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16. Abstract

This work proposes and implements a comprehensive evaluation framework to document the telecommuter, organizational, and societal impacts of telecommuting through telecommuting programs. Evaluation processes and materials within the outlined framework are also proposed and implemented. As the first component of the evaluation process, the executive survey is administered within a public sector agency. The survey data is examined through exploratory analysis and is compared to a previous survey of private sector executives. The ordinal probit, dynamic probit, and dynamic generalized ordinal probit (DGOP) models of telecommuting adoption are calibrated to identify factors which significantly influence executive adoption preferences and to test the robustness of such factors. The public sector DGOP model of executive willingness to support telecommuting under different program scenarios is compared with an equivalent private sector DGOP model. Through the telecommuting program, a case study of telecommuting travel impacts is performed to further substantiate research.

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DEVELOPMENT AND IMPLEMENTATION OF A TELECOMMUTING EVALUATION FRAMEWORK, AND MODELING THE EXECUTIVE TELECOMMUTING ADOPTION PROCESS

by

Vaishali Punamchand Vora

Hani S. Mahmassani

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Telecommunications-Travel Interactions: An Activity-Based Approach to Demand Management and Infrastructure Planning
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DISCLAIMER

EXECUTIVE SUMMARY

The spread of information technology coupled with the deteriorating conditions of many metropolitan regions in terms of air pollution, traffic congestion, and lifestyle flexibility have motivated an interdisciplinary assessment of the relationship between telecommunications and transportation, particularly its substitutive nature. Many organizations are recognizing telecommuting as a promising strategy suggesting significant and substantial economic, environmental, and social benefits through partial or complete altering of the work environment from the central office to the home or satellite center.

Tasks suitable for telecommuting are activities wherein a person works alone, handling information such as reports, proposals, data or research. Writers, salespersons, accountants, programmers, researchers, engineers, architects, and many other professions are prime candidates for either part-time or full time telecommuting (Langhoff, 1995; Sullivan 1993a). However, with the growth of interconnected virtual communities, it is increasingly possible for organizations to operate in a spatially distributed manner.

Nevertheless, many public and private organizations are still somewhat hesitant to embrace telecommuting as a viable large-scale operating mode. Interested organizations usually start with small pilot programs which provide an opportunity to gauge the impacts of telecommuting on the particular candidate. To maximize the benefits of such pilot programs, a sound and reliable evaluation framework is desired.

The objectives of this study were to develop a systematic process by which telecommuting impacts can be assessed, to implement this process through a telecommuting program, to model the executive telecommuting adoption process, and to compare and contrast telecommuting-related characteristics of public and private sector executives. The evaluation framework devised in this study defines the relationships among measurement instruments, time frames, impact categories, and participation groups for a telecommuting program. The framework was implemented within the TxDOT Telecommuting Pilot Program. The executive willingness to support telecommuting programs was modeled using three model types: the ordinal probit, the dynamic probit, and the dynamic generalized ordinal probit. Comparisons are performed for the data acquired through the evaluation framework implementation with similar data from a previous study.

Data was acquired through the telecommuter, supervisor, and executive surveys, as well as travel logs, and accounting processes. Telecommuter and supervisor surveys, and travel logs from the TxDOT pilot program illustrated the identification of factors relevant to telecommuting,

and the impact analysis process. The case study showed travel impacts from telecommuting to be beneficial; organizational and telecommuter impacts were not assessed.

The exploratory analyses revealed that executive attitudes and preferences toward telecommuting are significantly influenced by personal characteristics and management concerns such as age, management style, familiarity with telecommuting, and organizational telecommunications penetrations. Executives appear to be most favorable toward telecommuting programs wherein telecommuter salaries remain the same and additional telecommuting costs are shared between the organization and the telecommuter.

A comparison is performed between public and private sector characteristics, attitudes toward telecommuting, and telecommuting adoption preferences. Private sector executive and organizational characteristics appear to be more favorable to telecommuting than similar public sector characteristics. These characteristics include executive age, education level, management style, familiarity with telecommuting, and telecommunications' penetration. Attitudes and preferences toward telecommuting of the public sector respondents are overall more favorable than those of the private sector respondents. This may be attributed to the fact that the private sector sample was conducted two years prior to the public sector sample and that telecommuting has gained popularity in that time. Also, the public sector sample was briefed on the benefits of telecommuting. Awareness of the policy considerations that motivate telecommuting may also contribute to this difference as TxDOT employees are highly likely to be aware of the growing concern about air quality, congestion, and fuel consumption.

Models of executive willingness to support telecommuting programs were calibrated based on stated preference responses to a set of telecommuting program scenarios. The estimated model provides the opportunity to identify the significance of specific factors to the attractiveness of telecommuting to executives. Correlation among the disturbances of the latent variable of individual response over the nine scenarios was shown to be significant through the DGOP and dynamic probit model.

Factors associated with economic implications of telecommuting are found to be most important, followed by executive and organizational characteristics. These results are promising for the telecommuting policy maker as control or modifications of cost factors is more feasible than of executive or organizational characteristics.

Additional research on the individual and aggregate impacts resulting from telecommuting needs to be performed to confirm the findings of the pilot work presented here. Processes to assess longer term impacts related to land use and household structure also need to be

developed as such impacts may significantly change the form of shorter term impacts on the transportation system and on energy consumption.

ABSTRACT

This work proposes and implements a comprehensive evaluation framework to document the telecommuter, organizational, and societal impacts of telecommuting through telecommuting programs. Evaluation processes and materials within the outlined framework are also proposed and implemented. As the first component of the evaluation process, the executive survey is administered within a public sector agency. The survey data is examined through exploratory analysis and is compared to a previous survey of private sector executives. The ordinal probit, dynamic probit, and dynamic generalized ordinal probit (DGOP) models of telecommuting adoption are calibrated to identify factors which significantly influence executive adoption preferences and to test the robustness of such factors. The public sector DGOP model of executive willingness to support telecommuting under different program scenarios is compared with an equivalent private sector DGOP model. Through the telecommuting program, a case study of telecommuting travel impacts is performed to further substantiate research.

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CHAPTER 1. INTRODUCTION

1.1 MOTIVATION

The explosion and diffusion of information technology coupled with the deterioration of metropolitan regions in terms of air pollution, traffic congestion, and lifestyle flexibility have necessitated an interdisciplinary assessment of the relationship between telecommunications and transportation, particularly its substitutive nature. Of the array of transportation/ telecommunications substitutive activities such as teleshopping, teleconferencing, tele-medicine, and telemarketing, telecommuting has gained attention nationally, and internationally in countries such as Japan, United Kingdom, Australia, Germany and elsewhere in Europe. Organizations recognize telecommuting as a promising strategy suggesting significant and substantial economic, environmental, and social benefits through partial or complete altering of the work environment from the central office to the home or satellite center.

Estimates of telecommuting within the United States for 1995 range from six to nine million with growth rate forecasts at 18% (Jala International, 1996). Companies such as AT&T, Pacific Bell, IBM, GTE, the Walt Disney Co., Blue Cross/ Blue Shield, American Express and others are strong promoters of the telecommuting concept. Tasks suitable for telecommuting are activities wherein a person works alone, handling information such as reports, proposals, data or research. Writers, salespersons, accountants, programmers, researchers, engineers, architects, and many other professions are prime candidates for either part-time or full time telecommuting (Langhoff, 1995; Sullivan 1993a).

Telecommuting impacts are complex and have gained attention in planning, transportation, management, and sociology literature. Initial telecommuting research has predominantly been qualitative, hypothesizing a range of short-term and long-term impacts, with sparse quantitative assessments focusing on transportation impacts. Relatively fewer studies have empirically examined the behavioral and organizational impacts of telecommuting. Of the empirical studies completed, there has been criticism that methods used to evaluate impacts have not always been rigorous, and that additional studies using sound research methods are vital to understanding telecommuting impacts (Handy and Mokhtarian 1994a). More recent efforts in telecommuting research have been directed toward identifying the interaction between telecommuting adoption and the environment, and modeling the adoption process. Through such efforts factors which promote telecommuting can be identified and implemented at regional levels or within organizations as they strive to implement a telecommuting policy.

Presently public and private organizations are approaching telecommuting as an

implementable strategy, and most are likely to initiate pilot programs. These programs provide valuable opportunities to gauge the impacts of telecommuting, provided the evaluation methodologies are sound. As noted, present literature does not provide a robust, comprehensive, applicable evaluation framework; thus, it is essential to develop a framework which addresses the impact assessment needs of organizations. The presence of such a unified evaluation framework, enables organizations to identify the benefits and costs of telecommuting with relative ease. Moreover, it provides an excellent opportunity for researchers to compare and contrast telecommuting impacts over organizational and environmental differences.

1.2 RESEARCH OBJECTIVES AND APPROACH

The objectives of this work are 1) to develop a comprehensive evaluation framework for assessing telecommuting program impacts, 2) to operationalize this framework to the extent possible through construction and implementation of evaluation materials for a telecommuting pilot program, and 3) to provide a case study which gauges travel impacts of telecommuting as recognized through implementation of evaluation materials. The evaluation framework synthesizes past evaluation efforts into a set of workable modules which, when applied, have the potential to measure the range of telecommuting impacts.

The framework is operationalized through the Texas Department of Transportation (TxDOT) Telecommuting Pilot Program; however, not every evaluation module is applied due to program acceptance constraints. Although the evaluation framework is not operationalized in its entirety, it provides an opportunity to significantly contribute to the body of telecommuting work by the following three activities:

1. conducting exploratory data analysis from implemented evaluation materials,
2. modeling the executive telecommuting adoption preferences, and
3. comparing public and private sector (Yen and Mahmassani, 1994) attitudes, characteristics, and preferences that significantly influence telecommuting adoption.

The first activity provides insight into attitudes, characteristics, and policy actions that foster or hinder telecommuting adoption; whereas the third identifies differences which may be strategically valuable in promoting telecommuting within the organization (public vs. private).

The second of three activities identifies the magnitude and relative importance of specific factors to telecommuting adoption. Moreover, three different adoption model types are implemented (ordinal probit, dynamic probit, and dynamic generalized ordinal probit (DGOP)), to gauge the robustness of explanatory variables. Each model contributes information as to the nature of the adoption behavior and data. Preference models for the public sector are also

compared to a private sector preference model developed and calibrated by Yen and Mahmassani (1994).

1.3 STRUCTURE OF REPORT

This work is organized as follows. A literature review is presented in Chapter 2 of the hypothesized individual, household, organizational, and societal impacts of telecommuting. Empirical tests validating impacts are also presented. Also discussed is the state of the art in behavioral modeling of the telecommuting adoption process. Research on the employer and employee decision processes are assessed. Chapter 3 presents the evaluation framework to assess impacts discussed in Chapter 2. Sample evaluation materials associated with the framework are developed. These are discussed within the framework of telecommuting program implementation and evaluation. In this chapter, a case study of telecommuting feasibility and travel impacts is presented for illustrative purposes through the implementation of three evaluation materials. Chapter 4 summarizes the method for implementation of one of the evaluation materials developed in Chapter 3, the general characteristics of the empirical data used in this research, and results of exploratory analysis of data. This chapter also presents a comparison of results from the exploratory analysis of the present public sector empirical data to similar work by Yen and Mahmassani (1994) for private sector data. The specification and estimation of executive choice models are presented in Chapter 5. This chapter then presents a comparison of results from model specification and exploratory analysis of the present public sector empirical data to similar work by Yen and Mahmassani (1994) for private sector data. Finally, Chapter 6 concludes the report and provides direction for future research.

CHAPTER 2. LITERATURE REVIEW

2.1 OVERVIEW

The concept of telecommuting, has been discussed in transportation literature for over 30 years. Its first consideration emerged as early as 1957 from the field of automation and design by Jones (1957) who referred to the "electronic homeworker." Telecommunications substitution for travel such as telecommuting was further discussed qualitatively in transportation literature in the early 1960s on topics such as potential benefits, approaches to analyze substitutability of activities, and characterization of interactions between individual, machine, and information (Memmott, 1963). Research on telecommuting; however, was sparse prior to the energy crisis of the early 1970s. Prompted by the potential for national fuel savings, initial work focused on technology assessments and telecommunications penetration forecasts (Huws et. al., 1990). Toward the end of the 1970s, as the energy crisis subsided, research in telecommunications-travel interaction also waned. The mid 1980s proved a cross disciplinary resurgence of interest in telecommuting. This interest, which has been maintained henceforth, is attributed primarily to ever-increasing urban traffic congestion, degradation of air quality, and penetration of information technologies (Mokhtarian, 1990).

