones
- Desk-to-desk teleconferencing/videoconferencing
- Telecommuting center, satellite office hookups

The "1991 Home Office Overview" published by LINK Resources Corp. provides us with some interesting statistics based on their survey of telecommuting services and technologies used in the United States. Their survey revealed 38.4 million homeworkers part- or full-time in 31.2 million U.S. households, up from 34.3 million homeworkers in 26.4 million households in 1990. People who work at home at least occasionally now constitute one-third of the entire U.S. work force aged 18 or older.

- Home information products now constitute 25 percent of total consumer electronic product factory shipments, as reported by the Electronic Industries Association.

- Sales of home office products and services are estimated to total $21.2 billion for the 12 months ending in the second quarter of 1991.

- Work-related telephone spending reflects 35 percent of total household monthly phone spending. The latter averages $80/month in homeworker households. Call waiting continues to rank first among custom calling services used by homeworkers, but speed calling and three-way calling are gaining in popularity.

- Computers are now found in 47.5 percent of work-at-home households. And in 5.9 percent of U.S. households, individuals bring PCs home from work at least occasionally. Selected work-at-home computer peripherals include: hard drives, modems, laser printers, scanners, and fax-boards.

1.3 Value-Added Network Services

Value-Added Networks (VANs) permit data communications between similar or dissimilar customer premises equipment. VANs offer enhanced services that change the data stream in some way upon entry to and/or exit from the network. These services include packet assembly/disassembly and protocol, speed, and code conversion. In an effort to meet the demand for a more advanced means of data transfer, VAN providers offer enhanced, application-oriented services to their customers. These services are critical to many businesses' everyday communications needs and are being heavily used by telecommuters.

Applications that currently use VAN packet switching include: electronic mail, credit card verification, point-of-sale transactions electronic data interchange (EDI), database search, order entry, electronic messaging, LAN/WAN connections, remote computing services, distributed data processing, ATM networks, information gateways, international access services, fast packet switching, frame-relay services, electronic publishing, and electronic trading.

One example of a successful VAN is CompuServe Information Service. Since its

introduction in 1979, CompuServe has become a leading worldwide provider of on-line information services for personal computer users, both in terms of the number of members and the amount and scope of information offered. More than one million members can now access the service by a local phone call in most U.S. cities and by local phone call or gateway network from more than 100 countries. CompuServe members can choose from a selection of more than 1700 databases for data retrieval, including information resources, communications, and transactional services. As an enhancement to its basic service, CompuServe also offers an Executive Service Option with access to exclusive financial databases, a special news clipping service, and other amenities.

CompuServe Mail users represent the largest group of E-mail recipients in the world and also have links to other worldwide E-mail networks, such as AT&T Mail, MCI Mail, and Internet. Fax, bulletin boards for special interest forums, and the CB Simulator which permits electronic dialogs are other services. Particular applications of such services include: News, weather, sports, travel, shopping, as well as investment data and on-line brokerage.

1.4 Telecommunications Infrastructure

1.4.1 LANs, WANs andMANs

The telecommunications infrastructure that supports the above end-user technology services consist of various public and private local, metropolitan, and wide area networks.

Local area networks (LANs) are data communication networks that are relatively limited in their reach. They generally cover the premises of a building or a campus. Like all networking technologies, LANs facilitate communication and sharing of information and computer resources by the members of a group.

Wide area networks (WANs) are data communication networks that provide long-haul connectivity among separate networks located in different geographic areas. Many businesses are using WANs to extend and restructure their operations on a national or worldwide basis, while at the same time gaining the economies of scale and scope that can be achieved by large-scale, shared networks. WANs make use of a variety of transmission media, which can be provided on a leased or dial-up basis. WANs can also be privately owned. Recently, many businesses have chosen satellite networks, taking advantage of the recent development of relatively low-cost small aperture terminals to link their various offices to a headquarters facility.

Metropolitan area networks (MANs), still in the field-testing stage, provide switched data networking services at very high speeds (45 to 50 megabits per second) within a geographic area of at least 50 miles. MANs connect LANs to LANs, as well as LANs to WANs.

1.4.2 Telecommunications Infrastructure Contributions

The telecommunications industry has become one of the most technologically advanced and efficient industries in the United States. At the same time, major structural changes in the U.S. economy, most notably, the shift from basic manufacturing industries toward services, have greatly increased the demand for telecommunications as a vital input to commercial and industrial activity.

A study, "The Contribution of Telecommunications Infrastructure to Aggregate and Sectoral Efficiency," commissioned by a group consisting of most of the major U.S. telephone companies and prepared by DRI/McGraw-Hill, made estimates of the relationship between telecommunications infrastructure investment and economic growth. According to that study:

- Advances in telecommunications since 1963 saved the 1982 economy $81.3 billion in labor and capital.
- From 1963 through 1982 the telecommunications industry experienced a high and stable rate of efficiency growth relative to other U.S. industries.
- The ability to produce telecommunications more efficiently from 1963 through 1982 saved the 1982 economy $46.5 billion in labor and capital.
- From 1963 through 1982, the average industry has increased its rate of telecommunications usage by 167 percent; some industries have increased their usage by more than 800 percent.
- Increased use of telecommunications in place of other inputs from 1963 through 1982 saved the 1982 economy $52.0 billion in labor and capital. This was offset by a $17.2 billion increase in resources needed by the telecommunications industry to accommodate increased demand, for a net savings of $34.8 billion.
- Empirical evidence comparing the use of telecommunications in the economy in 1963 and 1982 suggests that increased telecommunications investment and usage causes economic growth in later years.

2.0 Assessment of Basic Trends in Functionality and Cost of Telecommuting Technology

2.1 Basic Trends

There is a clear trend toward greater ease of use, accompanied by expansion of the role of the computer and information services in problemsolving and transaction processing assistance. In addition, there is a trend toward greater standardization, linking, and integration of the different categories of services. Today the intelligent network is becoming the heart of the information system, consisting of an integrated system of communication and business applications. The network peripherals have become an array of attached personal computers, messaging facilities, file servers, special processors, and mainframes. The computer age is becoming the network age.

Accompanying this growth of the network is a growing demand for a common architecture across different machines and devices, that can provide the user with a single environment which can manage and coordinate multiple concurrent processes. This desire for greater integration, linking, and sharing of special resources has been accompanied by two trends: distribution and sharing of various specialized resources across a network; and greater standardization of the basic hardware, software, and network component building blocks.

This latter trend results in two benefits: it becomes easier for various distributed (often specialized) heterogeneous computing and messaging systems to communicate, to cooperate, and to share tasks and information; and basic technology components become more like commodities. This results in increased vendor competition and thus further acceleration of the trend toward cheaper, high-performance, easy-to-use components. Finally, there is a transformation of the software applications and basic services from specific problem-solving and custom-designed solutions to more generic service offerings that serve as a tool kit for the telecommuting user to do his or her own exploratory problemsolving without prior computer technology experience.

Many VAN providers are also vying for a dominant position in the development of enhanced services and the introduction of new products. Northern Business Information/Datapro reports that the market for E-mail and EDI is growing at an annual rate of 30 percent, sustained by the popularity of PC- and LAN-based messaging systems. This necessitates a need for third-party messaging services from VANs. An outcome of this demand for enhanced services is the widespread use of the CCITT-approved X.400 international messaging standard. In 1990, X.400 allowed several VANs including GEIS, AT&T, Infonet, and BT Tymnet, to connect their messaging systems, thus allowing public and private networks to communicate.

The VAN market will probably begin to slow down after 1993, due to the impact of several alternatives to CCITT X.25 packet switching, including bandwidth-on-demand services such as switched Tl, Switched Multimegabit Data Service (SMDS), and ISDN services. X.25 will not, however, become obsolete. While many of the larger companies will look to adopt the latest technologies, the appeal of a less expensive, low-speed service will still remain prevalent among smaller businesses and telecommuters. Datapro forecasts continued growth in VAN revenues at an annual rate of 17 percent over the next 3 years.

SMDS is a high-speed (1.544M and 45M bps), connectionless public packet switched service that can provide LAN-like performance and features over a metropolitan area. SMDS complies with the IEEE base standard for MANs at the protocol level and is the first step in the evolution toward high-speed WAN service. Although initially local exchange and interexchange carriers will offer SMDS as a data service only, future plans will include transporting voice, data, and video over an SMDS fiber-based network at the 155.52Mbps SONET standard rate.

Metropolitan area networks and SMDS use asynchronous transfer mode (ATM) technology, also known as "cell switching," at the Data Link Layer. ATM is an internationally agreed-to set of standards for high-bandwidth, low-delay, packet-based switching and multiplexing.

In a knowledge-oriented society, progress is greatly dependent on the means whereby both information and knowledge are captured, transmitted, stored, retrieved, manipulated, and used. Artificial Intelligence (AI) is a pivotal point in this progression of networks, databases, deep models that focus on specific applications, and human windows to ease human-machine communication problems.

Not only is the intelligent transfer of larger volumes of text, graphics, data, image, and voice important, but this must also be done at reduced communications costs. Greater cost-effectiveness is likely to be achieved through a more advanced organization of resources by using computers and AI in the communications domain. This will include intelligent networks, evolving from the current, rather embryonic state of network usage to an expanding horizon of any-to-any multimedia support.

Although multimedia technology is still in its infancy, many industry analysts believe it will become the premier desktop technology for the 1990s. In the United States alone, gross earnings from sales of multimedia devices and technologies were almost $4 billion in 1991, and may reach $15 billion by 1994, depending on how multimedia is defined.

In the near term, highly-compressed multimedia applications will be supported over WANs via frame relay, a bandwidth-on-demand service that can handle bursts of traffic up to the T3 rate of 44.736M bps. Over time, the demand for more sophisticated multimedia

applications will overwhelm even frame relay and SMDS. The ultimate solution for interconnecting FDDI standard fiber optic networks without regard to distance rests on the successful deployment of Broadband ISDN (BISDN) expected by 1995, which employs the SONET fibre optic standard for the physical medium. Multimedia is just one example of the dynamic and innovative application market that will shape the direction of the telecommunications infrastructure because of its demand for bandwidth and range of integrated technologies required to support it.

Four enabling technologies that are emerging now will reshape existing telecommunications products and services across a wide range of industries by the year 2000:

- Commodity bandwidth;
- Wirelessness;
- Intelligent network management; and
- People-oriented product design.

By the year 2000, corporate telecommunications users will have greatly improved ability to match their communications networks to their actual needs, essentially unconstrained by the network operators and independent of distance.

Wireless products sell. In the past 10 years, a large number of products that previously used cables have been freed of their umbilical cords and successfully launched in wireless form. Wirelessness will spawn many new businesses by adding a communications link to devices that were previously stand-alone. The prevalence of wireless communication within offices will lead to more flexible working practices, including the ability of intelligent wireless devices to travel with the user.

From the user's point of view, the intelligent network will provide seamless integration and control over many public and private networks, both wired and wireless. Intelligent network management will support the birth of the truly portable office, as the network will be able to provide the bandwidth and the services than an individual requires wherever he or she is, i.e., not only at prearranged, fixed locations.

Advances in the technology of hand-held electronic products make it easier to offer very powerful features in compact packages. Soon there will be no physical reason why one hand-held device should not incorporate all the features of a telephone, a pager, an electronic organizer, a calculator, a fax terminal, and a game machine.

Personal communicators will have embedded tools to facilitate organization, document preparation, and planning. They will also communicate through the network with our office

information systems in order to help us be more effective. The ability to handle this level of machine support will depend on the power and simplicity of the user interface.

Telecommunications technology in the year 2000 will be powerful but also very expensive if misused. Furthermore, when it fails, it can demoralize staff, paralyze the organization, and alienate customers, as demonstrated by much-publicized complaints about voice mail systems and the recent outages of telecommunications service in several regions of the United States.

2.2 National Network Developments

The Internet is a global network linked by means of various protocols, a collection of interconnected regional and wide-area networks based on the ARPANET, the first packet-switched network sponsored by ARPA under the DoD. As of 1990, it was estimated that the Internet consisted of up to 50,000 hosts, more than l,000,000 users, and at least 400 interconnected networks in several dozen countries of the world. It is a collaboration involving private, public, and government- and industry-sponsored networks, whose operators cooperate to maintain the infrastructure.