In light of the objectives of the present effort, the telecommuting literature review is conducted in two parts. The first explores the hypothesized impacts of telecommuting, and verification of hypotheses through empirical study. The second reviews literature in the area of adoption, assessing the state of the art in behavioral models of telecommuting adoption. These two sections form the groundwork for the evaluation framework and modeling approach formulated in Chapters 3 and 5 respectively.

2.2 REVIEW OF TELECOMMUTING IMPACTS

Examining and understanding the range of potential telecommuting impacts is essential to the formulation of the evaluation framework; thus, the present section discusses impacts as suggested by literature. Empirical work in the form of surveys, case studies, and experiments is also reviewed. The effects of telecommuting are categorized and discussed below by individual, organizational, and societal impacts, and are further identified by time frame and penetration.

2.2.1 Impacts of Adoption on Individuals (and Households)

Of the impacts associated with telecommuting, those related to individuals and their households are recognized as the most complex and of greatest importance to the success of

telecommuting. On the positive side, telecommuting can reduce or eliminate the commute time, cost and stress; decrease clothing and food costs; eliminate distractions from the office; increase schedule flexibility and autonomy; improve job satisfaction and bonds with family; and provide for a more comfortable work environment. Possible disadvantages incurred from telecommuting include professional and social isolation; decreased professional visibility and credibility; loss of office support services; reduction in work benefits; increased home utility and telephone costs; difficulty in separation of work and home; home distractions; and family conflicts (Huws et. al., 1990; Cross and Raizman, 1986; SCAG, 1985).

Telecommuting requires a certain adaptation of household roles and activities. Interactions that would previously have been carried out after work hours are now continuously available to household members. Household members may initially be uncertain as to telecommuters' accessibility during 'work' hours and non-work hours when the telecommuter is working from the home. Over the long term these accessibility and role issues will dictate the success of telecommuting for the individual. No research beyond anecdotal information documents the psychological or structural impacts of telecommuting on the household. Investigation of telecommuting impacts on household and telecommuter travel behavior have been conducted; these are discussed in the "societal impacts" section.

Surveys and case studies do effectively illustrate the multidimensional impacts of telecommuting on the individual. To test specified hypotheses regarding the effects of telecommuting, Ramsower (1983) implemented pre- and post-telecommuting interviews and questionnaires to full and part time telecommuters (16 participants) and a control group (14 participants). Full time telecommuters experienced significantly different impacts. Analyses related to individual impacts indicate full time telecommuters experienced a greater decrease in work group identification and job satisfaction (Ramsower, 1983) than those telecommuting part time. In a 1994 survey, reported by Bredin (1996), 50 Hughes employees participating in a part time telecommuting pilot program indicated an overall improvement in telecommuters' autonomy and personal life. Sixteen percent of the respondents found maintaining ties with co-workers problematic while telecommuting. Only five percent found telecommuting to reduce their professional visibility. None found distractions at home to adversely affect their experience (Bredin, 1996).

A more comprehensive effort in 1994 conducted a pre- and post-telecommuting questionnaire in Smart Valley, California. Survey respondents telecommuted on average 2.3 days per week. They experienced a significant increase in satisfaction related to commuting time and expenses, quality of personal life, quality of work life, and ability to manage dependent care. When asked to

rate telecommuting related concerns from one (not at all significant) to five (extremely significant), respondents showed greatest concern over career advancement opportunities (2.8) and recognition by managers and peers (2.7). Telecommuters reported an overall telecommuting satisfaction score of 4.4 from a range of one (not at all satisfied) to five (extremely satisfied) (Smart Valley, Inc., 1994).

The variance in individual impact realization has been attributed to several situational factors. These factors include telecommuting form and frequency, adoption motivation and work type, individual personality, and gender (Huws et. al., 1990). Each of these factors are discussed in turn below.

2.2.1.1 Telecommuting Form and Frequency: Characterized by location and proprietorship, telecommuting forms include the home, neighborhood center, regional center, satellite center, and local center (Nilles 1988). The latter four share significant benefits over home based telecommuting by providing telecommuters interaction opportunities, distinction between work and home, and access to equipment not available at home. Conversely, non-home based telecommuting requires some form of physical commuting, reduces autonomy, and can reintroduce office related distractions (Huws, et. al., 1990; Healy, 1968).

The importance of telecommuting frequency and individual personality to telecommuters' experienced impacts is straight forward. Part-time telecommuting eliminates or significantly reduces professional and social related disbenefits; however, such a telecommuting scenario partially reintroduces the disbenefits associated with physical commuting and office distractions.

2.2.1.2 Adoption Motivation and Work Type: Adoption motivation and work type influence the psychological impacts experienced by telecommuting. Olson (1987), in the context of full time telecommuting, identifies four adoption scenario types: exploitation, autonomy, tradeoff, and privilege. 'Exploitation' refers to low-skilled clerical workers that are forced to telecommute at lower salaries and/or benefits due to economic and family constraints. The 'autonomy' scenario is that of the entrepreneur who has a need to be independent and prefers self-employment. 'Tradeoff' describes the professional worker who chooses to telecommute based on personal circumstances, and more on a temporary basis. 'Elite' refers to employees with bargaining power to dictate their own working conditions because their skills are unique. Those in the elite, trade-off or autonomy group telecommute because they recognize benefits from telecommuting, whereas disbenefits are more prevalent with the exploitation group who are forced to telecommute (Olson, 1989; Gregory, 1985).

2.2.1.3 Individual Personality: Literature has recognized the relevancy of individual personality in realization of specific telecommuting impacts. Characteristics such as discipline, independence, self-sufficiency, and organization, or lack there of, influences the extent of work related stress, home distractions, family conflicts, and social isolation (Huws et. al., 1990; Cross and Raizman, 1986).

2.2.1.4 Gender: Telecommuting impacts are suggested to differ for male and female telecommuters for two major reasons. In general, female household and dependent care responsibilities are greater than male responsibilities; thus females would find the home a more stressful environment (Huws et. al., 1990; Christensen, 1987; Gregory, 1985; Vedel and Gunnarsson, 1985). Furthermore, reflecting occupational segregation, females, more than males, are likely to conduct routine/repetitive tasks providing less job satisfaction and social interaction (Chamot and Zalusky, 1985; Gregory, 1985). These reasons, translated to the context of adoption scenarios, suggest exploitation and tradeoff telecommuters are more likely to experience disbenefits associated with telecommuting whereas the autonomous and elite telecommuters are more likely to experience benefits associated with telecommuting.

2.2.2 Impacts of Telecommuting on Organizations

Telecommuting impacts organizations in two aspects: economic and structural. Economic impacts have been explored thoroughly in literature; however, empirical work on specific financial costs and benefits has been slow and cautiously reported. Impacts of telecommuting on organizational structure are qualitatively addressed in literature and confirmed to some extent by empirical work. These impacts refer to the communications, management, and spatial evolution of organizations due to telecommuting. Each of these aspects of telecommuting impacts on the organization are explored in greater detail below.

2.2.2.1 Economic Impacts of Telecommuting on Organizations: Financial benefits of telecommuting are realized from savings on office overhead costs, access to expanded labor pools, lower rate of staff turnover, increased telecommuter productivity, reduced telecommuter absenteeism, and compliance with air quality legislation (Gray et. al, 1993, Edwards and Edwards, 1990; Gordon and Kelly, 1986; Rifkin, 1983). Given a significant number and frequency of telecommuting employees, office overhead savings can be recognized through reduced janitorial, parking, water, space, furniture and power expenses.

Of the range of organizational benefits, those related to productivity and office space savings have been reported and quantified most in literature. Telecommuting has decreased office space

requirements by 33% in one organization while its staff had increased by 22% (Commission Appeals Department, 1995). A rigorous cost/benefit analysis by AT&T of 600 telecommuters in their North Central New Jersey Alternative Officing program showed annual real estate savings of $6.33 million. This was achieved by closing an entire office complex (North Bay Council, 1995).

Studies show that on average telecommuting employee productivity increases from 10% to 20% in the long run (Miller, 1986). The AT&T study suggested an annual gain of $8.2 million from productivity hours and efficiency increases (North Bay Council, 1995). Many organizations have found productivity of telecommuters to increase as much as 50% (Deloitte & Touche Study, 1991). Moreover with a flexible telecommuting agreement individuals can arrange their schedule to reduce absenteeism due to family requirements or health needs. This flexibility has also been shown to increase job satisfaction and thereby improve the organization's employee retention (Huws et. al., 1990; Geisler, 1985; Manning, 1985).

Financial expenses associated with telecommuting are attributed to start-up and continuing communications (Gray et. al., 1993; Huws et. al. 1990). Start-up costs can include feasibility studies, training programs for the telecommuters and managers, data security safety measures, equipment needs, and legal issues. Feasibility study and training program costs depend on the size and complexity of the program as well as the presence of outside consultants. Data security costs may require the installation of safety procedures and software. Equipment costs account for items such as a computer, telephone, fax machine, printer, and data transmission link and can range from a few dollars to a few thousand dollars per telecommuter depending on the individual's task requirements and cost sharing scenario. Communications cost can be on-going and include items such as phone, Internet or e-mail charges. Legal costs may arise in insuring the alternate work area and developing telecommuter contracts (Gray et. al., 1993; Huws et. al., 1990; Gordon and Kelly, 1986). As telecommuting costs are organization and program dependent, quantification of costs are sparsely reported in literature. The AT&T program average cost per employee was $3,000 for office alteration costs, $4,000 for equipment costs, and $1250 for phone, fax, copy, and postage bill per year.

2.2.2.2 Structural Impacts of Telecommuting on Organizations: Telecommuting impacts the communication structure of organizations at the base level – between managers, telecommuters, and co-workers. Telecommuter interaction shifts to some extent from face-to-face contacts to other forms such as postal services, phone calls or e-mail (Gordon and Kelly, 1986). Moreover, a slight restructuring of job tasks between telecommuters and co-workers may occur to accommodate telecommuting (Gordon and Kelly, 1986). The work structure may also

shift from team-based to individual oriented. To maintain a successful telecommuting policy, the organization's management style also makes a transition from evaluation by presence to evaluation by results. Management and employee trust must be maintained through non-visual verification (Gray et. Al, 1993; Gordon and Kelly, 1986; Raney, 1985). As telecommuting is adopted at greater levels within an organization, its structure in terms of office size and locations as well as activity/business task patterns may change over a longer time frame (Huws et. al., 1990). This type of impact has been presented in the literature on an individual case basis (Shirley, 1985).

2.2.3 Societal Impacts

Society, through significant penetration of telecommuting over a longer span of time, may recognize benefits in areas of travel, energy consumption, and the environment. These benefits emerge through the aggregation of individual and household changes in travel behavior as well as spatial changes in organizations and households. Over the longer time horizon, changes in planning and land use may also arise from telecommuting. Depending on the form of land-use reorganization, the impact of telecommuting on travel, energy, and the environment may change significantly. These societal changes as suggested in literature are discussed below.

2.2.3.1 Transportation Impacts of Telecommuting: When telecommuting, an individual's work-related constraints such as the commute to and from work and a fixed lunch hour are eliminated. With this flexibility individuals and their household may change travel behavior to best accommodate activity needs (Garrison and Deakin, 1988; Kitamura et. al., 1990a, Mokhtarian, 1991). At the elemental level, telecommuting can eliminate or significantly reduce the work trip. The aggregate reduction in work trips can reduce peak period traffic and vehicle miles traveled (VMT). However, this reduction may not be as significant if the mode of travel was car or van pooling, or public transit (Mokhtarian, 1991). Moreover, in the presence of telecommuting, efficient linked activities performed during the work trip may be split into several one-stop trips causing greater vehicle miles traveled and peak hour travel (Kitamura et. al., 1990; Mokhtarian, 1991). The availability of the telecommuter's vehicle to other household members during telecommuting days can also contribute to increases in household travel.

Researchers have hypothesized both positive and negative impacts of telecommuting on transportation infrastructure and efficiency; however, studies to date have shown that telecommuting reduces peak hour travel and off-peak travel of telecommuters and their households. Pendyala et al. (1991) administered two-wave pre- and post-telecommuting three day panel travel diaries and found that telecommuters significantly reduce their total number of

trips and VMT. Telecommuters reduced peak period trips by 60%, reduced total distance traveled by 75%, and freeway miles by 90% on telecommuting days. Another study of 15 telecommuters by Hirita and Uchida (1990) found trips to the downtown region reduced by 76% for telecommuters. In Irving Texas a survey of 69 individuals prior to and after telecommuting showed that morning and evening peak commuter trips on telecommuting days decreased 88%. VMT during both peaks on telecommuting days decreased by 91% (DBR & Associates, 1993). A telecommuting study in the Netherlands conducted surveys before telecommuting and multiple surveys after telecommuting. The multiple surveys showed that the initial decrease in telecommuters' trips and VMT is not maintained over a longer time frame. The study found that, on average, when 20% of the employees' time was spent telecommuting the total number of telecommuter trips decreased by 17% and the number of peak hour car trips decreased by 26%. Trips by household members were reduced by 9% (Hamer et. al., 1991).

These results are promising; however, they have three weaknesses: small sample sizes, the possibility of respondent travel behavior being influenced by surveying, and under reporting of "after" telecommuting trips attributed to respondent fatigue (Handy and Mokhtarian, 1994b; Hamer et. al. 1991; Pendyala et. al., 1991). Nonetheless, they affirm that telecommuting can be an effective strategy reducing peak hour congestion and total vehicle miles traveled.

2.2.3.2 Energy Consumption Impacts of Telecommuting: Direct energy savings are realized through the reduction in fuel consumption via decreases in total miles traveled by telecommuters and household members. Sullivan (1993a) discusses the direct as well as indirect benefit of telecommuting on energy. Sullivan developed a model to estimate potential fuel savings under different levels of telecommuting activity for the cities of Austin, Houston, and Dallas. He suggests an indirect benefit is derived only during average peak traffic flows that approach or exceed capacity when the removal of telecommuter vehicles increases average speeds up to 40 miles per hour.

Telecommuting can increase the home consumption of energy through heating/cooling of the home environment, computer and lighting use, and other appliances; however, empirical work has not confirmed this hypothesis (Edwards and Edwards, 1990; Huws et. al., 1990). Similarly telecommuting has been suggested to decrease office energy requirements; but again confirmation of this hypothesis was not found in the literature. Thus the net impact of telecommuting on energy consumption through home and office use is yet to be explored.

2.2.3.3 Environmental Impacts of Telecommuting: The environmental benefit of telecommuting is recognized through the altering of telecommuter and household travel behavior. Henderson (1996) shows that telecommuting, through a reduction in the number of daily trips, travel miles, and cold auto starts, decreases pollutants emission on telecommuting days by 50 to 60%. In a Texas telecommuting program (DBR & Associates, 1993) with 69 participants' annual reductions in hydrocarbons, carbon monoxide, and nitrogen oxides are estimated at 8.0 tons, 49.2 tons, and 5.1 tons respectively.

2.2.3.4 Land Use and Planning Impacts: Telecommuting, over a long time horizon and adequate penetration, may contribute to further suburbanization and urban sprawl by releasing households from locational constraints related to maximum acceptable commute time and distance (Mokhtarian, 1991b). Because telecommuting is such a relatively new activity, no studies have been able to confirm or deny this hypothesis (Handy,1994). If this indeed occurs, the environmental costs of further sprawl could far outweigh benefits recognized by reduced automobile and office use. The study of approximately 250 California state employees found that telecommuters reduced the spatial extension of their daily activities when compared to non-telecommuters. This contraction of action space took place on both telecommuting and regular commuting days (Pendyala, 1991). Thus, increases in telecommuting may lead to more activity near the home, which would have a centralizing effect on household location. It is difficult to estimate with accuracy the likelihood of either scenario because of the relatively brief penetration history and existence of multiple factors contributing to housing location decisions.

2.3 REVIEW OF TELECOMMUTING ADOPTION MODELING

Early work on the employer's telecommuting adoption process has been largely qualitative, examining the motivations and deterrents to adoption, and on executives' attitudes toward telecommuting (e.g. Edwards and Edwards 1985; Gordon, 1988; Nilles, 1988). These motivations and deterrents are the impacts presented in the section "Impacts of Telecommuting on Organizations." The qualitative discussion on the adoption process of organizations has taken new directions through the development of adoption frameworks and consequent operationalization through probabilistic behavioral models.

Sullivan et al. (1993b) developed the first comprehensive analytical framework of the adoption process wherein the environment (land use, telecommunications technologies, etc.), managerial characteristics, organizational characteristics, job characteristics, and situational constraints affect the company's choice to provide telecommuting. The employee's choice to telecommute is

constrained by the company's decision to make a program available. The authors administered a survey which captured employee's travel, work, and socio-economic characteristics, and stated preferences toward telecommuting. The respondents' preferences to home telecommuting are related to their characteristics through a multinomial logit model. Bernardino et al. (1993) presented a similar analytical framework and an ordinal probit model for the employee adoption process wherein the authors discussed the employer offering decision as necessary and a function of organizational characteristics, organizational structure, and mangers' attitudes and perceptions toward telecommuting. These works made significant advances in modeling the employee adoption choice; however, they did not perform any quantitative assessments or modeling of the employer adoption choice.

Mokhtarian and Salomon (1994) presented a conceptual framework for explaining the choice of employee telecommuting making a distinction between factors or drives motivating telecommuting adoption and binding constraints to the adoption choice. Only when the constraints are not binding do individuals have the choice to telecommute. In a second work (1996a) these authors test the role of constraints and make a distinction between telecommuting preference models and choice models. This work found that 88% of the respondents would prefer to telecommute; however only 13% do telecommute, indicating the significance of constraints. A third paper by Mokhtarian and Salomon (1996b) applies a binary logit model to the choice of telecommuting adoption and demonstrated the importance of attitudinal measures over socio-demographic characteristics. Although these works concentrate on the employee adoption process, the concept of constraints and the importance of attitudinal factors are equally applicable to the employer's adoption choice and provides new directions of research in modeling employer telecommuting adoption.

Yen and Mahmassani (1994) presented a comprehensive adoption framework of employers and employees, and developed the first employer adoption model. The adoption framework identifies external factors (telecommunications technologies, public policies, transportation system performance, and land use pattern) and primary actors in the adoption process. Specific to the employer adoption process, this framework recognizes differences among organizations by size of decision group and decision mechanism, and identifies five categories of factors to influence employers' adoption choice (indifferent to the decision group and mechanism). These categories include executive characteristics, perceptions and attitudes toward telecommuting, organizational characteristics, type of business, and situational constraints.

Based on this framework, Yen and Mahmassani (1994) designed and distributed 397 questionnaires to executives within 68 Texas-based private organizations through company

personnel officers. Eighty three executives from 31 organizations responded. Questionnaires elicited information on executive and organizational characteristics, executive's attitudes toward telecommuting, stated preferences on the willingness to support a telecommuting program, and executive's socio-economic characteristics. Executive's stated preferences for telecommuting under nine scenarios are obtained and used to empirically estimate a model of employer support for home based telecommuting. Each scenario presents a home-based telecommuting program with differing telecommuter salary (+5%, same, -5%), and company coverage of program costs (none, some, all).

Yen and Mahmassani developed the dynamic generalized ordinal probit (DGOP) model which captures stochastic features of utility thresholds, and correlation among responses from each individual. The sample size used in calibration of the DGOP model is somewhat small, and restricted to private sector enterprises. The DGOP model is presented in Chapter 5. Model estimation results suggest that employers are not likely to support telecommuting programs which increase or decrease employee salaries. Moreover, estimation results confirmed that executive support of telecommuting is influenced by personal characteristics, attitudes toward telecommuting, and organizational characteristic.

Bernardino (1995) developed an employer adoption modeling framework consisting of two sequential decisions: the program design decision and the program offering decision. The author assumes that the employer's objective is to maximize profit. The employer first selects from a set of telecommuting programs the one program which maximizes profit. Program characteristics include minimum and maximum telecommuting days per week, telecommuting schedule flexibility, office/desk sharing, salary changes for telecommuters, distribution of telecommuting expenses between employer and employee, telecommuting location (home versus telework center), and equipment requirements. Upon the program design choice, the employer compares the telecommuting program productivity and cost impacts with those of the currently available arrangement and decides whether to offer telecommuting to employees. Based on this framework, Bernardino designed and distributed a survey to a convenience sample of 120 organizations in a range of industries with characteristics favorable to telecommuting implementation. Eighty executives from 28 organization responded.

The program selection decision of these executives is modeled by a structural and measurement model with random disturbances independently and identically gumbell distributed. Model explanatory variables include program and organization characteristics, and results suggest program preference is affected by organization size (small versus large) and work structure (individual versus team). Moreover, employers are more likely to select programs

wherein they provide necessary equipment, pay phone bills, maintain employee salary, and are liable for employee property and safety. These results seem counterintuitive as all these attributes tend to increase corporate costs.

The program offering decision is modeled as a combination of a discrete (logit) choice model and latent variable models with continuous and discrete ordered categorical latent variables. Model explanatory variables include productivity and cost change as compared with currently available arrangement, organizational experience with telecommuting, employee interest, and other characteristics. Coefficient estimates of the change in productivity and cost, however, are significant only at the 10% and 20% respectively.

Research in employer telecommuting adoption in terms of an adoption framework and probabilistic behavioral modeling is limited to the two works discussed above. Both Yen and Mahmassani (1994) and Bernardino (1995) present mathematically sound adoption models. Bernardino assumes in the analytical framework that the telecommuting program selection decision occurs prior to the offering decision; however, these decisions may occur simultaneously or the offering decision may be made first. The decision order was not assessed for appropriateness; hence the analytical framework and modeling results are questionable.

In light of the limited research in modeling the employer adoption process, and the importance of such models in identifying policies that encourage telecommuting as well as in providing a foundation for predicting telecommuting penetration, the need for additional in-depth work is clear. The adoption framework developed by Yen and Mahmassani provides a strong base for further work. The ordinal employee adoption model proposed by Bernardino (1993) can also be used in employer modeling, but will not capture correlation in the data set.

2.4 SUMMARY

A review of telecommuting impacts and adoption models has been performed in this chapter. The impacts identified in this review are addressed in the evaluation framework of Chapter 3. The review of adoption models provides the basis on which the preference models are selected for this research. Of the models reviewed, the ordinal probit and DGOP will be employed in Chapter 5.

CHAPTER 3. TELECOMMUTING EVALUATION FRAMEWORK AND IMPLEMENTATION

3.1 INTRODUCTION

Telecommuting program evaluation is essential for adequate understanding and prediction of individual, organizational, and social impacts at microscopic and macroscopic levels. Chapter 2 identified hypothesized impacts over a time horizon and adoption penetration. In certain cases empirical work has supported hypotheses suggested in literature. Research is required, specifically in the development of a framework which can validate these hypotheses. This chapter presents a comprehensive evaluation framework which can be implemented to assess various telecommuting impacts.

Because the impacts of a telecommuting program are influenced by the strategies followed in its development and implementation strategies, this chapter first discusses telecommuting program planning and implementation. The role of the evaluation framework in the program start-up process is briefly introduced. The evaluation framework, which provides a systematic basis for program evaluation, is then presented in detail as a concurrent component to the planning and implementation phases. Evaluation processes and materials are also formulated and explained in detail. The final section presents the application of the proposed evaluation framework in the context of a telecommuting pilot program through the implementation of four evaluation materials. The content and analyses of three of these four evaluation materials are included in this chapter: the telecommuter survey, the supervisor survey, and the travel log. The content and analyses of the fourth element, the executive survey, is presented in the following two chapters.