Connectivity to the Internet allows users access to a wide variety of resources. Of these, electronic mail, bulletin board, file transfer, and news services are perhaps the most widely used.

The Internet is growing at an exponential rate. Trends in the Internet community are rapidly evolving in many areas including bandwidth, media, protocols, and standardization. The Internet backbone is currently transitioning to T3 (4.6 M bps). Soon, with the advent of the National Research and Education Network (NREN) even greater bandwidth will be implemented. Test-bed efforts and research are already underway with Gigabit networking. Speed and cost remain critical factors.

Proposed public investments in information infrastructure would include funds for the National Science Foundation (NSF) for work on developing massive databases. The databases, called digital libraries, would make text, imagery, video and sound available over networks such as the foundation's NSFNet. NASA would make databases of software and remote-sensing images available over the Internet. NIST also would spearhead development of networks for manufacturing. NSF would fund projects to give primary and secondary schools access to NSFNet, which already connects colleges and universities. NSF and the National Institutes of Health would develop health care applications that could link doctors' offices, hospitals, and universities.

NREN will lay the groundwork for the universal fiber-optic "intelligent network" likely to

connect virtually all homes, offices, and schools nationwide, making high-speed, seamless interactive communications among sophisticated computer devices as simple as using the telephone.

A nationwide fiber optic network will upgrade the capacity of the existing copper network from 2,400 bits/sec to between 45,000,OOO to 5OO,OOO,OOObits/sec. The effects of this will be dramatic. For example, fiber-to-the-home will provide full color, high definition, video capabilities, rather than limited graphics currently provided by shop-at-home services.

A question frequently asked in the business world is, "When will the truly mobile office actually appear?" In fact, much of it is here and available today. Wireless handsets are already operating in office environments behind local switches or private branch exchanges, and radio technology has been incorporated in laptop and palmtop computers and in electronic diaries. One phenomenon fueling the growth of wireless communications activity is that, as subscribers begin to use these new products, services, and technologies, they quickly find new applications for them. These in turn broaden the market for wireless products and services and create demand for new ancillary services.

Clearly, the institutions that will feel the greatest impact from the introduction of these new services are the well-established wireline telephone and cellular networks. Arthur D. Little estimates (Prism, 2Q 92) that some $10 billion to $15 billion will need to be invested in network facilities over the next 10 years in the United States alone merely to support future wireless operations. These investment projections are based on current industry estimates that average investment per subscriber will total $200 to $300 and that networks must be configured to handle upwards of 60 million subscribers in North America.

The wireless personal communications market will attract many new players beyond today's telephone companies and providers of cellular and radio paging service. Other radio service entrepreneurs are appearing encouraged by the FCC's emphasis on competition. Key factors for success in the wireless marketplace are:

- The ability to obtain government franchises and an adequate radio spectrum.
- The ability to gain access to adequate levels of capital investment.
- The ability to develop complementary strategic alliances and partnerships to satisfy the full range of needs and political influences in the marketplace.
- The ability to develop effective distribution channels and pricing strategies to meet the widely varying needs of different market segments.

In order for the above forecasts for greatly enhanced wireless services (e.g., personal computer networks) to become realities, further developments of equipment must occur in a timely fashion in the following areas: intelligent network hardware and software; radio transmission standards; and multimode portable radios.

2.3 The Cable-Fiber Connection

Telephone companies are busy laying fiber-optic wires, and are planning to deliver movies and newspapers, along with bill paying, banking and other two-way video services to American homes. However, the cable TV (CATV) companies are also in this market. For example, Tele-Communications Inc., the country's largest cable operator agreed to buy 49 percent of Teleport Communications Group, Inc. from Merrill Lynch in February 1992. Teleport has built up a $100 million-a-year business by interconnecting major buildings and corporations with fiber-optic cable and linking customers to other phone networks, thereby often bypassing the local telephone companies and their higher switching costs.

With phone company data service revenue rising some six times faster than voice service revenue, the TCI-Teleport connection will be used to challenge the phone companies in one of their most profitable areas. The CATV industry is changing from being a video entertainment source to being a full-service telecommunications supplier.

The CATV companies already enjoy a substantial lead over the telephone companies in the race to put smart wires into U.S. households. Currently, 93 percent of American homes are wired for cable TV. Likewise, 93 percent of U.S. households are connected for telephone service.

But those penetration figures are misleading. What matters is not the quantity of wire but its quality: how much data can be passed through the wires, and how easily. On this score, the CATV companies are far ahead of the telephone companies.

The arteries of a CATV system are the coaxial cables that run from the center of the system, the so-called head end, out to subscribers' homes. Over long distances, coaxial cable is not a very efficient conduit of electronic impulses; it is far inferior to fiber-optic cable. About every quarter-mile, coaxial cable requires an amplifier to boost the signal and compensate for resistance on the line.

Over short distances, however, coaxial cable is a highly efficient data conduit. Over stretches of 300 feet or less into the home, coaxial cable requires no amplifiers. Thus, across the so-called drop (the distance from the curbside into the living room) coaxial cable can now handle as much data as fiber-optic cable, and far more than phone companies' conventional twisted-pair copper wires can transmit.

In telecommunications industry jargon, coaxial cable over short distances is what is called a "broadband pipe" -- a conduit through which huge amounts of data can flow at enormous speed. Through a broadband pipe, for example, the entire contents of the Library of Congress could flow in under 8 hours. To send the same quantity of information by modem over a conventional telephone line would require 500 years.

The point is this: the telephone companies' existing narrow band copper wire links to homes can normally carry only voice and data. But CATV's coaxial broadband links to the home can carry full-motion digital video, high-resolution medical images, vivid educational simulations, and lifelike videoconferences.

Congress and the courts continue to limit the freedom of the telephone companies on the grounds that they are local monopolies. Thus the phone companies generally cannot own cable franchises in their own service areas, or have they been allowed, until recently, to get into electronic publishing. This allows cable operators to explore parts of the telephone business before the companies can get into their business.

One thing is already clear. The telephone, television, and computer are rapidly merging into a single, very intelligent box -- a telecomputer. This telecomputer will be linked to the rest of the world by high-capacity smart wires. As things now stand, the cable companies have done more to move these broadband wires close to homes and offices than anyone else. Telecommuters will readily be able to take advantage of these services.

2.4 Open Systems Standards

Today most of a business's systems are incompatible, resulting in the multiple appearance of data in inconsistent or inaccessible forms, a prohibitively high cost of updating data and applications, awkward manual interfaces, and little systematic support for ad hoc decisionmaking. This often becomes a roadblock in any effort to achieve important strategic and tactical objectives requiring integration and linking of these systems. To help overcome these problems, it is important to move toward standards and open systems.

Open systems will allow users to take an architectural approach, making available a variety of systems that may be purchased and adapted so that businesses can take advantage of telecommuting opportunities in creative and efficient ways. With an open systems architecture, users will no longer need to restrict themselves to the purchase of a short list of allowable vendor's products. This increases in importance as the useful life of the technology products grows progressively shorter, while the useful life of an application can be relatively much longer.

Open systems promise to eliminate much of the redundant effort involved in maintaining today's plethora of operating environments and in building many one-to-one links between them. Not only must these standards address the operating system and communication data exchanges, they must also address interactive access to remote databases, human interfacing, security, and multilingual support.

2.5 Electronic Data Interchange

The American National Standards Institute (ANSI) has developed the Electronic Data Interchange (EDI) for computer-to-computer transactions involving ordering, shipping, and billing. EDI is a prime example of a set of standards for government and business transactions being widely adopted with huge telecommuting potential.

EDI is a worldwide phenomenon that provides the infrastructure necessary for mission-critical transactions. It is being aggressively implemented and backed by national governments in the United States, Canada, Europe, Asia, and the Pacific Rim. EDI has the potential to spur economic development by facilitating commercial transactions.

EDI is defined as the computer-to-computer interchange of business transactions that conforms with specified standards over a communications network that includes at least two trading partners. These transactions include the interchange of common commercial information typically consisting of purchase orders, invoices, shipping notices, and related acknowledgements.

Most notably, EDI has been more user-driven than any other automated business solution. This has been advantageous for users because they have not been constrained by corporate information systems organizations.

EDI growth has been bolstered by its appeal to some 30 vertical industry markets, each of which has become involved in specifying EDI standards for special interest organizations within that vertical industry. Three of the major EDI standards are:

1. Uniform Communication Standard (UCS), used primarily by the grocery industry;

2. Voluntary Interindustry Communication Standard (VICS), used by the general merchandise retailing industry; and

3. Warehouse Industry Network Standards (WINS), used by public warehouses and their depositor customers.

Although the EDI market is worldwide, it originated in the United States and continues to enjoy most of its popularity here. The EDI market comprises three components: EDI software, data transport/network services, and professional services. The International Data Corp. estimates that the EDI revenues for these three components in the United States, Europe, and Asia/Pacific was $368 million in 1991, and is expected to reach $1.8 billion in 1996. This represents a compound annual growth rate of 37 percent. The potential for telecommuting growth by tapping into these EDI networks for at-home and satellite office use is enormous.

Although communication carriers such as AT&T, MCI, Sprint, and the regional Bell operating companies are in their early startup stages for EDI, VANs may expect greater competition here once the carriers better understand the requirements of EDI. There is a challenge to carriers to become more than just a voice or data communications network offering customers wide area communications. Carriers have the opportunity to become more closely associated with customers and their business activities by managing EDI transaction sets. They also have the opportunity to provide enhanced services that significantly extend present voice and data communications infrastructures and offerings.

3.0 Technological Uncertainties and Issues with Potential Impact on Telecommuting

3.1 Uncertainties of Technology Standards and Integration

The network technology and standards needed to build network-enabled multimedia applications will become available in the next 5 years. For example, the emergence of high-speed networks based on FDDI and ATM standards will enable companies to distribute multimedia information on demand from network servers instead of physically distributing CD-ROMs to every desktop. This will make it easier for companies to provide up-to-date multimedia information, reduce equipment costs, and save time.

However, there are some challenges to overcome before networked multimedia becomes possible. While compression techniques can reduce the bandwidth required for full-motion video to 1.5M bit/sec, today's networks still have difficulty supporting multimedia information because of the different ways data, audio, and video consume bandwidth on a network.

Data is well suited for connectionless, data-packet environments because it is transferred in bursts and does not require packets to arrive in sequence. Audio and video, on the other hand, require steady high bandwidth (16K to 384K bit/sec) for the duration of a session, and packets that arrive sequentially.

FDDI offers one solution to this dilemma because it supports high-speed packet switching for digital data, and isochronous or time-dependent circuit switching for audio and video. Once users build FDDI-II networks, they will use FDDI Follow-On LAN standard being developed by the ANSI X3T9.5 committee to interconnect those nets.

Besides FDDI technologies, ATM will offer the best support of multimedia applications. ATM supports fixed-length cells and speeds up to 1G bit/sec, as well as connectionless channels for data and connection-oriented channels for audio and video.

Another problem facing networked multimedia is synchronizing video and audio segments. Most users today run parallel networks in which data, video, and audio run on separate networks.

Toward the end of the decade, many companies will run multimedia applications across public networks that support broadband Integrated Services Digital Networks (BISDN) or other broadband services. Following is a sequence of highlights of networked multimedia applications and the key technologies and standards supporting them:

	Technologies/Standards	Applications
1990	PX64 for video	Videoconferencing
1991	FDDI	Image management
1992	Switched Multimegabit Data Service	Multimedia presentations and training programs
1993	FDDI-II	Multimedia E-mail
1994	Asynchronous Transfer Mode/Synchronous Optical Network	LAN-based desktop Videoconferencing
1995	Broadband ISDN	-
1996	FDDI Follow-On LAN	
1997	Open Document **Architecture**	Network-enabled **Multimedia**

4.0 Possible Scenarios of Future Technological Developments Relevant to Telecommuting

4.1 Future Technologies

4.1.1 Advanced Multimedia and Virtual Reality

By the turn of the century, most companies will be implementing multimedia applications that pull digitized audio, full-motion video, image, and text information from distributed servers across an enterprise network.

Users will regard multimedia as an indispensable tool for enhancing corporate productivity and expect that network-based multimedia applications will make the same inroads into corporations that desktop publishing did in the 1980s. Perhaps the ultimate expression of multimedia is to be found in the emerging concept of "virtual reality." Virtual reality relies on a multimedia computer system that allows the user to become totally immersed in a computer-generated world of real-time simulation, an artificial world where objects and environments create the illusion of being real.

A new interface archetype, that of the virtual interface, permits us to revise both the way we think about computers and the way we think with them. These interfaces allow three-dimensional panoramic presentations to be made to the eyes, ears, and hands of the user.

Virtual images presented directly to the senses provide a participant with a total global experience. The human literally wears the computer. The participant is surrounded by a "circumambience" of computer-synthesized information, a spatial world in which the person and the computer can more effectively communicate. The user interacts with this inclusive medium by looking at objects, pointing his or her hands and giving verbal commands. The medium permits virtual objects which appear real to be touched and manipulated by the participant.

To create the virtual world representation of information, the virtual-display hardware components are programmed with "mindware." Mindware is a special class of software that takes into account human perceptual organization and dynamically creates three-dimensional sound, video, and tactile images which surround the user.

Virtual reality is not limited to a single person. Virtual worlds can be shared by two or more participants. Each participant has the ability to customize the rendering to his or her particular needs and preferences. With the addition of telecommunication links, these

worlds can be shared by many participants, at different locations and at different times. This creates a new medium of communication: televirtuality -- a form of future telecommuting .

Virtual interfaces solve many existing interface problems and empower new and novel interfaces for teleoperation, computer-aided design, education, medical imaging, entertainment, and prostheses for individuals with disabilities.

Virtual interface technology provides a bold new opportunity for solving many of the perplexing problems of interfacing human and machine intelligences. With systematic development, virtual interfaces can become one of the greatest advances of our age and a boon to industry.

Virtual Reality (VR) is one of the most promising of the advanced technologies that will influence telecommuting. Although it sounds like science fiction, VR is already a science, a technology, and a business, supported by significant funding from the computer, communications, design, and entertainment industries worldwide.

Imagine a wraparound television with three-dimensional programs, including three-dimensional sound, and solid objects that you can pick up and manipulate, even feel with your fingers and hands. Imagine immersing yourself in an artificial world and actively exploring it, rather than peering in at it from a fixed perspective through a flat screen in a movie theater, on a television set, or on a computer display. Imagine that you are the creator as well as the consumer of your artificial experience, with the power to use a gesture or word to remold the world you see and hear and feel. That part is not fiction. The head-mounted displays and three-dimensional computer graphics, input/output devices, computer models that constitute a VR system make it possible, today, to immerse yourseif in an artificial world and to reach in and reshape it.

Some of the advanced human sensing interface research technologies that support VR include:

- Eyes as output: this emphasizes looking at evidence of interest and as a means of reference.

- Observing people: noticing peoples' gestures and positions as they move about the work environment, e.g. ,lip reading and observations that lead to personal identification.

- Micromovies: window systems with multiple small moving images that can each become animated as they are signaled.

- Hyperspace: this enables a designer to "walk inside" the object designed (building, vehicle, etc.).

- Knowledge-based animation: an intelligent animation system which allows non-expert users to control the behavior of realistic, articulated figures in complex, simulated environments.

- Data glove: novel 3-D interaction techniques which have resulted in the implementation of hand gesture-driven interfaces to the computer graphics environment. This interface makes it possible for users to directly manipulate objects in these simulated environments.

- Tactile simulation: human interfaces which provide realistic, real-time, 3-D tactile simulation of computer-generated objects and environments.

- Alcove holograms: viewable version of the alcove projected image hologram which permits full-color "walk-around" images to be produced.

- Back seat driver: a computer program that accompanies a driver, keeping track of current positions and giving spoken directions to the destination.

- Pilot associate: a **computer** program that accompanies a pilot.

4.1.2 Coordination Science

It's an age old question: How can people and machines most effectively work together? In today's era of rapid technological and social change, new answers to this question are being formulated by researchers in industry and academia. Researchers are exploring the meaning of coordination and are developing collaboration technologies to help groups of people and firms better integrate their work.

The Massachusetts Institute of Technology (MIT) has gone so far as to call for a national research agenda to create a new interdisciplinary field called "coordination theory." The idea is to develop a scientific theory that would explain how the activities of separate players, both individuals and machines, can be coordinated.

An important area for coordination theory will be developing and using computer and communications systems to help people work together in small or large groups. Successful commercial versions of coordination technologies have already appeared under the names of "groupware" and "computer-supported cooperative work." Some industry observers maintain that in moving from stand-alone personal computers to a more distributed model

of computing, these applications represent a shift in computing paradigms equal in significance to the earlier shift away from sharing time on a mainframe computer.

Two years ago, MIT opened the Center for Coordination Science at the Sloan School of Management, with original sponsorship by Digital Equipment Corp. and the National Science Foundation. The MIT Center is working with people in a variety of disciplines, within and outside MIT, as it seeks to integrate existing coordination theories from such fields as economics, computer science, and organizational theory.

These coordination theories and emerging technologies are being applied to such telecommuting-related areas as developing decentralized organizational structures, exploring distributed systems that can coordinate multiple processors, and groupware.

A few examples of the MIT's innovative tools for supporting group and organizational coordination are listed:

- Oval - A tool kit for prototyping groupware applications.
- Answer Garden - A tool for growing organizational memory.
- Sibyl - A tool for supporting group decisionmaking.
- Hypervoice - A telephone interface for semistructured "voice databases."

4.2 Scenarios of Future Applications of Telecommunications

In this section, the three future technologies described above (advanced multimedia, virtual reality, and coordination science) will be illustrated in terms of possible future scenarios. These technologies are actually combinations of many other technologies under development in university, industrial, and governmental laboratories today. Although these scenarios may lie far in the future, they illustrate possible long-term implications that need to be understood in making near-term policy decisions.

If broadband network services were easy to use, with resultant high quality teleconferencing, much business-related and other travel would be unnecessary, we could all stay home, preserve the environment, energy resources, and our peace of mind. Yet, staying at home would not be the most interesting consequence of better networks.

The often overlooked point is that we can freely move about precisely because we have the electronic means to stay in touch with our home base. No one needs to be more than a telephone call, data transfer, or fax transmission away from the office -- indeed, from any

office. What network planners should be looking at is the computational and telecommunications resources that will allow us to be more or less independent of space and time.

Travel embargoes during the Persian Gulf War increased interest in video-conferencing and teleconferencing, which undoubtedly will continue to gain appeal. The more fascinating developments, however, will come from new services that free you to wander and that create an electronic surrogate for you on the network with which others can communicate.

These developments will hinge on storing and transmitting information, either through electromagnetic broadcasts or over optical fiber. Broadcast spectrum is scarce, whereas fiber, like computing power, can be produced in virtually unlimited amounts. These facts mean that the channels for distributing different types of information, as we know them today, will trade places. Most information we receive through the ether today, television for example, will come through the ground by cable tomorrow. Conversely, most of what we now receive through the ground, such as telephone service, will come through the airwaves.

Two rules of thumb guide decisions as to how information is best distributed. First, use the broadcast spectrum to communicate with things that move: e.g.,cars, boats, airplanes, and people with telecommunication terminals. Second, deliver information to the desktop or living room by fiber. Cellular telephones and cable television illustrate these "rules".

Television manufacturers are increasingly adding computing power to their receivers, and computer makers are putting more video into their workstations. Although this development may seem like a merger of the technologies, each side is disregarding the underlying utility of the other's techniques and aims. As a result, the television makers are cutting off their own access to the broader information delivery market, and computer manufacturers are missing an opportunity to become a part of the entertainment industry.

Two fundamental attitudes toward digital image transmissions in general and television in particular need to change before we will see creative thought in this area. First, we must think of images as scalable in physical dimensions and time. Second, in the long run, model-based image transmission and encoding are better than transmission of pictures alone. Mathematical models of a scene can describe the spatial relations of the objects in it and maneuver them through space.

Information has value, but it may be as perishable as fresh fruit. It varies from person to person, from moment to moment. But when information leads to a transaction, such as booking for an empty seat, the value is less ephemeral. A service that facilitates transactions earns the gratitude of both the buyer and seller.

Multimedia computing is likely to be an important tool for transactions. It is anticipated to be a serious bandwidth consumer; but short-term multimedia solutions need not be. Customers at home could access some information at a remote site by narrow band communications. The rest could already reside in the home, say on a videodisk, at the time of the transaction for fast access locally.

More generally, the problem and solution can be described as a kind of Yellow Pages. For example, electronic Yellow Pages could be geographically coded so that a company or service could be related to who you are, where you are, where you are going, and what might be along the way. The opportunity is made-to-order for multimedia network products and services.

Almost all services can distinguish themselves by becoming personalized. We are pleased to be recognized and catered to as individuals rather than being treated as a faceless part of the mob. Personal information systems are also extremely efficient. In this regard, the most desirable interaction with a network is one in which the network itself is invisible and unnoticeable.

The fax, a "dumb" terminal par excellence, perfectly represents the services that result when we do not focus on the intelligence of the network and its ends but instead rely on the lowest common denominator of transceiver. This approach limits the quality and originality of the products and services that can later arise.

One possibility is the increasing importance of "answer networks," networks of experts available to answer questions in different areas. One might go to these services with questions such as "How many bars of soap were sold in Guatemala last year?" or "What are the prospects of room-temperature superconductivity in consumer products by 1995?" The services would include massive data bases and access to people at various levels of expertise in many different topic areas.

Network marketing of services within geographically dispersed organizations could operate as follows. Extensive internal markets for the services of people and groups could replace reliance on supervisors to allocate work to people.

Improved technology can also help create decisionmaking structures that integrate qualitative input from many people. For instance, in making complex decisions, such as where to locate a new plant, the amassing of many facts and opinions is critical. Today, companies often make such decisions after incomplete discussions with only a few of the people whose knowledge or point of view might be valuable. In the future, companies may use computer networks to organize and record the issues, alternatives, arguments, and counter arguments, in graphical form. Then many different people can review and critique

the parts of the argument about which they know or care.

What will happen as the globally networked society leads to a world in which vast amounts of information are freely available or easily purchased? Clearly, this world will require services, both automated and human, to filter the tremendous amount of information available, In general, as the amount of information increases, people who can creatively analyze, edit, and act on information in ways that cannot be automated will become even more valuable.

But what else people will do will depend on the values that are important to them. When trains and automobiles reduced the constraints of travel time, other values became more significant in determining working and living patterns. Similarly, when the costs of information and coordination are not a barrier to fulfilling peoples' needs and wants, other values may emerge to shape the workplace and society, such as a need for self-actualization or spiritual fulfillment.

Virtual reality brings with it a set of questions about the industries and scientific capabilities it makes possible. It also brings with it a set of questions about human uses of technology, particularly the technologies that don't yet exist but are visible on the horizon. VR vividly demonstrates that our social contract with our own tools has brought us to a point where we have to decide fairly soon what it is we as humans ought to become, because we are on the brink of having the power of creating any experience we desire. The first cybemauts realized very early that the power to create experience is also the power to redefine such basic concepts as identity, community, and reality. VR represents a kind of new contract between humans and computers, an arrangement that could grant us great power, and perhaps change us irrevocably in the process.