3.2 TELECOMMUTING PROGRAM PLANNING AND IMPLEMENTATION

Considerable flexibility exists in the design and implementation of a telecommuting program; however, companies that have established successful programs tend to follow a similar set of processes for program planning and implementation (see for example Corrigan et. al., 1996; Pacific Bell, 1996; Baird, 1995; North Bay Council,1995; DBR & Associates, 1993). A core set of activities is essential to program success; however, the order may vary and other tasks may be added. These activities are presented in Figure 3.1 under three stages: planning the prototype; implementation; and monitoring, reporting and final roll-out (North Bay Council, 1995).

In the planning stage a task force, composed of individuals from key departments such as human resources and information services, identifies corporate needs, and assesses how telecommuting can be implemented to meet such needs (e.g. office space shortages, vehicle trip

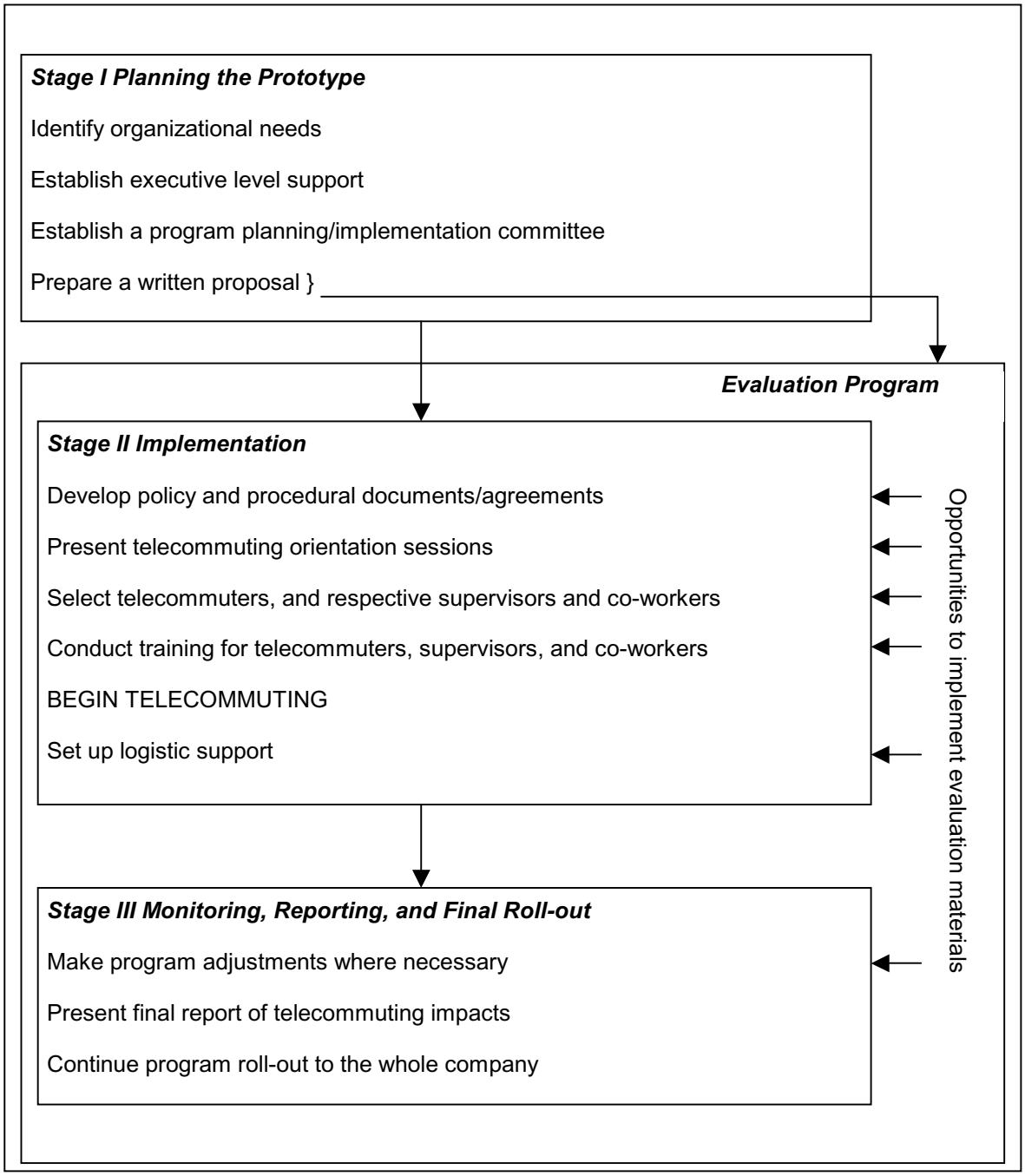

Figure 3.1 Telecommuting program setup process.

reductions, or employee retention) (Pacific Bell, 1996). The telecommuting program may not continue, or subordinates may be reluctant to participate in the absence of executive support; thus, establishing executive support is essential.

Various departments within the organization will play key roles in the planning and implementation process. These include, but are not limited to, the human resource/personnel, information systems, legal, purchasing, labor relations, security, tax, training, support services, transportation, and public relations departments. With more formalized, larger programs, an internal team or an external consultant group may also be required to perform the program evaluation.

Formal telecommuting programs are more likely to succeed than ad-hoc arrangements even for employers with few telecommuting employees (Corrigan et. al., 1996; Pacific Bell, 1996; Baird, 1995). The telecommuting policy, procedural documents, and agreements are the mechanisms for formalizing the program and ensuring that telecommuting is smooth-running. They provide the organization with clear, consistent guidelines on topics such as telecommuter selection criteria, course of action for home-located occupational injuries, equipment purchasing and maintenance responsibility, equipment damage or loss liability, child care arrangement, confidentiality issues, communications issues, work and overtime concerns, training and evaluation requirements for telecommuter and supervisors, grounds for telecommuting termination, and task performance agreements.

Orientation sessions and training seminars ensure that all parties affected by telecommuting are aware of required changes in work behavior and evaluation. The selection processes screen for feasibility of job tasks, and suitability of individual and supervisor characteristics. These processes, when executed appropriately, will promote positive impacts for the telecommuter, supervisor, and the organization. Logistic support upon the initiation of the telecommuting program also affects the realization of specific telecommuter impacts (Nilles, 1994; Baird, 1995).

The success of telecommuting cannot be gauged without a robust evaluation program. In accordance with the needs of the organizations, impact measures should be defined and criteria established to assess the program success. Both general progress and individual participation should be monitored. Based on evaluation results, the program can then be fine-tuned by adjusting such factors as shared office locations, or employee selection criteria. The following section presents the telecommuting program evaluation framework in terms of time frames, evaluation instruments, and measurement groups.

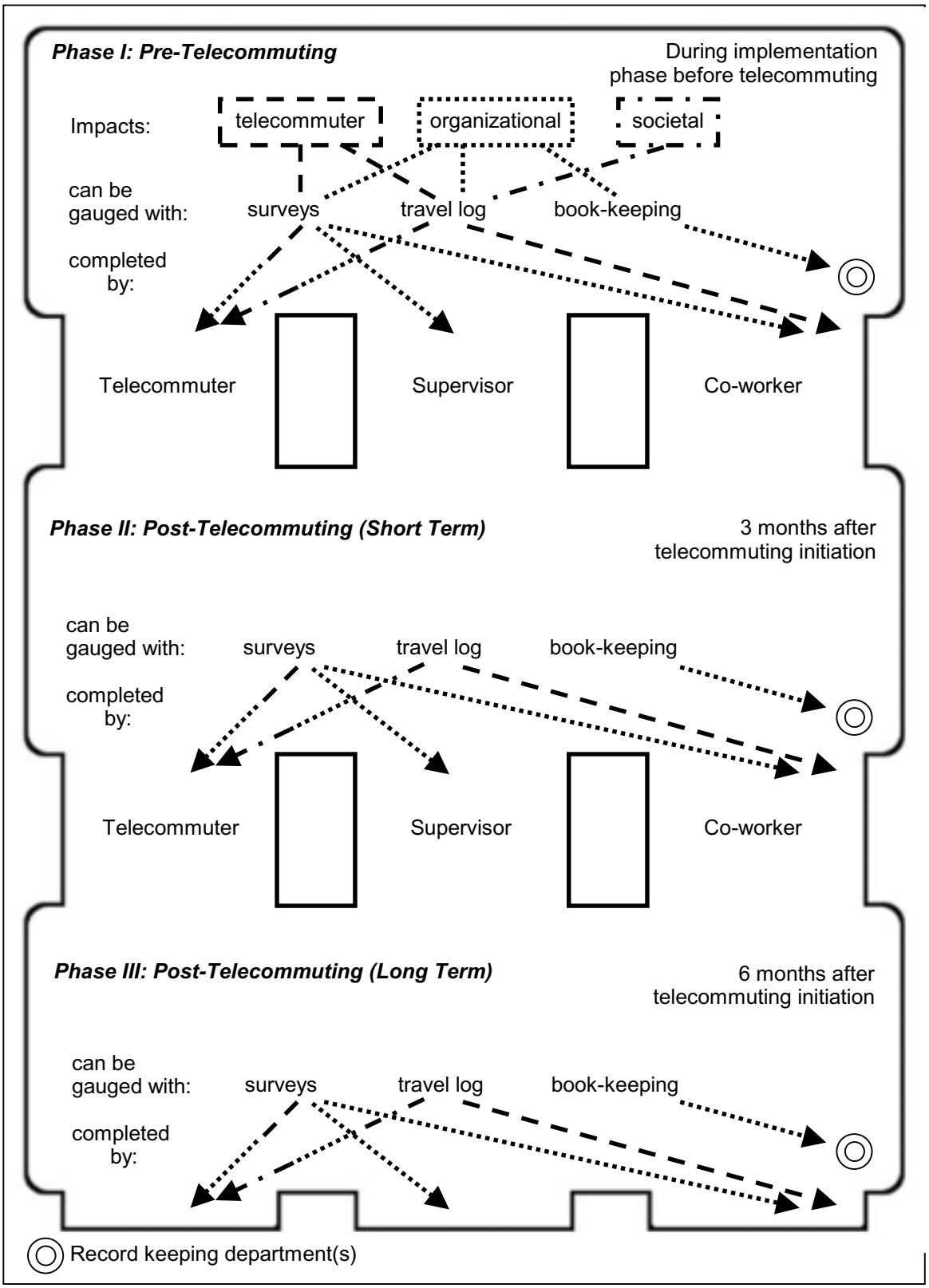

Figure 3.2 Telecommuting evaluation framework

3.3 EVALUATION FRAMEWORK

As discussed in Chapter 2, telecommuting impacts can be classified into three categories: telecommuter and household, organizational, and societal impacts. Impacts are user, program, environment, and time dependent and can be gauged through evaluation processes such as surveys, travel logs, interviews, and other forms of record keeping. Evaluation processes can be conducted more efficiently when performed in conjunction with program implementation. The framework presented in Figure 3.2 depicts these evaluation processes by time reference, party affected, and impact category. Moreover, it connects with the core set of program activities presented in Section 3.2 in terms of administration of evaluation materials.

Four elements are essential for a comprehensive evaluation: the telecommuter and his/her household, his/her corresponding supervisor, his/her co-workers, and keeping departments. Household participation enables changes in travel behavior and household dynamics to be examined. To adequately evaluate impacts such as productivity, individual effects, or job satisfaction, surveys of telecommuters and their supervisors are necessary. Participation of co-workers (who do not telecommute) is important, particularly to capture overall changes in office characteristics or dynamics. Co-workers also serve as a control group enabling distinctions to be made between impacts attributed to telecommuting as opposed to other factors. Various departments also may be required to complete information sheets to assess cost-related impacts. Such departments may include purchasing, for equipment costs, personnel, for absenteeism records, and others as necessary.