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Appendix B - Details of Analysis

	1992	1993	1994	1995
Information Workers				
United States Population	253,298,971	255,072,064	256,857,568	258,655,571
United States Labor Force	127,615,078	129,146,458	130,696,216	132,264,571
# of Information Workers	72,076,996	73,329,359	74,601,400	75,655,334
Info Worker % Total Labor Force	56.48	56.78	57.08	57.20
Potential Telecommuters	57,661,597	58,663,487	59,681,120	60,524,267
Telecommuters				
Part-Time – Home/CBD Office				
#	1,696,677	2,045,879	2,385,669	2,669,541
as % of Information Workers	2.354	2.790	3.198	3.529
Average # of Telecommuting Days/Week	2	2.1	2.1	2.2
Part-Time – Regional Center/CBD Office				
#	1,212	4,382	8,844	14,498
as % of Information Workers	0.002	0.006	0.012	0.019
Average # of Telecommuting Days/Week	2	2.1	2.2	2.3
Part-Time – Home/Regional Center				
#	7.473	47,462	104,505	177.523
As # of Information Workers	0.010	0.065	0.140	0.235
Average # of Telecommuting Days/Week – Home	1	1	1.1	1.1
Average # of Telecommuting Days/Week-Reg. Center	4	4	3.9	3.9
Full Time Home				
#	302,978	350,627	390,055	413,292
as % of Information Workers	0.010	0.065	0.140	0.235
Full Time Regional Center				
#	11,513	99,255	224,890	386,164
as % of Information Workers	0.016	0.135	0.301	0.510
Projected Total Telecommuters	2,019,853	2,547,604	3,113,963	3,661,018
% of Labor Force Telecommuting	1.583	1.973	2.383	2.768
% of Infoworkers Telecommuting	2.802	3.474	4.174	4.839
% of Potential Telecommuters Telecommuting	3.503	4.343	5.218	6.049
Total Telecommuting Days/Week	4,975,706	6,602,416	8,219,044	10,098,893
Total Roundtrips Avoided Annually	238,833,882	316,915,986	394,514,101	484,746,841
Average Round Trip Distance Home-CBD(miles)	21.4	21.4	21.4	21.4
Avg. Round Trip Distance Home-Reg. Cent. (miles)	9	9	9	9
Annual Passenger Miles Saved				
Part Time Home/CBD Workers	3,485,652,243	4,413,206,224	5,146,175,033	6,032,735,771
Part Time Regional Center/CBD Workers	1,442,660	5,476,998	11,580,235	19,846,677
Part Time Home/Regional Center Workers	25,469,538	161,750,027	360,666,270	612,666,559
Full Time Home Workers	1,556,094,751	1,800,818,929	2,003,322,508	2,122,669,366
Full Time Regional Center Workers	34,263,170	295,381,844	669,273,854	1,149,224,596
Total	5,102,922,362	6,676,634,023	8,191,017,899	9,937,142,969
Annual Vehicle Miles Saved				
Total	3,735,339,169	4,887,296,105	5,995,825,102	7,273,988,653
Annual Gasoline Savings				
Average MPG	20.92	20.92	20.92	20.92
Gasoline Saved Due To Telecommuting(Gal.)	178,553,498	233,618,361	286,607,318	347,705,003
Gasoline Saved Due To Telecommuting (Barrels)	4,251,274	5,562,342	6,823,984	8,278,691
State Excise Gas Tax Revenue Lost	$32,318,183	$42,284,823	$51,875,925	$62,934,605
Federal Excise Gas Tax Revenue Lost	$25,176,043	$32,940,189	$40,411,632	$49,026,405
Avg. Retail Price per Gallon (Reg. Unleaded)	1.14	1.14	1.14	1.14
Total $ Saved in Gas	$203,550,987	$266,324,931	$326,732,343	$396,383,703
Annual Pollution Avoidance (Tons)				
CO	98,753	129,208	158,515	192,307
NOx	11,852	15,508	19,025	23,081
Hydrocarbon	14,571	19,064	23,388	28,374
Particulates	177	231	284	344
Safety				
Fatalities Avoided	87	113	139	169
Annual Time Savings				
Commuting Info Worker Time Savings	156,216,466	207,288,408	258,043,783	317,063,214

Year						
1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
260,466,160	262,289,423	264,125,449	265,974,327	267,836,148	269,711,001	271,598,978
133,851,745	135,457,966	137,083,462	138,728,463	140,393,205	142,077,923	143,782,859
76,763,976	78,159,247	79,576,950	81,017,423	82,481,008	83,968,053	85,478,909
57.35	57.70	58.05	58.40	58.75	59.10	59.45
61,411,181	62,527,398	63,661,560	64,813,938	65,984,806	67,174,442	68,383,127
2,912,996	3,116,035	3,278,658	3,400,864	3,482,654	3,524,027	3,524,984
3.795	3.987	4.120	4.198	4.222	4.197	4.124
2.3	2.4	2.5	2.6	2.8	3	3.1
21,377	29,482	38,812	49,368	61,149	74,155	88,387
0.028	0.038	0.049	0.061	0.074	0.088	0.103
2.5	2.7	2.9	3.2	3.5	3.8	4.1
266,876	372,564	494,588	632,946	787,640	958,668	1,146,032
0.348	0.477	0.622	0.781	0.955	1.142	1.341
1.1	1.1	1.1	1.1	1.2	1.2	1.2
3.9	3.9	3.9	3.9	3.8	3.8	3.8
422,995	419,165	401,799	370,900	326,467	268,499	196,998
0.551	0.536	0.505	0.458	0.396	0.320	0.230
583,828	817,882	1,088,326	1,395,160	1,738,385	2,117,999	2,534,004
0.761	1.046	1.368	1.722	2.108	2.522	2.964
4,208,073	4,755,128	5,302,183	5,849,238	6,396,293	6,943,348	7,490,404
3.144	3.510	3.868	4.126	4.556	4.887	5.210
5.482	6.084	6.663	7.220	7.755	8.269	8.763
6.852	7.605	8.329	9.025	9.694	10.336	10.954
12,081,016	14,153,139	16,303,873	18,526,765	21,234,874	23,936,762	26,320,081
579,888,753	679,350,682	782,585,922	889,284,735	1,019,273,954	1,148,964,564	1,263,363,897
21.4	21.4	21.4	21.4	21.4	21.4	21.4
9	9	9	9	9	9	9
6,882,128,901	7,681,899,698	8,419,593,436	9,082,755,390	10,016,669,015	10859,641,122	11,224,677,441
31,808,992	47,378,422	66,992,582	94,027,446	127,384,682	167,720,715	215,691,996
921,042,416	1,285,793,839	1,706,920,829	2,184,423,387	2,752,327,539	3,349,969,663	4,004,693,564
2,172,504,878	2,152,829,043	2,063,641,861	1,904,943,333	1,676,733,458	1,379,012,236	1,011,779,803
1,737,472,271	2,434,016,880	3,238,858,422	4,151,996,897	5,173,432,306	6,303,164,649	7,541,194,931
11,744,957,457	**13,601,917,880**	**15,496,007,129**	**17,418,146,453**	**19,746,547,000**	**22,059,508,385**	**23,998,037,735**
8,597,308,859	**9,956,603,888**	**11,343,077,219**	**12,750,083,203**	**14,454,472,404**	**16,147,560,138**	**17,566,563,622**
20.92	20.92	20.92	20.92	20.92	20.92	20.92
410,961,227	475,937,088	542,212,104	609,468,604	690,940,363	771,871,900	839,701,894
9,784,791	11,331,835	12,909,812	14,511,157	16,450,961	18,377,902	19,992,902
$74,383,982	$86,144,613	$98,140,391	$110,313,817	$125,060,206	$139,708,814	$151,986,043
$57,945,533	$67,107,129	$76,451,907	$85,935,073	$97,422,591	$108,833,938	$118,397,967
1.14	1.14	1.14	1.14	1.14	1.14	1.14
$468,495,798	**$542,568,281**	**$618,121,799**	**$694,794,209**	**$787,672,014**	**$879,933,965**	**$957,260,159**
227,292	263,229	299,884	337,082	382,142	426,903	464,418
27,280	31,593	35,992	40,457	45,865	51,237	55,739
33,536	38,839	44,247	49,735	56,384	62,988	68,524
407	471	537	603	684	764	831
199	**231**	**263**	**296**	**335**	**375**	**408**
379,293,636	**444,349,694**	**511,873,800**	**581,663,359**	**666,686,708**	**751,514,742**	**826,341,058**

Table B-1. Transportation Impacts of Telecommuting – Projected (Lower Bound)

	1992	1993	1994	1995
Information Workers				
United States Population	253,298,971	255,072,064	256,857,568	258,655,571
United States Labor Force	127,615,078	129,146,458	130,696,216	132,264,571
# of Information Workers	72,076,996	73,329,359	74,601,400	75,655,334
Info Worker % Total Labor Force	56.48	56.78	57.08	57.20
Potential Telecommuters	57,661,597	58,663,487	59,681,120	60,524,267
Telecommuters				
Part-Time – Home/CBD Office				
#	1,696,677	2,045,879	2,385,669	2,669,541
as % of Information Workers	2.354	2.790	3.198	3.529
Average # of Telecommuting Days/Week	2	2.1	2.1	2.2
Part-Time – Regional Center/CBD Office				
#	1,212	4,382	8,844	14,498
as % of Information Workers	0.002	0.006	0.012	0.019
Average # of Telecommuting Days/Week	2	2.1	2.2	2.3
Part-Time – Home/Regional Center				
#	7.473	47,462	104,505	177.523
As # of Information Workers	0.010	0.065	0.140	0.235
Average # of Telecommuting Days/Week – Home	1	1	1.1	1.1
Average # of Telecommuting Days/Week-Reg. Center	4	4	3.9	3.9
Full Time Home				
#	302,978	350,627	390,055	413,292
as % of Information Workers	0.010	0.065	0.140	0.235
Full Time Regional Center				
#	11,513	99,255	224,890	386,164
as % of Information Workers	0.016	0.135	0.301	0.510
Projected Total Telecommuters	2,019,853	2,547,604	3,113,963	3,661,018
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% of Infoworkers Telecommuting	2.802	3.474	4.174	4.839
% of Potential Telecommuters Telecommuting	3.503	4.343	5.218	6.049
Total Telecommuting Days/Week	4,975,706	6,602,416	8,466,162	11,030,780
Total Roundtrips Avoided Annually	238,833,882	316,915,986	406,375,763	529,477,460
Average Round Trip Distance Home-CBD (miles)	21.4	21.4	21.4	21.4
Avg. Round Trip Distance Home-Reg. Cent. (miles)	9	9	9	9
Annual Passenger Miles Saved				
Part Time Home/CBD Workers	3,485,652,243	4,413,206,224	5,300,902,556	6,589,413,985
Part Time Regional Center/CBD Workers	1,442,600	5,476,998	11,928,413	21,678,054
Part Time Home/Regional Center Workers	25,469,538	161,750,027	371,510,246	669,201,130
Full Time Home Workers	1,556,094,751	1,800,818,929	2,063,555,424	2,218,541,328
Full Time Regional Center Workers	34,263,170	295,381,844	689,396,583	1,255,270,728
Total	**5,102,922,362**	**6,676,634,023**	**8,437,293,222**	**10,854,105,225**
Annual Vehicle Miles Saved				
Total	**3,735,339,169**	**4,887,296,105**	**6,176,098,638**	**7,945,205,025**
Annual Gasoline Savings				
Average MPG	20.92	20.92	20.92	20.92
Gasoline Saved Due To Telecommuting (Gal.)	178,553,498	233,618,361	295,224,600	379,789,915
Gasoline Saved Due To Telecommuting (Barrels)	4,251,274	5,562,342	7,029,157	9,042,617
State Excise Gas Tax Revenue Lost	$32,318,183	$42,284,923	$53,435,653	$68,741,975
Federal Excise Gas Tax Revenue Lost	$25,176,043	$32,940,189	$41,626,669	$53,550,378
Avg. Retail Price per Gallon (Reg. Unleaded)	1.14	1.14	1.14	1.14
Total $ Saved in Gas	**$203,550,987**	**$266,324,931**	**$336,556,044**	**$432,960,503**
Annual Pollution Avoidance (Tons)				
CO	98,753	129,208	163,281	210,052
NOx	11,852	15,508	19,597	25,210
Hydrocarbon	14,571	19,064	24,092	30,993
Particulates	177	231	292	376
Safety				
Fatalities Avoided	87	113	143	184
Annual Time Savings				
Commuting Info Worker Time Savings	156,216,466	207,288,408	265,802,259	346,320,617

Year						
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76,763,976	78,159,247	79,576,950	81,017,423	82,481,008	83,968,053	85,478,909
57.35	57.70	58.05	57.40	58.75	59.10	59.45
61,411,181	62,527,398	63,661,560	64,813,938	65,984,806	67,174,442	68,383,127
3,452,946	4,049,903	4,693,848	5,363,519	5,952,210	6,536,725	7,049,968
4,498	5,182	5,899	6,620	7,216	7,788	8,248
2.3	2.4	2.5	2.6	2.8	3	3.1
25,339	38,317	55,565	77,858	104,509	137,613	176,774
0.033	0.049	0.070	0.096	0.127	0.164	0.207
2.5	2.7	2.9	3.2	3.5	3.8	4.1
316,344	484,221	708,070	998,222	1,346,156	1,779,052	2,292,063
0.412	0.620	0.890	1.232	1.632	2.119	2.681
1.1	1.1	1.1	1.1	1.2	1.2	1.2
3.9	3.9	3.9	3.9	3.8	3.8	3.8
501,401	544,787	575,231	584,948	557,965	498,268	393,995
0.653	0.697	0.723	0.722	0.676	0.593	0.461
692,046	1,062,999	1,558,088	2,200,314	2,971,076	3,930,484	5,068,007
0.902	1.360	1.958	2.716	3.602	4.681	5.929
4,988,076	6,180,228	7,590,801	9,224,861	10,931,916	12,885,143	14,980,807
3.727	4.562	5.537	6.650	7.787	9.069	10.419
6.498	7.907	9.539	11.386	13.254	15.345	17.526
8.122	9.884	11.924	14.233	16.567	19.182	21.907
14,320,337	18,394,800	23,341,227	29,218,649	36,292,562	44,420,732	52,640,159
687,376,187	882,950,386	1,120,378,909	1,402,495,174	1,742,042,968	2,132,195,117	2,526,727,626
21.4	21.4	21.4	21.4	21.4	21.4	21.4
9	9	9	9	9	9	9
8,157,791,464	9,984,145,875	12,053,800,910	14,324,456,616	17,119,507,231	20,152,818,034	22,449,353,383
37,705,066	61,577,616	95,909,054	148,291,131	217,713,392	311,248,319	431,383,963
1,091,765,653	1,671,143,045	2,443,690,899	3,445,064,487	4,704,008,002	6,216,718,240	8,009,386,593
2,575,197,588	2,798,026,536	2,954,385,901	3,004,295,167	2,865,708,202	2,559,106,912	2,023,559,471
2,059,527,897	3,163,485,667	4,636,869,336	6,548,134,005	8,841,922,564	11,697,120,446	15,082,388,856
13,921,987,668	**17,678,378,739**	**22,184,656,096**	**27,470,241,407**	**33,748,859,393**	**40,937,011,950**	**47,996,072,266**
10,190,894,973	**12,940,573,237**	**16,239,168,262**	**20,108,216,710**	**24,704,165,075**	**29,965,892,748**	**35,133,124,898**
20.92	20.92	20.92	20.92	20.92	20.92	20.92
487,136,471	618,574,247	776,250,873	961,195,827	1,180,887,432	1,432,404,051	1,679,403,676
11,598,487	14,727,958	18,482,164	22,885,615	28,116,367	34,104,858	39,985,802
$88,171,701	$111,961,939	$140,501,408	$173,976,445	$213,740,625	$259,265,133	$303,972,065
$68,686,242	$87,218,969	$109,451,373	$135,528,612	$166,505,128	$201,968,971	$236,795,918
1.14	1.14	1.14	1.14	1.14	1.14	1.14
$555,335,577	**$705,174,641**	**$884,925,995**	**$1,095,763,243**	**$1,346,211,672**	**$1,632,940,618**	**$1,914,520,190**
269,423	342,118	429,325	531,613	653,119	792,227	928,836
32,336	41,061	51,528	63,804	78,387	95,083	111,479
39,753	50,478	63,346	78,438	96,366	116,891	137,047
482	612	768	952	1,169	1,418	1,663
236	**300**	**377**	**467**	**573**	**695**	**815**
449,599,016	**577,520,189**	**732,817,437**	**917,344,043**	**1,139,435,465**	**1,394,626,182**	**1,652,682,005**

Table B-2. Transportation Impacts of Telecommuting – Projected (Upper Bound)

Assumptions

Total Telecommuters = Sum of the number of telecommuters in each of the 5 categories.

percent of Infoworkers Telecommuting = Total Telecommuters/# Infoworkers

Telecommuting Days/Week = (# of Home-CBD telecommuters*Avg. Days per week) + ... (sum of the 5 categories)

Average Days / week - beginning with 1-2 days per week and gradually increasing (rate?).

Commute Distance

Assume no exacerbation of urban sprawl.

The average distance traveled to work according to the NPTS 1990 is 10.7 miles one way / 21.4 miles round trip, this figure was uses as the distance from home to CBD Office, Distance for regional offices is anticipated to be substantially less, we assume 9 miles (round trip) for the home to regional center commute.

Since data indicates that commute distance has not been changing annually, this figure was not adjusted over the spreadsheet time frame.

Commute Time

This is generally increasing with the years. 1990 Journey to Work reports average commute time is 22.4 minutes

Home to CBD - 22.4 minutes
Home to Regional Center - 11.2 minutes

This figure was not adjusted over the spreadsheet timeframe.

Commute Speed

19.6 mph was used for urban since that is the default for mobile 4.1; 45 mph was used for rural.

Average Fuel Efficiency

Impacted by improved automobile efficiency. This has risen slightly in the past 10 years; new car fuel economy seems to be leveling.

Average MPG for US passenger cars for 1990 = 20.92 Miles per Gallon (NTS Table 52). The average increase per year for 1988 - 1990 was 2.8%.

Gasoline Prices

Average Retail Price in 1991 for regular unleaded was $l.l4/gallon (NTS 1992, Table 49).

Gasoline Saved
Gasoline saved due to telecommuting = (Vehicle Miles Saved)/(Average MPG)

total fuel 1990 - 72,434,884,000 gallons
average consumption for 1990 -- 505 gallons per year/vehicle

42 gallons per barrel was used as the conversion factor.

Mode **Choice**

Gradual but slow move to ridesharing and mass transit

average vehicle occupancy 1.6 -- 1990
76 percent of all Carpools - 2 person
private auto used 73.2 percent of the time - 1990 (Journey to Work)

VMT

Table B-3. Vehicle Miles Traveled

RURAL AND URBAN MILES OF TRAVEL BY VEHICLE TYPE, 1990

	PASSENGER VEHICLES					TRUCKS					
	Personal Passenger Vehicles					Single Unit					
	Passenger Cars	Motor-cycles	Total	Buses	All Passenger Vehicles	2-Axle 4-Tire	Other	All Single Units	Trailer Combi-nations	All Trucks	All Motor Vehicles
Motor Vehicle Travel: (Millions of Vehicle-Miles)											
Interstate Rural	129.047	1,173	130,220	568	130,788	33,078	5,949	39,027	30,758	69,785	200,573
Other Arterial Rural	215,847	1,533	217.380	996	218,376	80,846	11,108	91,954	20,896	112,850	331,226
Other Rural	217,080	1,674	218.754	1,889	220,643	94,292	12,775	107,067	10,900	117.967	338,610
All Rural	581,974	4,380	566,354	3,453	569,807	208.216	29,832	238,048	82,554	300,602	870,409
Interstate Urban	207,911	1,145	209.056	452	209,508	45,966	6.210	52,176	16,720	68,898	278.404
Other Urban	745,485	4,047	749,532	1,823	751,355	212,645	17.480	230,125	17,208	247,333	998,688
All Urban(1)	953,396	5,192	958,508	2,275	960,863	258,611	23,690	282,301	33,928	316,229	1,277,092
Total Rural and Urban	1,515,370	9,572	1,524,942	5,728	1,530,670	486,827	53.522	520,349	96,482	816,831	2,147,501

(1) Represents travel on all roads and streets in urban places of, 5,000 or greater population.
SOURCE: U.S. Department of Transportation. Federal Highway Administration, Table VM-I.

Assume trip savings are not offset by increased noncommute travel.

total VMT 1990 passenger cars - 1,515,370,000,000
32.1 percent of VMT are for work (NTS Table 72).

Calculations for savings as percent of total VMT were made with the assumption that VMT would increase 3.7 percent per year; this is the average percent increase from 1988-1990 (NTS 1992, pg. 51)

Passenger/Vehicle Miles Saved

Vehicle miles slightly lower because most telecommuters travel by private automobile with no passengers other than the driver.

Passenger Miles Saved

Part Time Home, CBD Workers: = (# Home,CBD Workers) * (Telecommuting Days per Week) * (Average Round Trip Dist. Home,CBD) * (48 weeks)

Part Time RC, CBD Workers: = (# RC,CBD Workers)*(Telecommuting Days per Week) * (Average Dist. Home,CBD - Average Dist. Home,RC) * (48 weeks)

Part Time Home, RC Workers: = (# Home, RC Workers)*(Home Telecom. Days per Week) * (Avg. Dist Home, CBD)*(48 weeks) + (# Home, RC Workers) * (5 - Home Telecom. Days per Week) * (Average Dist. Home,CBD - Average Dist. Home,RC) * 48 weeks

Full Time Home Workers: = (# Full Time Home Workers) * (5 days) * (Average Dist. Home,CBD) * (48 weeks)

Full Time RC Workers: = (# Full Time RC Workers) * (5 days) * (Average Dist. Home,CBD - Average Dist Home,RC) * (48 weeks)

Note: 48 weeks = 52 weeks - 2 vacation - 2 holiday

Vehicle Miles Saved = (Total Annual Passenger Miles Saved)*(73.2 percent)

Note: 73.2 percent is the amount of commuters who drive alone. (NPTS)

1.16 is the average occupancy per car.

Annual Pollution Avoidance

Table B-2 lists figures used from the EPA MOBILE 4.1 model in calculating emissions avoided.

Table B-4. EPA MOBILE 4.1 Emissions

Default Operation	EPA - MOBILE 4.1 Average Emissions (grams/mile)	
	Urban (1990 Base Fleet)	Rural (1992 Base Fleet)
Average speed	19.6 mph	45.0 mph
Pollutant		
Total HC	4.71	2.44
Exhaust CO	29.01	8.83
Exhaust NOx	3.02	2.46

Carbon: = [(Total Miles Saved)*(.78,Urban Commuters)*(29.01 grams)/ + (Total Miles Saved)*(.22,Rural Commuters)*(8.83 grams)]/(454,grams per lb.)

The other pollutants were calculated in a similar manner.

Notes: The urban pollution rate was taken from grams of emission at the average urban commute speed 19.6 mph. The rural rate was calculated at 45 mph default operation. The emission figures at varying speeds were taken from the EPA Mobile 4.1 model. The percentages of urban (75.2%) vs. rura1(24.8%) commuting were obtained from the 1990 Journey to Work.

Gasoline Excise Tax

An average tax rate for all states was calculated to be 15.8 cents/gallon
Source: U.S. Department of Commerce Statistical Abstracts of the U.S. 1992

Safety

Fatalities avoided = (Total Passenger Miles Saved)/(1,000,000)*(.0232)

The annual fatal accident rate of .0232 fatal accidents per l,000,000 miles travelled was taken from 1989 rate in MVMA Facts & Figures.

No adjustment was made for time of day of accidents.

Appendix C - Profiles of Major Demonstration Projects

California Telecommuting Project

Federal Flexiplace Project

Hughes Ground Systems Group Telecommuting Pilot

Los Angeles County Pilot Project

Puget Sound Telecommuting Demonstration Projects

Sears

SNET (Southern New England Telephone Network)

Project: California Telecommuting Project

POC: Pat Mokhtarian (UC, Davis)
Phone: 916-752-7062
David Fleming (formerly with CA)
Phone: 916-752-1987
Carol Nolan (Pacific Bell)
Phone: 213-975-7495
Fax: 213-977-0641

Company: State of California
Department of General Services
601 Sequoia Pacific Blvd.
Sacramento, CA 95814

Type of Business: State government

Project: California Telecommuting Project

Implementation Date: January 1988

Formal/Informal: Formal

Funding: California state. Caltrans funded some evaluation.

Telecommuting Strategy:

Program objectives were to study telecommuting as a response to traffic and air pollution problems and a state mandate to reduce trips for state employees. Telecommuting in San Francisco, Sacramento and Los Angeles. Provide options for physically disabled. Predominantly work-at-home using telephone and/or personal computers.

Effects on Business:

Productivity Gains: Productivity hasn't suffered on the whole. Potential for space savings: Over-crowding in state facilities. Share existing space more efficiently.

Direct benefits include: increased employee effectiveness, decreased sick leave, decreased medical costs, increased organization effectiveness, decreased turnover, decreased move rates, reduce parking requirements, and office space savings. Indirect benefits include: decreased energy consumption, decreased air pollution, decreased highway costs, and decreased

traffic congestion.