In addition to the above elements, three measurement phases are suggested within the evaluation framework. Phase I establishes base characteristics of the organization and program participants through executive, supervisor, telecommuter, and co-worker surveys as well as travel logs completed by the latter two and the telecommuter household. Phase II gauges short term, transitional impacts of telecommuting, while Phase III captures long-term, stabilized telecommuting impacts. Task structures in each phase are further explained below.

Within the first phase, the executive survey is suggested as a tool to elicit general interest in and organizational suitability for telecommuting. Executive survey administration can be performed concurrently with telecommuting orientation sessions. This survey can also be used as a tool to identify potential participants as perceived and supported by executives. A sample form of this survey is presented in Appendix A.. The complete description and analyses of the executive survey instrument are presented in Chapters 4 and 5.

Once individuals with interest in telecommuting are identified, the supervisor and telecommuter surveys can be implemented as a screening tool to identify participants, and as a

means of identifying co-worker counterparts. In addition, these surveys serve as a measurement tool for establishing base characteristics, identifying telecommuting form and frequency, and documenting equipment needs. This task should be performed prior to or concurrently with training sessions. The sample telecommuter form is presented in Appendix B, and the sample supervisor form is presented in Appendix C. Each is briefly discussed in Sections 3.4.2 and 3.4.3 as relevant to the evaluation processes. Addition description and analysis of these surveys are presented in Sections 3.5.1 and 3.5.2.

Training sessions may be started once telecommuters, supervisors, and co-workers are selected. Sessions may be used as a means of implementing the co-worker survey and administering telecommuter/household and co-worker travel logs. Travel logs document base information on the travel behavior of telecommuters, their households, and co-workers. Co-worker base travel logs are compared with Phase II and Phase III travel logs to capture seasonal changes in travel behavior. A sample travel log is presented in Figure 3.3. The co-worker survey content is discussed but the actual form is not developed.

Approximately three and six months after program participants have begun telecommuting, evaluation Phase II and Phase III, respectively, may be implemented. Three months is suggested as an adequate time for initial adjustments to the telecommuting policy by all parties. Six months is suggested as an adequate time for stabilization of changes attributed to telecommuting. A fourth phase approximately one year after telecommuting, although not critical, may provide insight into longer term impacts of telecommuting as related to land use. As evaluation materials administered during this phase are equivalent to those in Phase I with the exclusion of the executive survey, sample survey instruments are not specifically developed.

In administering each phase, the organization must recognize the importance of respondent fatigue and should attempt to make surveys as concise and clear as possible. The following section presents means of capturing various impacts in terms of quantities/items to be gauged and sample questions. References are made to evaluation materials which capture specific telecommuter, organizational, and societal impacts. These materials, presented in Appendices A through C, can be modified according to organizational evaluation needs.

TODAY'S DATE: _____

TODAY I AM:
- ☐ Working at main office
- ☐ Home telecommuting
- ☐ Satellite telecommuting
- ☐ Attending School
- ☐ Not working
- ☐ Other _____

TRIP ORIGIN: ☐ Home ☐ Work ☐ School ☐ Other _____

DESTINATION: ☐ Home ☐ Work ☐ School ☐ Other _____

TRIP PURPOSE: _____

PASSENGERS ON TRIP: _____ *(Report only if you are driving; do not include self)*

BEGINNING TRIP TIME

☐☐:☐☐ ☐ am ☐ pm

TRANSPORTATION MODE
- ☐ Personal Vehicle # _____
- ☐ Mass transit
- ☐ Car/vanpool driver
- ☐ Passenger: ☐ household driver ☐ car/vanpool ☐ Other
- ☐ Walk/bicycle
- ☐ Other _____

BEGINNING ODOMETER:
(personal vehicle use only)

☐☐☐☐☐.☐

ENDING ODOMETER:
(personal vehicle use only)

☐☐☐☐☐.☐

ENDING TRIP TIME

☐☐:☐☐ ☐ am ☐ pm

SIDE TRIP INFORMATION

STOP 1	Purpose _____
Arrival time:	☐☐:☐☐
Odometer:	☐☐☐☐☐.☐
Departure time:	☐☐:☐☐

STOP 2	Purpose _____
Arrival time:	☐☐:☐☐
Odometer:	☐☐☐☐☐.☐
Departure time:	☐☐:☐☐

STOP 3	Purpose _____
Arrival time:	☐☐:☐☐
Odometer:	☐☐☐☐☐.☐
Departure time:	☐☐:☐☐

*A side trip is any trip which requires a stop of less than one hour and is made enroute to your destination. Remember to record all side trips made during your travel.

Please write any comments/notes in the following space:

Figure 3.3 Travel log.

3.4 EVALUATION PROCESSES AND MATERIALS

This section presents the means by which telecommuting impacts may be measured. Societal impacts as gauged through the travel log are addressed first. It must be recognized that not all societal impacts can be gauged through survey instruments within the time frame specified by the evaluation framework. Evaluation of impacts as derived from changes in travel behavior is addressed in Section 3.4.1. Telecommuter and household impacts can be derived from the travel log and telecommuter surveys and are discussed second. Evaluation of organizational impact is addressed last as surveying of multiple groups is required to capture these impacts.

Measurement instruments developed within this research include the executive survey, the supervisor survey, the telecommuter survey, and the travel log all of which may be implemented during Phase I of the evaluation process. Each of these is discussed within the context of the evaluation process. Although survey instruments for Phases II and III of the evaluation process are not developed, the principal elements that should be included are discussed.

3.4.1 Evaluation of Societal Impacts

Societal impacts of telecommuting, as discussed in Section 2.2.3 are categorized by land use, transportation, energy consumption, and environmental related impacts. Land use impacts such as urban sprawl or neighborhood cohesiveness are difficult to assess without longer time assessments and will affect the net change in the latter three categories. The impacts addressed in this section can be considered as “first order” impacts derived directly from changes in the travel behavior of telecommuters and their households. These may be gauged through the travel log presented in Figure 3.3. Second order impacts refer to changes in transportation, energy consumption, and environmental states resulting from land use pattern changes.

It is suggested that the selected co-worker, the telecommuter, and each member of the telecommuter’s household with a license to drive complete an individual travel log for a consecutive seven-day period during each of the three evaluation phases discussed in Section 3.3. Because changes in telecommuter travel behavior may be attributed to factors other than telecommuting(for example-seasonal or regional transportation infrastructure changes), travel logs completed by the co-worker can serve as a statistical control. Previous telecommuter travel logs have taken place over a fewer number of days (e.g. Hamer et. al. 1991; Kitamura, et. al., 1990); however, these cannot capture shifts in discretionary trips between weekday to weekend, nor can they adequately observe adjustments in travel behavior and activity patterns. Furthermore, one week appears a natural period within which trips shifts associated with telecommuting may occur. For these reasons, the present framework suggests a one-week

period for travel log completion.

Individuals should record every trip made during the seven-day period as well as associated trip characteristics. Characteristics include trip origin, destination, and purpose; beginning and ending time for each trip; transportation mode used, number of passengers if driving, beginning and ending odometer reading if a personal vehicle is used; and side trip information such as arrival and departure time, and odometer reading. Recorded at the start of the travel log are vehicle ownership data such as number of household vehicles, vehicle make and model, and primary users of each vehicle. All of the above information, when obtained from both Phases I and II of the evaluation, provides data which can then be used to evaluate short-term societal impacts. Phase III travel log implementation is suggested to confirm the findings from Phases I and II, and to capture long-term changes.

A household, telecommuter, or co-worker's change in total vehicle-miles traveled (VMT) can be computed by Equation 3.1. Individual changes may be summed to derive an aggregate decrease or increase in VMT of the telecommuter, household, and co-worker for the sample set. Inferences to population impacts should account for differences between the sample set and the population in terms of commute distances, household size and vehicle ownership, and other related factors. Telecommuting frequency and type (home based versus satellite station) should also be considered when making inferences to the population.

$$\text{change in VMT} = \left(\begin{array}{l} \left[\sum_{\substack{\text{before telecommuting all trips}}} (\text{ending odometer reading} - \text{beginning odometer reading}) \right] \\ - \left[\sum_{\substack{\text{before telecommuting all trips}}} (\text{ending odometer reading} - \text{beginning odometer reading}) \right] \end{array} \right) \qquad 3.1$$

Direct energy consumption savings for the program sample can be calculated by multiplying the VMT by an average fuel consumption rate (gallons/mile). Indirect impacts on energy consumption due to telecommuting (e.g. lighting or heating at home that wouldn't be other wise used) cannot be gauged by the travel log and would require survey information such as pre- and post-telecommuting monthly home heating/electricity bills. These, however, would require adjustments for seasonal energy use patterns.

As trip timing information is recorded, reductions in peak hour travel can be measured by counting the total number of trips made during peak hour before and after telecommuting. Changes in trip chaining behavior such as the length and number of trip chains can also be calculated from a comparison of pre- and post-telecommuting data. Furthermore, the impact of

telecommuting on carpooling or use of transit can be assessed by comparing the travel logs before and after telecommuting. In the absence of travel logs, these factors can also be obtained by the telecommuter survey. Questions 12 to 18 of Section I of the telecommuter survey presented in Appendix B addresses factors such as commute time, trip chaining, and commute mode.

From the travel log data, vehicle emissions reduction can be estimated using more or less elaborate emissions models with varying degrees of accuracy (see e. g. Henderson et. al., 1996). In general the percentage change in emissions is not equal to the percent change in VMT. Factors such as number of trips, cold starts, trip speeds, ambient temperature, and season of vehicle activity affect the air quality impacts of telecommuting. All but the last two of these are captured in the travel log, and can be implemented in an emissions model to obtain reduction in air pollution attributed to telecommuting for the sampled group. Extrapolations to the population again must be made with consideration of sample representatives.

As stated earlier, impacts on land use cannot be obtained from travel logs, but intentions may be gauged through telecommuter survey questions (e.g. "Are you considering a household relocation decision? If yes, please indicate the role of telecommuting in your relocation decision?"). Answers may be measured by Likert's five-score, bipolar scales (Fishbein and Ajen, 1975). However, actual impacts on location decisions and land use can only be obtained through a longer-term study of telecommuter household relocation decisions.

3.4.2 Evaluation of Telecommuter and Household Impacts

Possible impacts on telecommuters are outlined in Section 2.2.1. Telecommuting effects on factors such as schedule flexibility, job satisfaction, social distractions, environmental comfort, commute stress, family discord, professional isolation, or workaholic tendencies are non-tangible, and thus, do not lend themselves to standard measurement units. Such factors can, however, be assessed through quantification of responses to survey questions. Section II of the telecommuter survey presented in Appendix B provides questions to ascertain many of these and other effects. Responses to these questions prior to telecommuting and similar questions after telecommuting can be compared to assess telecommuting-induced changes.

Impacts that can be gauged quantitatively include commute time and cost; clothing and food costs; and home utility and phone costs. Commute time and cost impacts can be obtained from the Phase I travel log data by multiplying the number of telecommuting days by round trip commute time, and by multiplying the round trip commute VMT by a cost per mile ratio for the vehicle. The cost per mile ratio may include items such as vehicle maintenance costs and fuel

costs.

Food costs associated with the traditional work lunch can be measured through each phase of the telecommuter survey and compared to identify possible savings. Home utility and phone costs can also be computed through the telecommuter surveys of each evaluation phase. Utility and phone bills prior to telecommuting and upon telecommuting can be compared to gauge the magnitude of these impacts. As stated in Section 3.4.1, utility and phone bill comparisons should account for seasonal changes as well as changes in the number or communications activities of other household members.

3.4.3 Evaluation of Organizational Impacts

The economic viability of a telecommuting program is evaluated by cost categorization and identifying changes in these categories. These include training, computer hardware and software, maintenance contracts, end user support, furniture and moving, communications, performance evaluation, and project administration. Not all cost categories are applicable in each program. For most categories cost documentation can be performed accurately by program evaluators, through the telecommuter, or through accounting departments.