Project Manager: David Fleming

Participants:

California Energy Commission, California Youth Authority, Department of General Services, Department of Social Services, Franchise Tax Board, Public Utilities Commission, CalTrans.

Type: The average telecommuter is 41 years old and employed by the state for 14 years. Sixty-four percent are male. Ninety percent own their home. Most are seasoned state employees.

Jobs: Jobs range from accountant to researcher, including administrative law judges, lawyers, policy analysts, and appraisers. Secretaries and clerical workers: 3 percent, managers: 3 percent, managers and professionals: 18 percent.

Number: 150 (1990) Mostly from 6 of 14 participating state agencies. Twenty-two agencies involved at different points in time.

Employee Type: Seventy-two percent considered professional. Half own a personal computer.

Home / Center: Home.

Number of Days: 1.6 full days and .4 partial days per week. Some more than 3 days per week.

Technology/Services Used:

Most telecommuters did not require separate phone lines. Those who needed separate lines telecommuted more than 3 days per week or required dedicated lines in order to connect to establish a mainframe connection. Thirty-six percent of telecommuters have multiple phone lines. Sixty percent of participants and 80 percent of telecommuters own personal computers. Several agencies supplied telecommuters with laptops for home and office.

Equipment Provider:

Mostly the telecommuter, but the state provided equipment in some cases.

Who pays for:

Equipment(emp/company/both-reimbursement): Primarily employee-owned equipment.

Maintenance: About $250 annually.

Electricity: Telecommuter.

Phone: State pays for phone services. The average telecommuter paid an average of $9.43 more than other employees for phone services.

Transportation:

How did employees formerly commute: For nonwork trips and household as a whole, trip making didn't increase.

Labor:

Union:

Workmen's Comp:

General Problems/Barriers:

Legal:

Labor:

Documentation:

Documents/Citations:

Empirical Studies:

Panel Three-day Travel Diary Survey (1988: 252 respondents, 1989: 219 respondents)

Project: Federal Flexiplace Project

P O C : Wendall Joice
Phone: 202-606-0860
Fax:

Company: Federal Government
Type of Business:

Project:

Implementation Date: September 1990
Formal/Informal: Formal
Funding:
Telecommuting Strategy:
Effects on Business: See report below.
Productivity Gains:
Project Manager:

Participants:

Type: 13 Federal agencies
Jobs: General Services Administration

. Position Classification Specialist
. Budget Analyst
. Architect
. Clerk-Typist
. Chemist

Department of the Interior (Washington, DC and Denver, CO)

.Geologist
.Accounting Technician
. Program Analyst
. Physical Scientist
.Oceanographer

Department of Agriculture

· Secretary
. Editorial Assistant
. Regulatory Analyst
· Program Analyst
. Management Analyst
. Budget Analyst

Department of the Treasury

. Comptroller
. Federal Finance
. Personnel Specialist

Department of Health and Human Services

. Medical Officer
. Pharmacologist
. Personnel Management Specialist
. Writer-Editor
. Biologist
. Supervisory Medical Officer

Office of Personnel Management

. Employee Development Specialist
. Investigator
. Psychologist

Number: 6/92: 700, 13 agencies

Employee

Type: Seventy-two percent of 522 participant survey respondents were married and/or living in families, 47 percent had children under 18 living at home. Seventy percent were full-time professional employees and 80 percent had pre-Flexiplace job performance ratings in the "Exceeds Fully Successful" or "Outstanding" levels. Most worked in urban downtown areas. Sixty-one percent were 40 or more years old and 84 percent had 11 or more years of work experience. The participant group had proportionally more females, higher grades, more part time employees, and more employees with outstanding job performance ratings than the Federal workforce in general. Forty-three percent reported that their most productive work was accomplished outside normal working hours.

Home/Center: Home
Number of Days:

Technology/Services Used:

Equipment Provider:

Who pays for:

Equipment(emp/company/both-reimbursement):

Maintenance:

Electricity:

Phone:

Transportation:

How did employees formerly commute:

Labor:

Union:

Workmen's Comp:

General Problems/Barriers:

Legal:

Labor:

Training:

A workshop for employees, supervisors and personnel specialists is part of the U.S. Office of Personnel Management training curriculum and available to agency offices nationally through OPM Training Centers and the Washington Area Service Center. The package, "Flexiplace: A Workshop for Employees, Supervisors and Personnel Specialists" is also available from the National Technical Information Service (NTIS). Component training materials include fifty 35mm color slides, and instructor's manual, participant handouts and preclass exercises. The 30-minute "Federal Flexible Workplace Project Training Overview" videotape is also available from NTIS.

Documentation:

Documents/Citations:

Empirical Studies:

"The Federal Flexible Workplace pilot Project Work-at-home Component", June 1992, Summary report condensed below.

Data Results:
522 participant background/baseline questionnaires
224 participant 6-month evaluations
102 participant l-year evaluations
388 supervisor baseline evaluations of participants
213 supervisor 6-month evaluations of participants
100 supervisor l-year evaluations of participants
62 supervisor 6-month evaluations of organizational performance
49 supervisor l-year evaluations of organizational performance
40 supervisor evaluations of control participants
40 control participant evaluations of work experience
30 customer/client 6-month evaluations of participants

. Participant Job Performance Ratings

More than 90 percent of the supervisors and 95 percent of the participants judged that job performance was either unchanged or improved relative to previous levels.

. Customer/Client and Control Group Ratings

Samples of 30 customer/client ratings, 40 supervisor ratings of control employees and 40 control employee self-assessments considered too small.

. Interpersonal Communications

The pattern of judgements regarding interpersonal communication is similar to that regarding job performance. More than 90 percent of the respondents, both participants and their supervisors, judged that there was no change in the effectiveness of work-related interpersonal communication; of those perceiving a change, significantly more saw an improvement as opposed to a decline in communication effectiveness.

. Quality of Personal Life

Flexiplace has positively affected personal life quality. For most of the examined factors, more than half of the participants responded that there had been at least some improvement attributable to the advent of Flexiplace (3 percent or less reported a decline).

. Quality of Work Life

Ninety percent indicated no change or improved. Twenty-five percent and 37 percent for the first six months (17 percent and 29 percent for the final six months) indicated that the job-related home office equipment and access to work materials were less adequate than their at conventional offices.

. Participant Costs

More than 70 percent reported reductions in job-related transportation and miscellaneous costs and no change in dependent care costs. Approximately one-third of the participants, however, experienced increased home maintenance costs due to participating in Flexiplace. In terms of an overall cost assessment, more than half of the indicated no change in job-related costs while nearly a third reported a reduction.

. Other Findings

Participants indicated reductions in both rush-hour vehicle usage and sick leave.

. Organizational Performance

(This information is based on a relatively small sample of organizations.) Data suggest that Flexiplace is a desirable option for most organizations. More than 70 percent of supervisors indicated that Flexiplace is feasible in meeting organizational objectives and supervising participants and more than 90 percent indicated that it did not result in significant organizational expenses. Focus group summaries and information from agency Flexiplace coordinators suggest that some of the modifications desired by supervisors include more supervisor control over selection and number of participants,

more guidance on technological issues, more flexibility in agency-specified procedures and increased agency funding.

. Overall Reactions

About 80 percent of the supervisors and nearly all participants judged Flexiplace to be a desirable option requiring minimal refinement.

Project: Hughes Ground Systems Group Telecommuting Pilot

POC: Michael Chaffee
Commuter Services Administrator,
PO Box 3310, MS TC12/A104
Phone: (714) 732-7433
Fax:

Company: Hughes Ground Systems Group
PO Box 3310
Fullerton, CA 92634

Type of Business: Aerospace and Defense sector

Project:

Implementation Date: May-Oct. 1990
Formal/Informal: Formal
Funding: Hughes Ground Systems Group (HGSG)
Telecommuting Strategy:

Telecommuting has been implemented in several small organizations on a "pilot program" basis, in order to ascertain the feasibility of expanding its use. The pilots focus on maintaining or increasing productivity over conventional work arrangements, and contribute to clean air efforts. Telecommuters completed a questionnaire and were selected by supervisors to participate in the pilot. Participants were required to sign agreements detailing company and employee liabilities and responsibilities. Only salaried exempt employees participated. HGSG reserved the right to inspect the home work environment provided 24 hours notice and the right to terminate telecommuting at any time. The pilot was supported by Carol Nolan of Pacific Bell.

(HGSG has also implemented a video-teleconferencing capability that was not part of the telecommuting pilot. Teleconferencing is available to all employees who have reserved the on-site studio on a first-come/first-serve basis. The studio has 35-inch color video screens, and provides connections to eight other Hughes sites.)

Effects on Business:

Telecommuting required new clerical procedures to report and record daily time card data. Time keeping procedures were

approved, documented, and issued. Also, customers were unaware that they might be being serviced by an off-site employee. Most customer servicing was accumulated and handled at appointed times. Only emergency requests were handled immediately. Internal departmental support requirements changed, requiring better planning for meetings, and work coordination.

Productivity Gains:

Benchmarks measuring overhead costs throughout the pilot indicated a 55-percent drop. According to Mr. Chaffee, the productivity of employee's performing quantitative tasks increased significantly and telecommuting makes good business sense from this perspective. According to supervisors, telecommuting promotes high morale, better time management, Rideshare participation and productivity, while reducing absenteeism. Customers were not affected by telecommuting , All telecommuters responded that their morale had improved and 60 percent believed their quality of work improved. They also desired better telecommunication links and more flexible days for telecommuting. On-site colleagues favored telecommuting, but found some increase in interruptions and workload and also had to arrange meetings around the telecommuters' schedules. From management's perspective, telecommuting promotes employee retention, attracts new employees and supports Rideshare participation. The project also resulted in a 55 percent reduction in paid time off.

Project Manager: Multiple managers by site.

Participants:

Type: Information Systems professionals, ranging from programmers to senior computer scientists.

Jobs: Documentation, performance appraisals, analysis, program coding and testing, course development, training preparation, and special assignments.

Number: 12

Employee Type:
Home/Center: Home.
Number of Days: l-2 days, or special assignment

Technology/Services Used:

PCs with modems, intercom telephones for group communication, and normal telephone service. Employees must have necessary software. Employees communicated via telephone and E-mail.

Equipment Provider: Employee.

Who pays for:

Equipment(employee/company/both-reimbursement): employee.

Maintenance: Employee.

Electricity: Employee.

Phone: HGSG. For security reasons, the HGSG host computer always connected to the remote PC, resulting in connect charges being billed to the company. Additional phone lines at employee homes were considered a convenience and the responsibility of the employee.

Empirical Studies:

Multiple surveys were completed by telecommuters, management, in-office colleagues and customers throughout the pilot.

Project: Los Angeles County Telecommuting Project

POC: Carol Nolan, Pacific Bell
Phone: 213-975-7495
FAX: 213-977-0641
Nancy Apeles, LA County
Phone: 213-974-2637

Company: Los Angeles County government

Project :

Implementation Date: September 1989
Formal/Informal: Formal
Funding: County of Los Angeles
Telecommuting Strategy: Home and Telework Center.

The county has a work force of 80,000 distributed across 39 departments. Its population is 8.5 million and it encompasses 4083 square miles (800 square miles larger than Delaware and Rhode Island together). The county represents 31 percent of the state's population and is growing. Since the passage of Proposition 13, the county has experienced budgetary difficulties.

Many employees commute long distances to work. According to the Wall Street Journal the average person living in Moreno Valley (about 65 miles from Los Angeles) spends less than four waking hours at home. People from Santa Barbara commute about 105 miles each way. Also at issue is Regulation XV of the Air Quality Management Plan for the South Coast Air Basin mandating the reduction of vehicle ridership. The telecommuting project seeks to reduce work-related vehicle usage by local government employees 12 percent by 1994.

Other factors affecting the work environment is increasing traffic congestion. In 1988 California had 22.4 million vehicles and 16.6 million drivers. By the year 2000, California anticipates about 23.8 billion vehicles, 22 million drivers and a 200 percent increase in traffic delays. It is interesting to note, that two hours on the freeway is equivalent to 3 months in a car, instead of at the office. California drivers spend 400,000 hours a day in traffic delays at a cost of $2.4 million a day or $600 million per year.