The desirability of a telecommuting program is determined by comparing total organizational costs to benefits. The potential benefits, as identified in Chapter 2, include savings in office overhead costs, increase in employee effectiveness, decrease in telecommuter absenteeism, reduction in staff turnover, and compliance with air quality legislation. In organizations where office space is at a premium, full-time or desk-sharing telecommuting strategies can translate to significant cost savings, by eliminating the need for office expansion. With larger numbers of telecommuters, savings can also be recognized through reductions in common spaces such as dining facilities. This cost saving can be quantified by multiplying the area of telecommuter office space made available for other use by the cost per area of the office complex.

An important criterion in assessing organizational benefits from telecommuting is the impact on employee effectiveness. Effectiveness could be gauged through pre- and post- telecommuting survey questions on how measures of output quality and quantity have changed. In the absence of, or in addition to quantitative measures of output change, surveys can elicit productivity change as perceived by telecommuters and their supervisors through questions such as “What effect did telecommuting have on your productivity? _____% increase or _____% decrease.” The percentage of productivity change can then be multiplied by telecommuter salary to estimate benefits in monetary units. Other non-tangible impacts such as improved management effectiveness, communications between supervisor and telecommuter, group cohesiveness, or

higher morale can also be addressed by questioning supervisors, telecommuters, and co-workers on perceived impact. Response to such questions may also be measured by a five score bipolar scale. Example questions can be found in the Telecommuter Surveys in Appendix B, questions 23 and 24.

Changes in overall sick leave utilization can be obtained either from the telecommuters or the personnel department and can also be translated to monetary benefits by multiplying the reduction in sick leave days by telecommuter salary. To assess benefits from employee retention, telecommuting participants can be asked whether the ability to telecommute was a moderate to decisive influence on their decision to stay with a company. The reliability of such stated responses should be established. The reduction in employee turnover directly affects the need for personnel searches, hiring, and training costs. A percentage value of employee salary can be obtained from personnel departments and used to quantify this benefit.

3.5 TELECOMMUTING PROGRAM AND EVALUATION IMPLEMENTATION

The first four sections of this chapter described the evaluation framework in conjunction with a telecommuting program as well as the evaluation processes and measurement instruments to implement the framework. This section illustrates these in the context of implementation by TxDOT of a Telecommuting Pilot Program. The TxDOT program policy was initiated in July, 1994 and the program itself was implemented in April, 1995.

TxDOT is a public sector agency of approximately 14,400 employees and over 50 departments throughout the state of Texas. Figure 3.4 presents the organizational breakdown of TxDOT. Telecommuting is approached as a means for meeting a variety of TxDOT strategic objectives such as improving overall productivity, reducing traffic congestion and improving air quality by reducing employee commute and single occupancy vehicle trips. The organization formed a telecommuting task force from various districts, divisions and special offices. The task force developed an initial policy statement and appointed a telecommuting advisory team, which then developed telecommuting guidelines and procedures prior to implementation. The program was presented as a “management option, not an employee right.”

First, executive orientation sessions were conducted at 33 offices to brief management of the benefits of telecommuting. Figure 3.4 shows these offices boxed in bold. Executive surveys were distributed at each office to orientation session participants to capture general interest in and organizational suitability toward telecommuting. Analyses and specific content of the executive

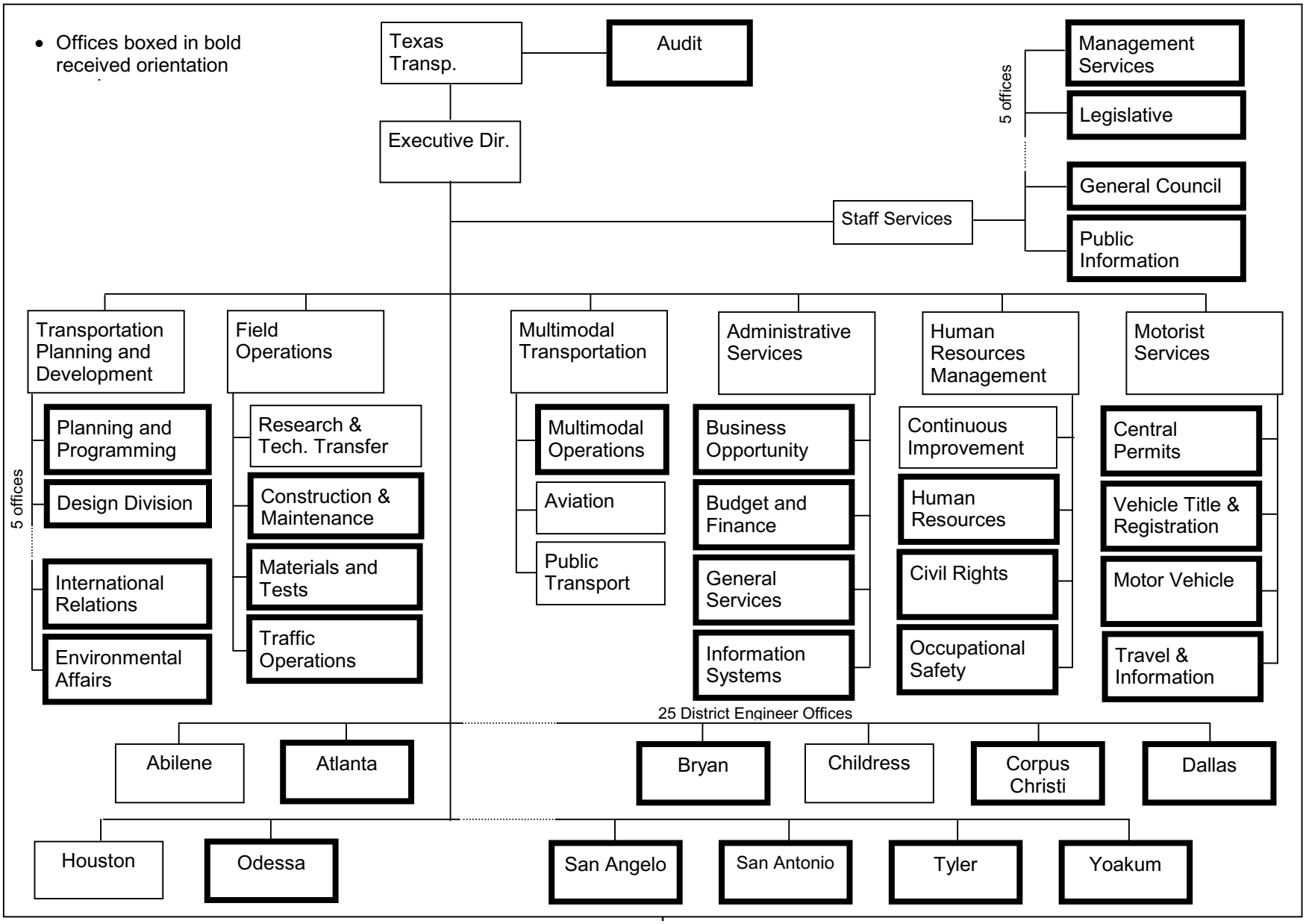

Figure 3.4 Texas Department of Transportation office organizational chart.

survey are presented in Chapter 4. From this, survey preference models for telecommuting adoption are developed and estimated in Chapter 5.

After the orientation session, executives were to distribute telecommuting program information to subordinates, and in the event of mutual interest in telecommuting, they were to contact the telecommuting task force. A total of fifteen individuals, and their supervisors, contacted the task force. Of these fifteen, six were permitted to telecommute by their supervisors. This rather low contact and approval rate is attributed primarily to executive reluctance to distribute program information to subordinates, and also to the perceived absence of support for telecommuting from TxDOT "upper management". Telecommuting, within the TxDOT program, was apparently perceived as solution to temporary employee flexibility needs rather than a long-term work arrangement.

A telecommuting training session was held for the supervisor and telecommuters. Prior to the training session the six telecommuters and their supervisors completed the telecommuter and supervisor surveys. Phase I evaluations were completed by five of the six telecommuters and their supervisors. Co-worker participation was not achieved. Moreover, the only Phase II evaluation implemented was the travel log –for three of the six telecommuters. In light of insufficient program participants the program evaluation was not fully executed. The following three sections discuss the content and analyses of the telecommuter survey, the supervisor survey, and the travel log. As the sample size for these measurement instruments is inadequate for statistical tests, response trends are described.

3.5.1 Telecommuter Survey and Results

The telecommuter survey, presented in Appendix A.2, consists of three sections. The first captures characteristics related to job suitability for telecommuting; and potential for transportation-related benefits; and telecommuting program characteristics and equipment needs. The second captures characteristics of the telecommuter's personality and perceptions toward job tasks, coworkers, supervisors, home environment, and commute environment. The final section is similar to the preference section for the executive survey in that it asks preferences toward telecommuting under seven telecommuting cost and salary scenarios.

Of the six telecommuters, only one had a commute greater than 15 miles, and three had commutes less than 5 miles. Three of the six telecommuters reported making multiple trips on the commute to and from work. Of the three, two reported that when telecommuting they still would have to make these peak hour trips. Thus, for this group the societal benefits of telecommuting would be significantly reduced.

With regard to the types of communications used with customers, clients, supervisors, and co-workers, most telecommuters indicated either 1 to 4 times per week or none. Tasks such as auditing, record keeping, editing, spreadsheet analyses were identified to perform during telecommuting days. Four of the six telecommuters indicated they already possess equipment required for telecommuting. The other two indicated the need for a computer, modem, and software. Overall, the telecommuters' work tasks, communications structure and equipment requirement suggest telecommuting as a feasible and cost-effective alternative.

Responses to the second section varied significantly among telecommuters; thus, trends could not be identified. Most telecommuters indicated willingness to work from home everyday or several days per week under almost every scenario. None, however, were willing to telecommute if their status was changed from a regular employee to a contract employee.

3.5.2 Supervisor Survey and Results

The supervisor survey, presented in Appendix A.3, consists of two sections. The first measures the supervisor's perceived suitability of telecommuting for his/her subordinate. The preferred telecommuting frequency, equipment provisions, and telecommutable tasks, are also elicited by the first section of this survey. The second section measures the level of comfort the supervisor has toward the telecommuting arrangement.

Responses to the first section are similar to those of the telecommuter survey in terms of telecommuting frequency, equipment provisions, and telecommutable tasks. Responses regarding the satisfaction of communications between the supervisor and telecommuter were unanimously positive and all supervisors reported being completely comfortable with their respective subordinates telecommuting.

3.5.3 Travel Log and Results

Of the six telecommuters, only four completed before and after travel logs. None of these four, however, completed the full seven days for the "after" travel log. Thus, results have been adjusted for the seven-day period. Three of the four respondents are over the age of 50, and two of the four telecommute due to health related factors. The one way commute distance ranges from 55 to 4 miles for the four individuals. The outcome of before and after travel behavior from these logs are presented in Table 3.1.

Of the four, telecommuters 1, 2, and 3 commuted part time (1, 2, and 3 days per week respectively); the fourth respondent telecommuted full time. As expected, the total VMT, the number of trips, and the number of peak hour trips all decrease. The average VMT during non-

telecommuting days increases from the "before" log for two of the three part-time telecommuters suggesting trips are shifted from telecommuting to non-telecommuting days. Trip chaining activity is also reduced for three of the four telecommuters suggesting less efficient trip scheduling behavior when telecommuting. Because of the limited sample size further analyses are not performed.

TABLE 3.1 RESULTS FROM TELECOMMUTER TRAVEL LOGS

Telecommuter Attributes	***T1***		***T2***		***T3***		***T4***	
Age	61		35		55		54	
Gender	male		female		female		female	
Position	-		planner		admin. technician		Clerk	
one way commute distance (miles)	10		10		55		54	
number of telecommuting days/wk	1		2		3		5	
Travel Characteristics	***pre/***	***post***	***pre/***	***post***	***pre/***	***post***	***pre/***	***post***
Total VMT	142.1	131.7	245	158.2	582	355.8	182.9	32.2
Total number of trips	14	11	22	10	18	17	30	25
Number of peak hour trips	14	8	19	3	16	7	26	13
telecommuting day average VMT	-	0	-	0	-	8.833	-	4.6
non-telecommuting day avg. VMT	20.3	25.53	36	33	111	129.8	26	-
Number of Trip chains	6	6	10	8	3	2	16	3

T=telecommuter
*values adjusted for a seven day period

3.6 SUMMARY

This chapter presented an evaluation framework for assessing societal, telecommuter and household and organizational impacts of telecommuting. The evaluation framework is described in the context of telecommuting program initiation and implementation tasks. Key measurement instruments and implementation time frames are identified within the evaluation framework. Measurement processes were explained and the following four sample measurement instruments were developed: the executive survey, the telecommuter survey, the supervisor survey, and the travel log.

The telecommuting program and evaluation framework were partially implemented for a public sector agency, and described in the final section. Program success and level of

implementation are discussed. The telecommuter survey, supervisor survey, and travel log are discussed in the context of evaluation implementation. Results from these measurement instruments are also presented. The executive survey data and analyses are presented in Chapters 4 and 5.

CHAPTER 4. SURVEY DATA AND EXPLORATORY ANALYSIS

4.1 INTRODUCTION

As outlined in Phase I of the evaluation framework of Chapter 3, a survey instrument was administered to obtain stated preference, attitudinal, organizational, and managerial information related to telecommuting from the Texas Department of Transportation (TxDOT) executives. The survey instrument measures base characteristics of the organization and its executives, and serves to identify executives who might be interested in telecommuting for themselves or for their employees. These managers and employees can then be screened for participation in the telecommuting program.

The survey instrument and the survey dissemination process are first discussed, followed by a description of general respondent characteristics. Then executive and organizational characteristics are discussed. In order to identify factors that influence executives' attitudes toward telecommuting, tests are performed to examine the independence of the distributions of responses to each attitudinal question and the levels of executive and organizational characteristics. Next confirmatory factor analysis is presented to further examine factors underlying the attitudinal responses. Stated preference data is also examined for general trends and correlation with executive and organizational characteristics. Public sector executive attitudes and preferences are compared with those of the private sector identified by Yen and Mahmassani (1994). Comparisons are also made of the attribute sets identified to significantly influence attitudes and preferences for the public and private sector executives. These analyses yield insight into the telecommuting adoption process of executives within a public sector agency, and form the basis for the preference model specification of the public sector executives, which is discussed in the next chapter.

4.2 SURVEY METHOD AND COMPOSITION

The survey is administered in coordination with the TxDOT Telecommuting Pilot Program to those divisions scheduled for telecommuting briefings. These briefings introduce executives to the concept of telecommuting and the range of possible impacts pertaining to their position, the telecommuter, and the organization. Survey participants, referred to as executives, are those who supervise, manage, or direct one or more individuals. The sample of executives to whom surveys are distributed are presently facing the previously unavailable option of permitting employee telecommuting; therefore, information responses may be approached more seriously, and preference responses may more accurately reflect adoption decisions than would have been the case for a purely hypothetical situation.

The survey, included in Appendix A, consists of four sections and is based on a survey administered in a study by Yen and Mahmassani (1994) with slight modifications. The first section elicits information on general characteristics of respondents and their offices such as job title, methods of supervision, availability of telecommunications and computer network facilities, and number and educational level of direct subordinates. It is recognized that attitudes play an important role in telecommuting adoption; thus the second section addressed executive's attitudes toward telecommuting in terms of management concerns such as productivity, morale, absenteeism, and information security. Also elicited in this section are executives' beliefs on upper management's receptiveness to telecommuting, and on the effectiveness of a voluntary telecommuting program. The third section measures executive preference for alternative telecommuting scenarios defined by employer-telecommuter cost responsibility structures and telecommuter salary changes. The final section elicits information on executive socio-economic characteristics such as age, gender, education, and vehicle ownership.

4.3 CHARACTERISTICS OF RESPONDENTS

Of the 463 surveys administered through the TxDOT telecommuting briefings, 300 usable surveys are obtained from 9 sections comprising 25 divisions. The respondents' distribution across section and by work level are presented in Table 4.1 and Table 4.2 respectively. Respondents' section is relevant to the telecommuting adoption decision as telecommuting may not be feasible for certain sections' tasks (e.g. field operations). Executives at higher administrative work levels are expected to have a larger staff than those at lower supervisory work levels and thus may perceive subordinate telecommuting differently.

Executives' socio-demographic characteristics are listed in Table 4.3. Most executives (79%) are male which corresponds with the overall make-up of TxDOT (77% male). Of the respondents, 72% are between 31 and 50 years of age. About 74% of the executives have completed college or university studies, and 15% have attained a master's, Ph.D., or equivalent degree. Comparatively, 34.4% of their staff have completed college or university studies, and 3.5% have attained a master's, Ph.D., or equivalent degree. Less than 20% of the executives and their households subscribe to an electronic database at home.

Questions related to managerial and organizational characteristics are included in the survey as they are believed to affect executive preferences for permitting employee telecommuting. Responses to these questions are presented in Table 4.4. The average number of immediate subordinates for executives is 17 with a standard deviation of 38. Methods of supervision most mentioned by executives are on-site supervision (83%), review of completed tasks (83%), and

review meetings (70%), whereas supervision by activity logs (32%) is relatively less practiced.

TABLE 4.1 CATEGORIZATION OF SURVEY RESPONDENTS BY TXDOT SECTIONS

Number of Respondents	*(by percent)*	*Section Name*
45	(15.0)	Administrative Services
4	(1.3)	Audit Office
77	(25.7)	District Engineers
69	(23.0)	Field Operation
4	(1.3)	Human Resource Management
25	(8.3)	Motorist Services
12	(4.0)	Staff Services
59	(19.7)	Transportation Planning & Development
5	(1.7)	Unknown Division
300	(100.0)	TOTAL

TABLE 4.2 CATEGORIZATION OF SURVEY RESPONDENTS BY WORK LEVEL

Number of Respondents	*(by percent)*	*Work Level*	*Work Type*
18	(6.0)	Administrators	Automation/Information, Programs, Other
68	(22.7)	Directors	Administration, Design, Planning, Programs, Maintenance, Construction, Environmental, Hydraulic, Operations, Other
57	(19.0)	Managers	Operations, Planning, Purchasing, Payments, Budgeting, Finance, Traffic Systems, Traffic Operations, Other
55	(18.3)	Supervisors	Audit, Payments, Billing, Revenues, Engineering, Field Area, Mapping and Data Collection, Roadway Maintenance, Other
73	(24.3)	Engineers	Area, Design/Planning, District, Specialists, Programs, Projects, Other
29	(9.7)	Unknown	
300	(100.0)	TOTAL	

With reference to technology penetration associated with telecommuting, data on the availability of personal computers, dedicated word processors, and mainframe terminals for staff were obtained. Fifty-five percent of the executives indicate at least 5 personal computers available to their staff, with 27% indicating at least 10. Only 4% of the executives indicate at least

5 dedicated word processors available to staff, and 25% of the executives indicate at least 5 mainframe terminals available to staff. The average number of personal computers per supervised staff member per manager is 1.2, dropping to 0.39 for mainframe terminals. Across executives and divisions the average number of personal computers per staff member for the sample is 0.62 and the average number of mainframes is 0.25. This indicates that executives with fewer subordinates have proportionately more personal computers for their staff than those with more subordinates.

TABLE 4.3 EXECUTIVES SOCIO-DEMOGRAPHIC CHARACTERISTICS

Characteristics	***Category***	***Frequency (%)***
gender	male	79.4
	female	20.6
Age	under 30	3.3
	31-40	37.5
	41-50	34.3
	51-60	21.3
	above 60	3.6
education level	completed high school	7.6
	some college or university	18.3
	completed college or university	59.0
	master degree	12.6
	Ph.D. or equivalent	2.5
	other	1.4
number of household passenger cars	none	0.0
	one	13.8
	two	60.9
	three or more	26.3
subscribe to an electronic database	yes	17.6
	no	82.4
distance from residence to work (miles)*	mean	15.8
	standard deviation	11.6

* Number for these items are not frequencies

Table 4.5 presents questions related to executive and organizational familiarity with telecommuting which is expected to influence their attitudes or preferences toward supporting such programs. Only 12% of the executives are very familiar with telecommuting whereas 30% are aware of someone who telecommutes. In contrast, 34% are not familiar with telecommuting. Such results indicate that the majority of sampled executives may have limited appreciation of the possible benefits of telecommuting.

Regarding the availability of alternate work arrangements within divisions of TxDOT, 89% of the respondents indicate the existence of a flexible hour work schedule program. Moreover, 19%

of survey respondents are aware of some employee within their division who telecommutes at least part time. This result is surprising as TxDOT had not promoted or permitted such a work policy. This result suggests that telecommuting is presently being practiced on an informal basis within the agency.

Executives' awareness of divisional policies can be assessed by evaluating the consistency of responses from executives within the same division. The policy question employed in this assessment is whether a flex-time policy is present in the division. Among the twenty five divisions, one division has only one respondent. Of the 24 divisions with more than one respondent, and excluding respondents who did not know his/her division policy status, 13 have full consensus that the flex-time program is available, 8 have from 80% to 99% consensus, and 3 have from 55% to 79% consensus. Regarding the presence of an employee telecommuting at least part time within the division, 9 divisions have full consensus that no employee telecommutes, 5 have from 80% to 99% consensus, 6 have from 55% to 79% consensus, and 4 have from 50% to 54% consensus. These results reveal that the flex-time policy is well recognized, whereas telecommuting is much less recognized.

4.4 ATTITUDES TOWARD TELECOMMUTING

Executive responses to attitudinal questions are summarized in Table 4.6. With regard to the impacts of a voluntary telecommuting program on the organization and employees, 60% of the executives believe such a program would enhance their organizations' ability to retain and recruit employees; only 6% believe this impact to be negative. Twenty-nine percent of the executives believe that a telecommuting policy negatively impacts the organizations' public image; however, 27% believe this impact to be positive. Similar attitudes are noted for executives within the private sector with the exception that fewer (54%) expect telecommuting to enhance employee retention and recruitment ability (Yen and Mahmassani, 1994).

Over 80% of the executives in the public sector sample indicate that a telecommuting policy would improve telecommuter morale; however, only 49% expect telecommuter productivity to increase, and almost 24% expect productivity to decrease. A lower percentage of private sector executives expect improvements in telecommuter morale (67%). Moreover, the percentage of executives who expect telecommuter productivity to decrease (50%) is more than twice that of the public sector.

TABLE 4.4. EXECUTIVE AND ORGANIZATIONAL CHARACTERISTICS

Characteristic	*Category*	*Frequency (%)*
employment duration in organization (years)*	mean	16.9
	standard deviation	9.2
employment duration in present position (years)*	mean	4.4
	standard deviation	4.5
number of staff directly supervised	less than 6	37.2
	six or more	62.8
education level of aggregated staff	completed high school	44.6
	some college or university	20.7
	completed college or university	30.9
	master or Ph.D.	3.5
method of supervision (checked all that applied)	review meeting	69.5
	review completed task	82.6
	on-site supervision	82.6
	activity logs	32.2
	time sheets	49.0
	written reports	47.3
management style is results rather than activity oriented	very unlikely/not at all	4.4
	neutral	17.9
	very likely/definitely	76.7
number of personal computers available to staff	none	3.0
	one to five	50.2
	six or more	46.8
number of dedicated word processors available to staff	none	81.1
	one to five	15.0
	six or more	3.9
number of mainframe terminals available to staff	none	35.7
	one to five	44.9
	six or more	19.4
percentage of terminal interconnectedness	all	58.2
	more than 50%	15.3
	less than 50%	6.2
	none	20.2
existence of flex-time programs in the organization	yes	88.7
	no	8.0
	don't know	3.3
existence of employee in agency who telecommutes	yes	19.1
	no	60.9
	don't know	20.1
authority to initiate a telecommuting program	yes	27.1
	no	53.8
	don't know	19.1

*Numbers for these items are not frequencies

TABLE 4.5 EXECUTIVES FAMILIARITY WITH AND PERCEPTIONS TOWARD TELECOMMUTING

Characteristics and Perceptions	*Category*	*Frequency (%)*
familiarity with telecommuting	very familiar	11.7
	somewhat familiar	54.0
	not familiar	34.3
worked in organization that had a telecommuting program	yes	6.7
	no	3.3
awareness of someone who telecommutes	yes	29.7
	no	70.3
perceived receptiveness of upper management to a voluntary telecommuting program	very negative	14.7
	somewhat negative	30.0
	neutral	29.3
	positive	20.9
	very positive	5.1
perceived effect of telecommuting on improving community traffic conditions	very negative	3.3
	somewhat negative	7.7
	neutral	40.2
	positive	31.4
	very positive	17.3
perceived cost effectiveness of a voluntary telecommuting program	cost effective	28.2
	possibly cost effective	44.4
	not cost effective	27.4

Twenty-eight percent of public sector executives believe non-telecommuter productivity may decrease, and even more (47%) believe telecommuting would negatively affect non-telecommuter morale. In comparison, more private sector executives (45%) expect telecommuting to decrease non-telecommuter productivity. These results reflect similar public and private sector executive concerns in terms of telecommuter work performance and negative impacts on non-telecommuters. The private sector executives, however, perceive greater negativity and lesser benefits in most respects than the public sector.