County Management Issues

. Shortage of funds and increased demands for services.
. Increase employee productivity.
. Improve ability to recruit and retain employees.
. Decrease absenteeism and sick leave
. Improve management effectiveness

. Reduce employee stress
. Address air quality/traffic management problems.

Effects on Business:

Telecommuting reduces hours of child care needs and supports sick child and elderly care. Savings are realized by both the employee and the employer. Managers tend to manage better and employee loyalty increases, promoting recruitment and retention.

. Reduced commute time, cost, and frustration
. Decreased stress
. Increased flexibility to handle work/family schedule
. Better work environment
. Increased job satisfaction
. Wider opportunities for the handicapped
. Decreased number of employees on workers compensation
- Decreased cost of clothing, food, dry cleaning
. Closer bonds with the family/community
. Increased safety in the home/community

Productivity Gains: According to a survey of employees performed by Shirazi and Associates:

Work Hours

	More	Same	**Less**
Prior	18%	80%	2%
One year later	28%	70%	2%

Productivity

	Increased	Same	Decreased
Prior	61%	34%	5%
One year later	65%	32.5%	2.5%

Ouality of Work

	Improved	Same	Decreased
Prior	50%	45%	5%
One year later	48%	52%	0

Problems Completing Work on Time

	AGREE	Neutral	Disagree
Prior	6%	18%	76%

One year later	0	30%	93%

Quantity of Work

	More	Same	Less
Prior	77%	16%	7%
One year later	70%	30%	0

Project Manager: Management of the overall county program is the responsibility of the Chief Administrative Office. The program is decentralized to line departments which implement the program according to local needs.

Participants: More than 950 people telecommute under the aegis of the Los Angeles County Telecommuting Project. This includes employees of:

. Department of Community and Senior Citizens Services
. Department of Public Social Services
    . Bureau of Planning and Program Development
    . Management Information and Evaluation Division
. Department of Health Services
    . Contract Monitoring Unit
    . Civil Service Advocacy Unit
. Probation Department
    . Central Adult Investigation Section
    . Transcriber Typists
· Assessor
. Superior Court
. Department of Public Works
. Auditor-Controller
. Chief Administrative Office
    . Office of Affirmative Action
    . Human Relations Commission
    . Coroner
    . Sheriff
    . Marshall
. Internal Services Department
. Department of Children's Services
. Department of Mental Health
. Department of Animal Control
· Museum of Art

Type: 68 percent female/32 percent male

Use computers: 48 percent
Married: 55 percent
Single: 25 percent
Widowed/divorced: 20 percent
Children under 18 at home: 33 percent
Average Tenure: 15 years
Income between $25,000 to $50,000: 34 percent
Income less than $25,000: 14 percent

Jobs: Wide range, including accountants, administrators, clerical staff, nurses, psychologists, analysts, data processing personnel, tax collectors, division chiefs, environmental health specialists, electricians, office managers, auditors, property agents, personnel clerks and managers, transcription typists, investigators, and word processors.

Number: About 950

Employee Type: Managers, administrators, technical, and clerical personnel.

Home/Center: Home and center

Number of Days: Average about two days per week.

Technology/Services Used: PC (preferably laptops) and telephone services from home or telework center.

Equipment Provider: The employee may use personal equipment or equipment may be provided by the employee's department.

Who pays for:

Equipment(employee/company/both-reimbursement): County pays for equipment provided by the county, Employees may elect to use personal equipment.

Maintenance: Employee is responsible for the repair and maintenance of personal equipment, otherwise, the county is responsible.

Electricity: Employee.

Phone: Individual county department.

Transportation:

How did employees formerly commute:

Drive alone: 76 percent
Carpool: 14 percent
Vanpool: 1 percent

Bus: 5.3 percent
Mix: 4 percent
Avg. commute mileage: 19
Avg. commute minutes: 75

Labor:

Union: Resistance from Unions.

Workmen's Comp: Employees only are covered by Workman's Compensation at home for job-related accidents. The county reserved the right to inspect the employee's work area at home, as well as maintain, repair, inspect or retrieve county-owned equipment.

General problems/barriers:

. Reluctance of some managers to try new programs
. Union resistance
. Delays in computer programming
. Delays in equipment procurement
. Reluctance of some managers to deal with non-telecommuters

Empirical Studies: Shirazi & Associates Telecommuting Survey

Project: Puget Sound Telecommuting Demonstration Project

POC: Maureen Quaid or Dee Christensen
Phone: (206) 956-2000
FAX: (206) 753-2397

Company: Washington State Energy Office
809 Legion Way SE, PO Box 43165,
Olympia, WA 98504-3 165
Type of business: State energy office working in conjunction with local businesses.

Project: Washington State Telework Center
Implementation Date: October 1990
Formal/Informal: Formal
Funding: Washington State Department of Information Systems

Telecommuting strategy:

The telework center was established on the fifth floor of an office building in North Seattle, supporting state employees who normally work in Olympia. The center consisted of an entry area, conference room, lunch room, computer room, and workstation area. The workstation area was partitioned into 13 cubicles using modular furniture and dividers. The center provided work space for state employees living in King and Snohomish counties. A consultant from WCCCC, available full-time, provided part-time on-site hardware and software support. The center closed in January 1992 because of a lack of funding.

Effects on Business:

Productivity Gains: Unknown.

Time savings for employees who reduced commute by as much as two hours per day and reduced travel costs. Telecommuters indicated an improvement in job performance because of fewer interruptions and reduced stress associated with commuting.

Project Manager:

Participants:

Twenty-four employees from state agencies used the center. Participating agencies included the Department of General Administration, Department of Transportation, Department of Social and Health Services, Department of Employment Security, Utilities and Transportation Commission, African-

American Affairs Commission, Department of Community Development, Washington Community College Computer Consortium (WCCCC) and Washington State Energy Office. The federal Bonneville Power Administration rented one workstation, but rarely used it. Employees volunteered to use the Telework Center and none were screened or formally selected.

Type: Primarily administrators and managers.

Jobs: Support staff; assistant, deputy and executive directors; administrators; program managers; planners and analysts; and field workers.

Number: 24

Employee Type:

Home/Center: Center.

Number of Days: Variable.

Technology/Services Used:

PCs (80286 microprocessors) with 40MB hard-drives connected by LAN to a file server and Laserjet printer. Each workstation had a touch-tone phone accessing the state's long-distance phone system. Some people added answering machines. The conference room was equipped with a speaker phone and a security card access system was installed at the facility'sentrance.

Equipment Provider:

Leased from R&D Industries, a regional distributor for Hewlett-Packard, by the state.

Who pays for:

Equipment(emp/company/both-reimbursement): Primarily state.

Maintenance: State.

Electricity: State.

Phone: State. Long distance calls were not tracked.

Transportation:

How did employees formerly commute: Most commuted by automobile from the Seattle area to Olympia. Just more than half used the center regularly. The rest used it less than one day in two weeks or did not use it for more than six months at a time. Several people found it more convenient to telecommute from home. Three people moved to Olympia and another three changed jobs. Five people normally used the center for three or more days per week. Transportation characteristics tended to be complicated. Some

performed field work or had business elsewhere. The one-way commuting distance to the main office was typically more than 60 miles. The center did not reduce the number of commute trips; however, it did reduce mileage. The estimated annual savings was about 60,000 miles or 2,600 miles per telecommuter. The six telecommuters with the highest annual savings accounted for more than 80 percent of the total estimated savings.

General Problems/Barriers:

Initial funding was expended after 13 months. Agencies using the center could not pay the monthly workstation cost and the center was closed. Telework center was less than half occupied when open.

Documentation:

Empirical Studies: Case study based on interviews with employees estimates affects on energy consumption for transportation, office and home computer equipment, lighting and heating. Energy consumption was not measured directly. Energy use changes were estimated for transportation, home, office, and the telework center.

Project: Puget Sound Telecommuting Demonstration Project - GTE

POC: Maureen Quaid or Dee Christensen
Phone: (206) 956-2000
FAX: (206) 753-2397

Company: GTE Northwest

Project:

Implementation Date: November 1990.
Formal/Informal: Formal.
Funding: GTE Northwest.
Telecommuting Strategy:

The objective was to develop data, experience, and knowledge in telecommuting. Participants worked from home. Prior to the project a few GTE employees telecommuted informally. GTE had no formal telecommuting policy and no official budgets or policies were established for the project. Telecommuter support (mostly technical) was limited and handled informally.

Effects on Business:

Benefits to GTE are difficult to quantify. The project resulted in minimal office savings of about $50 per year.

Productivity Gains:

The major benefits to telecommuters were fewer interruptions, additional time.

Project Manager:

Participants:

Twenty-three official participants: 7 from Canyon Park and 16 from Everett, WA. About two-thirds telecommuted regularly; the remainder generally started then either stopped telecommuting for six months or more or quit altogether because of job demands, job changes or inability to get required support. Less than half are telecommuting and intend to continue. About one-third intend to discontinue formal telecommuting.

Type:
Jobs: Canyon Park: (client/sales focus) applications specialist and account executives. Everett/main office: administrators, analysts, programmers and other central office support and development staff.
Number: 23
Employee Type:

Home/Center: Home
Number of Days: Variable.

Technology/Services Used:
Personal computer, modems and telecommunication lines.

Equipment Provider:
Most equipment supplied by GTE. Some individuals used their own personal computers. GTE installed business lines as necessary.

Who pays for:
Equipment(employee/company/both-reimbursement): Mostly GTE.

Maintenance: minimal/GTE.

Electricity: telecommuter.

Phone: unknown.

Transportation:
How did employees formerly commute:
Distance to site: The average commute distance was 19 miles and required about 26 minutes. The maximum one-way commute was 63 miles. The minimum commute was three miles. Eleven of the 18 survey participants have one-way commutes of 15 miles or less. Sixteen respondents indicated that telecommuting required no additional travel, but two respondents said they incurred additional travel to day care facilities twice each day. During the first year, the 18 respondents saved an estimated 940 gallons of gasoline and eliminated 29,800 miles of highway travel. One telecommuter had higher gasoline consumption, although another saved 179 gallons alone (more than three times the average). The telecommuters reduced the number of trips by 18.5 percent or about 650 trips per year, which is consistent with telecommuting one day per week.

Documentation:
Empirical Studies: Case study interview conducted with 21 GTE employees of which 18 interviews were usable. Discussions were held with the telecommuting coordinator, public affairs director, office services manager, building manager, and a representative of Information Systems Field Services. Information was collected on office characteristics and the operation and implementation of GTE's telecommuting pilot. An analysis of affects on transportation is based on interviews, as well as affects on energy consumption connected with commuting and computer, lighting and heating in the home

and office.

Project: Puget Sound Telecommuting Demonstration Project - Redmond

POC: Maureen Quaid or Dee Christensen
Phone: (206) 956-2000
FAX: (206) 753-2397

Company: City of Redmond, WA

Project:

Implementation Date: October 1990
Formal/Informal: Formal
Funding: City of Redmond
Telecommuting Strategy:

The primary goal was to demonstrate on an organization can reduce demand on the region's transportation network. Other factors included stress reduction, overcrowding in city facilities and the 1989 Governor's Conference on telecommuting.

Effects on Business:

Unoccupied offices were used for informal meetings or by interns and temporary staff. There were no formal desk sharing arrangements. The city established telecommuting policy, covering eligibility, work hours, computer equipment availability and liability, workspace, injuries, and telephone expenses. Telecommuting had to requested and approved by an individual's supervisor, department head and a telecommuting committee.

Productivity Gains:

Not directly measured: Telecommuters indicated they were more productive because of fewer interruptions.

Project Manager:

Participants:

Type: Finance, planning, parks, public works, and human resources.
Jobs: Secretaries, administrators, planners, accountants, analysts, recreation directors and engineers. Many must interact with the public or staff.
Number: Officially, 10 city staff members and l0-15 unofficial participants, representing about 5-10 percent of the city's work force. Seven of ten official participants telecommute regularly.
Employee Type:
Home/Center: Home.

Number of Days: Variable. Virtually all telecommute at least one day per week.

Technology/Services Used:
IBM-compatible computers, modems, and standard telephone services.

Equipment Provider: City or Redmond and/or participant.

Who pays for:
(Costs for the telecommuting project were not tracked directly.)

Equipment(emp/company/both-reimbursement): Most equipment provided by the city (laptop computers). Telecommuters were responsible for damage to equipment due to negligence, intentional destruction and power surges. At the office, most employees have 80286 or 80386 PCs, linked to local printers.

Maintenance: The city covered maintenance, repair, and replacement costs.

Electricity: Employee covers electrical costs in the home.

Phone: City of Redmond. No additional phone lines were installed. Some employees did not submit phone bills for reimbursement.

Transportation:

The average one-way commute for the ten official participants was 16 miles, requiring about 35 minutes to commute. All travel during peak hours (6-9 am and 3-6 pm). Three telecommuters sometimes came to work in car pools. The 10 official participants saved about 295 commute trips during the year -- a reduction of 13 percent representing about 9,000 annual commute miles and 336 gallons of gasoline. The unofficial participants reduced commute trips by 17 percent. All the participants indicated that telecommuting did not result in additional travel.

Labor:

Workmen's Comp: Policy in place to cover injuries at home.

Documentation:

Documents/Citations: "Puget Sound Telecommuting Demonstration Case Study: City of Redmond"

Empirical Studies: Case study interviews were conducted with each available person during a site visit. The rest were interviewed by telephone. Interviews were also conducted with other city staff who telecommute, but were not part of the WSEO Demonstration Project. Discussions were also held with the telecommuting coordinator. An analysis of telecommuting's effects on

transportation was calculated for 1991. Some of the telecommuters did not participate for the entire year. Costs and benefits for these individuals are annualized. The transportation analysis is based on information obtained from interviews. The reduction of commuting miles is based on the commute distance and the number of commute trips eliminated. The case study also analyzes the effects of telecommuting on energy consumption, including gasoline, power for lighting and equipment, and home and office heating costs. Energy consumption was not directly measured.

Project: Sears

POC: Audrey Walker
Phone: 708-286-8168
Jerry Esposito (Dept. **707-2)**
Phone: 708-286-8448
Fax:

Company:
Address: Chicago, IL.
Type of Business: Retail, Credit Card

Project:
Implementation Date: September 1990 (Gil Gordon)
Formal/Informal: Formal
Funding: Corporate
Telecommuting Strategy:
Project initiated in spring of 1990. Objective was to show that productivity and other gains could cost justify the continuation and roll out of the program. Ten associates from three departments (704F, 704MR and 704EUC) were selected initially. PCs and modems were obtained during the summer of 1990 along with access IDs and extra phone lines to the homes of associates. Gil Gordon provided training and helped establish project policy. Pilot was in progress in September 1990. Participants provided feedback after three months. Telecommuters working at home must manage dependent care and personal responsibilities in a way allowing them to successfully meet job responsibilities.

Effects on Business:
Productivity Gains:
Questionnaire results revealed: (1) without exception, all telecommuters said productivity increased with estimates varying from 5 to 50 percent, although many claimed a two- to three-fold increase in specific tasks. No negative comments were received. (5) Many felt that telecommuting motivated people and that in turn is likely to mean better service for the client.
(6) Telecommuters said they would like to continue telecommuting, although one indicated only for another year. Many said it gave them more time with family or on other interests, and still "do a fine job" for sears. Overall, they felt the arrangement made them a better employee. Some expressed interest in a satellite office.

Project Manager: Audrey Walker

Participants:

Type: Telecommuters have regularly scheduled work hours and are accessible at a "work site" during normal business hours.

Jobs: Selection as a telecommuter depends on mutual consent; the needs of the job, department and company; suitability and desirability, and the associates past and present levels of performance. Each arrangement is cost-justified, subject to benefit tracking and reviewed regularly. Jobs also characterized by:

. low face-to-face communication requirements
. individual works alone handling information
. clearly defined tasks and deliverables
. measurable work activities
. objectives with identifiable timeframes and checkpoints
. content- versus process-oriented
. tasks not driven from outside the work group with short term deadlines
. tasks require concentration and/or large blocks of time
. job performed with close supervision
. minimal requirements for special equipment and for non-portable resources (e.g., frequent access to file cabinets).

Number:

Employee Type:
. proven ability to perform; high job knowledge
. self-motivated, disciplined, and directed
. desires to make telecommuting work
. above average managerial skills
. lower need for office social contact

Home/Center: Home

Number of Days: l-5 days per week, generally split between home and office. A full home schedule requires justification and prior arrangement.

Technology/Services Used:

Equipment Provider:

Equipment needs vary. Sears may provide equipment as agreed between supervisor/department and associate and based on business need. Associates may use their own equipment if compatible with Sears' needs and approved by supervisor.

Who pays for:

Equipment(employee/company/both-reimbursement):

Telecommuters must absorb any costs related to remodeling and set up of work site. Expenses not specifically covered are dealt with on a case-by-case basis. Taxes related to the home workspace are the responsibility of the associate.

Maintenance:

Telecommuter is responsible for maintenance of associate-owned equipment. Sears installs, repairs, and maintains company equipment.

Electricity: Telecommuter.

Phone: Sears reimburses charges for all long distance business-related calls. Sears reimburses business-related expenses associated with additional telephone access line. The line must be used solely for business.

Transportation:

How did employees formerly commute:
Distance to Site:
then:
now:

Labor:

Union:
Workmen's Comp:

General Problems/Barriers:

Legal:
Labor:
Security: Equipment, software, data, and supplies provided by the company are limited solely to authorized persons conducting business for Sears. Telecommuters take all precautions to secure proprietary information in their home and prevent unauthorized access to any company system from their home.

Documentation:

Documents/Citations:
Empirical studies:

Project: SNET (Southern New England Telephone Network)

POC: Connie Goebel
Phone: 203-771-6301
Fax: 203-777-04 11

Company:

Address: 195 Church St, 5th Floor, New Haven , CT
Type of Business: Telecommunications company

Project:

Implementation Date: December 199 1, June/July 1992
Formal/Informal: Formal
Funding: SNET
Telecommuting Strategy:

Objectives:

- Use telecommunications internally increase effectiveness, improve morale, and provide greater flexibility to employees
- measure impact of telecommuting on individuals, work groups, and the environment
- develop expertise to assist other employers in setting up telecommuting programs
- identify components of possible telecommuting packages
- test relevant new technologies like ISDN.

Project team director formed an interdepartmental team with representation from Business Research, Corporate Telecommunications, External Affairs, Human Resources, Information Technology, Internal Auditing and Market Plans. Efforts included a corporate Telecommuting Policy and Handbook, internal and external communications, a research plan, a technical plan and a selection process to choose participants. Mandatory training for participants.

Effects on Business:

Productivity Gains: Tabulating data from a midpoint survey now. Three-types of survey based on target group:

March 1992: sample of participants (800-900 people), measured population: will be surveyed again in November. Collecting attitudinal info: qualitative information from telecommuter's perspective: co-worker oriented.

Telecommuter/Supervisor: one prior on sent out now and another at end: behavior changes: productivity/effectiveness, impact on peer/work group: transportation-related questions:

Transportation: mode of transportation/mileage, per leg of trip, standard 5-day week : all travel for 5 days. Bach month fill out same log for one week for only days they telecommute.

Project Manager: Connie Goebel

Participants:

Type: Various management positions, Business Services, Comptrollers, External Affairs, Human Resources, information Technology Center (data processing), Market Plans, Network staff, Operations South (field operations group/staff group -- planners), Secretary Treasury (finance, shareholders).

Jobs: programmers, planners, financial analysts, writers, sales support, field support, and customer contact personnel

Number: '100

Home/Center: Home

Number of Days: l-3 days

Technology/Services Used:

All have additional business line with custom calling features -- those on line a lot have two additional business lines, (eliminate use of private line for business-inconvenience). Some got equipment from department depending on availability. Some use pencil and paper (most want a computer) and primarily use voice line. Some use own computer: has been a real problem. Upgrading has been troublesome: in Connie's opinion the amount of time in human resource expended far exceeds cost of buying a computer. "Some companies it would work fine," but she stresses the need for standards for computing. Equipping the home office: in any situation of entitlement -- in local vanpooling -- some discussion of cellular phones in vans -- people want to be compensated. Some people are bought equipment -- some or not -- two-tiered society -- potential problem -- this is **not** a problem at SNET. Shouldn't burden employee with purchase requirement, but should offer payback. Higher technology provides better arrangements, such as LANs where people can share software. Microsoft has new arrangement for copyright -- may install in on a laptop and at home (stand-alone) as long at the prime computer is used 80 percent of the time. Some programmers have dumb terminals at home, not PCs.

Each telecommuter was provided a phone line with Totalphone (custom calling features) and telephone set. Individuals with heavy data communications requirements received an additional line. Telecommuters access mainframe applications via ConnNet (SNET's packet-switched network) protocol converters or a dedicated line. LAN access is via direct-dialing. In some cases, fax equipment is being provided by the individual's department.

Participants choose how they wish to handle incoming calls. Some give out home office numbers; some have notification at home anytime they receive a voice message at the office; some check in with the office and their ACE at set intervals. Regardless of how it is done, maintaining contact with the office is a critical success factor.

Each department assigned a PC coordinator to help assess the PC/technical needs of the telecommuters. Some individuals with PCs on their desk at work determined that the work they planned to do at home required little more than a pen and pencil. Others clearly needed to replicate the equipment they have in the main office. In the end, working with a limited budget, SNET was able to meet most of the needs of almost everyone.

Equipment Provider:

Who pays for:

All expenses are tracked to a work order number: Employees will also identify any costs or savings associated with their participation in telecommuting. Ascertain how it costs as a corporation. Tracking wages, department/PC coordinator hours tracked, contract services, printing, graphic design, computers, phone lines, consultant fees, etc.

Equipment(employee/company/both-reimbursement):

Maintenance: Internal maintenance organization: conflicts with users of personal PCs at home. One-year on-site with DELL,

Electricity: Telecommuters.

Phone: SNET provides line, telephone and modems.

Transportation:

How did employees formerly commute:

Distance to Site: Some have to commute more than 1.5 hours each way. Prior to beginning the project, telecommuters kept a log of travel for

five days. During a specified week each month, the same log will be completed. People that also walk or ride bike/take bus. carp001 vans -- long distance still in car-pools: as we move people forward:still need to maintain seat on van. Shoreline east train group: monthly pass so cheap, subsidized, few more empty seats, but tram will go anyway.

then:

now:

Labor:

Union:

Management senses the potential for PC maintenance people to be sensitive about loss of work related to personal PC use at home. Spreading equipment across a large geographic area creates **new** problems of how to staff the maintenance group. Also might **increase** their transportation requirements.

Workmen's Comp:

Having individual employees carry equipment: monitor down flight of stairs, fall, and break leg. Safety recommendations: educate employees to caution, supervisors have the right to inspect the work site -- no extension cords, not using a flimsy card table, etc. Talk about ergonomics in training, and other issues such as the placement of lighting relative to the terminal's screen. Employees encouraged to get a good chair. SNET is responsible only for work-related injuries.

General Problems/Barriers:

Legal: None specifically: one question is zoning. Many places have obsolete laws on the books. This is a potential problem. SNET tries to prepare employees for these issues while in training. Condos particularly present problems, because of the need to add a phone line -- may not allow another phone line. Employee should talk to the condo board first -- avoid them coming to the employee.

Labor:

Training:

Mandatory training was held for all participants and their supervisors prior to telecommuting. Employees in eligible departments were surveyed before the pilot was announced to get a benchmark of SNET attitudes towards telecommuting. These same employees will be surveyed again near the end of

the pilot to see it their attitudes have changed. Telecommuters and their supervisors were surveyed during training, prior to telecommuting. A survey with similar questions will be administered half way through the pilot and at the end. About six weeks after telecommuting begins, focus groups will be held with telecommuters and their supervisors to identify areas that need adjustment.

Prior to telecommuting, participants were asked to complete a transportation log for five days. The log identified ALL one-way trips, the distance and the mode of transportation, providing a baseline for a "normal" week without telecommuting. During a specified week each month throughout the pilot, the same log will be completed for telecommuting days. At the end, SNET will know the number of miles saved overall by SNET telecommuting participants.

Documentation:

Documents/Citations: very little -- mostly internal.
Empirical Studies: in progress -- not ready for dissemination.

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Appendix E - DOT Telecommuting Workshop Participants

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