Management impacts have been suggested as most important to telecommuting adoption (Gordon and Kelly, 1986). The response to management- related concerns are significantly more negative than positive in regard to workload (36% versus 24%), staff communications (44% versus 15%), and supervisory ability (38% versus 15%). Similar figures for the private sector show a greater dichotomy between expected negative and positive telecommuting impacts: 56% negative versus 21% positive with regard to work load management, 59% negative versus 11% positive with regard to staff communications, and 70% negative versus 6% positive with regard to supervisory ability. These figures confirm widely expressed views in literature that executives are

reluctant to adopt telecommuting due to serious concerns about retaining management control.

TABLE 4.6 EXECUTIVE RESPONSES TO ATTITUDINAL QUESTIONS

Scenario: Suppose your staff were part of a voluntary telecommuting program in which eligible employees worked from their homes twice a week. What effect do you think such a telecommuting Program on the following:	*Responses (frequency in %)* 1 very negatively	2	3 neutral	4	5 very positively
1. the agency's ability to retain and recruit employees	3.2	2.5	33.9	38.6	21.7
2. telecommuting employee productivity	7.6	16.3	37	31.9	7.2
3. non-telecommuting employee productivity	4.7	23.6	59.8	9.4	2.5
4. overall staff productivity	5.1	18.4	43	30.7	2.9
5. telecommuting employee morale	1.4	4.3	14.1	48	32.1
6. non-telecommuting employee morale	10.1	37.2	45.5	6.1	1.1
7. overall employee absenteeism	3.3	8.7	52.4	28	7.6
8. the agency's public image	9.4	21	42.8	20.3	6.5
9. your ability to manage your workload	9.0	27.1	40.1	18.4	5.4
10. ,your ability to communicate with your staff	9.7	34.7	40.4	12.6	2.5
11. your ability to supervise your staff	9.7	27.1	48.4	11.9	2.9
12. security of data and information	6.6	22.1	56.1	12.9	2.2

More executives in the private sector (40%) than the public sector (28%) believe data security would be compromised by telecommuting. Few executives in both the public (16%) and private (10%) sector believe telecommuting may positively affect data security. This seems appropriate as private sector agencies have a greater possibility for financial losses from information or product leaks.

Approximately 45% of the public sector executives believe that upper management is not receptive to telecommuting, and 28% believe that a voluntary telecommuting program would not be cost effective. Results as a whole indicate a strong reluctance on the part of executives consider telecommuting, and skepticism over the benefits of such programs.

4.4.1 Chi-Squared Tests of Independence

In order to identify the factors that influence employee attitudes toward telecommuting, chi-squared tests were performed. These examine the independence of the distributions of

responses to each attitudinal question and the level of each executive and organizational characteristic listed in Tables 4.2 through 4.6. The results are presented in Table 4.7. Similar tests for the private sector responses found executive socio-economic characteristics had no bearing on attitudes toward telecommuting; however, attributes related to telecommuting knowledge, organizational characteristics, and supervision method were found to be significant. Attributes related to management style were not elicited by the private sector survey of Yen and Mahmassani (1994). Twenty of the characteristics presented in Section 4.3 exert significant effects on the response to at least one of the twelve attitudinal questions for the public sector sample.

Executive educational level influences expectations of the likely impacts of telecommuting on the agency's ability to retain and recruit employees. Of those who have completed high school, 45% believe the impact would be positive, whereas a greater percent of those with college experience or degree (61%) and those with a Master or Ph. D. (71%) believe the impact to be positive. Gender also influences attitudes toward telecommuting. More females (38%) believe telecommuting to benefit the firm's public image than males (28%).

As expected, executive awareness of telecommuting influences his/her attitudes toward its impacts. Of the executives who indicated familiarity with telecommuting (group 1), 80% expect it to exert a positive effect on the firm's ability to retain and recruit employees; of those who indicated unfamiliarity with telecommuting (group 2) only 55% expect a positive effect. Only 17% of group 1 executives expect telecommuting to negatively affect security of data and information; in group 2, 34% believe this effect would be negative.

Surprisingly, executive familiarity with telecommuting did not significantly influence expectations of impacts on their ability to manage their workload. Moreover, almost equal percentages of executives in group 1 (43%) and group 2 (46%) expect telecommuting to have negative effect on their ability to communicate with staff. In contrast, 33% of the executives in group 1 expect positive impacts on staff communication, whereas only 8% of group 2 expect the same. Within the private sector, telecommunications awareness also exerted a positive influence on executive attitudes; however, as the measurement attribute for telecommunications awareness was "awareness of someone who telecommuted" rather than "familiarity with telecommuting," specific comparisons could not be performed.

Executives' organizational and managerial characteristics more so than their socio-economic attributes appear to affect their attitudes toward telecommuting. Executive designation influences his/her expectations of the likely impacts of telecommuting on telecommuter and on overall staff productivity. More administrators or directors (43% and 38%) than other executives (35% and

TABLE 4.7 RESULTS OF CHI-SQUARE TESTS OF INDEPENDENCE BETWEEN EXECUTIVE RESPONSES TO ATTITUDINAL QUESTIONS AND EXECUTIVE/ORGANIZATIONAL CHARACTERISTICS

	Attitudinal Questions (See table 4.6)											
Variables	1	2	3	4	5	6	7	8	9	10	11	12
socio-economic attributes												
gender						+		+				+
age	+											
educational level	+											
household vehicle ownership						+						
household subscribes to electronic database						+						+
commute distance						+						*
telecommuting knowledge												
familiarity with telecommuting	+									*		*
awareness of individual who telecommutes						+					*	+
worked in an organization with telecommuters						+					+	+
organizational characteristics												
work level (job title)	+	#		#	+							
time employed in present agency	+							+				
time employed in present position	+							#			+	
number of subordinates directly supervised						#	*					
subordinates' education level						#						#
number of personal computers per staff	+	+		*	*	#						
terminal interconnectedness	*								+	*		
method of supervision												
on-site supervision										#	#	#
supervision by time sheets/written reports					+	+						#
management style												
evaluation is results, not activity, oriented		+	#	#		+	#	#	#	#	#	#
clearly outline task expectations		*	+	+		*	+	+				

* significant at the 0.10 level but not at the 0.05 level
\+ significant at the 0.05 level but not at the 0.01 level
\# significant at the 0.01 level

31%) believe that telecommuter and overall staff productivity impacts would be positive. This result is not directly comparable to the sample of private sector executives who came from different organizations. For those, fewer (5%) presidents or vice presidents perceive positive benefits from telecommuting than other executives (26%).

Management span also influences executive attitudes toward telecommuting. More executives (54%) with at least six direct subordinates expect telecommuting to negatively impact non-telecommuting employee morale than executives (36%) with five or fewer subordinates.

The degree of penetration of relevant technology positively influences executive attitudes toward telecommuting. Approximately 68% of the executives in divisions with a personal computer to staff ratio (PCR) greater than 0.5 (group 1) expect telecommuting to have a positive effect on the firm's ability to retain and recruit employees whereas only 43% of other executives (group 2) have the same expectation. More executives in group 1 (47% and 41% respectively) expect telecommuting to positively effect telecommuting employee productivity and overall staff productivity than in group 2 (23% and 24% respectively). Moreover, 87% of the executives in group 1 expect telecommuting to improve telecommuter morale, whereas in group 2 only 68% expect the same result. Comparably, 60% of the executives in group 2 expect telecommuting to negatively impact non-telecommuter morale, and only 40% in group 1 expect the same.

A similar trend was found between telecommuting benefits and penetration of communications technologies for the private sector as for the public sector. Comparisons, however, cannot be made as the study by Yen and Mahmassani (1994) report tests using the total number of personal computers rather than the PCR.

As expected, supervision method and management style have the greatest significance in executive attitudes toward telecommuting. More executives who employ on site supervision (group 1) anticipate telecommuting to create negative impacts than those who do not exercise on site supervision (group 2): 47% of group 1 as opposed to 34% of group 2 expect a negative impact on their ability to communicate with staff, 42% of group 1 as opposed to 16% of group 2 expect a negative impact on their ability to supervise staff, and 30% of group 1 as opposed to 22% of group 2 expect a negative impact on the firm's data and information security. Conversely, those executives who employ time sheets or written reports as means of supervision expect greater positive and lesser negative telecommuting impacts than those who do not. Comparable to the supervision method is management style, ranging from evaluation by results to evaluation by activity. Fewer executives who employ the former management style expect negative impacts than those who employ the latter management style.

4.4.2 Confirmatory Factor Analysis of Attitudinal Information

The twelve questions seeking attitudinal information in the survey (Table 4.6) are intended to provide insight into four factor groups believed to affect executives' likelihood to adopt telecommuting. These four factors capture the anticipated impacts of a telecommuting program on:

1. telecommuting workers and organizational image (questions 1, 2, 5, and 8),
2. non-telecommuting workers (questions 3 and 6),
3. workers overall (questions 4 and 7), and
4. managerial effectiveness and related concerns (questions 9 to 12).

Confirmatory factor analysis (CFA) provides a procedure by which the twelve measured components can be translated into the four factors. While maintaining approximately equal explanatory power, CFA enables a significant reduction in the dimension of the directly measured responses. This section will present the CFA modeling framework and results.

Equation 4.1 presents the matrix factor equation where **x** is a (12 X 1) vector of observed dependent variables, λ is a (12 X 4) matrix of factor coefficients indicating loading on to the variables, ξ is a (4 X 1) vector of latent variables (factors), and δ is a (12 X 1) vector of error terms not explained by the factors, or uniqueness components corresponding to x. Taking the variance of equation 4.1 yields equation 4.2 where Σ is a (12 X 12) variance covariance matrix of the vector of dependent variables, Φ is a (4 X 4) symmetric matrix of the covariance among the common factors, and Θ is a (12 X 12) symmetric diagonal (by assumption) matrix of covariance among the uniqueness components.

$$\mathbf{x} = \lambda\, \xi + \delta \qquad 4.1$$

$$\Sigma = \lambda\, \Phi\, \lambda' + \Theta \qquad 4.2$$

The specified factor pattern for the executive attitudinal data is presented in Figure 4.1. It is assumed that all factors are correlated. As dependent and latent variables gauge the impacts of telecommuting (both positive or both negative), all factor loadings are expected to be positive. Subject to estimability constraints (Jöreskog and Sorböm, 1981), the parameters λ, Φ, ξ are calculated using maximum likelihood in the SAS CALIS (SAS, 1990) procedure.

The results of the CFA model parameter estimates (λ) and the corresponding t-values are presented in Table 4.8. The results indicate that all loadings are significantly different from zero at the 0.01 level. Eleven of the 12 variables have high loadings (greater than 0.60) on specified factors. In addition no variable has a low loading (less than 0.30). As expected, all parameter estimates loaded positively. Statistics such as the goodness-of-fit index (GFI = 0.895) and the adjusted GFI (0.829) also indicate that the model fits the observed data well.

Figure 4.2 presents the uniqueness parameters. All parameters are significant and positive suggesting that in addition to the hypothesized four common factors, there are unique factors

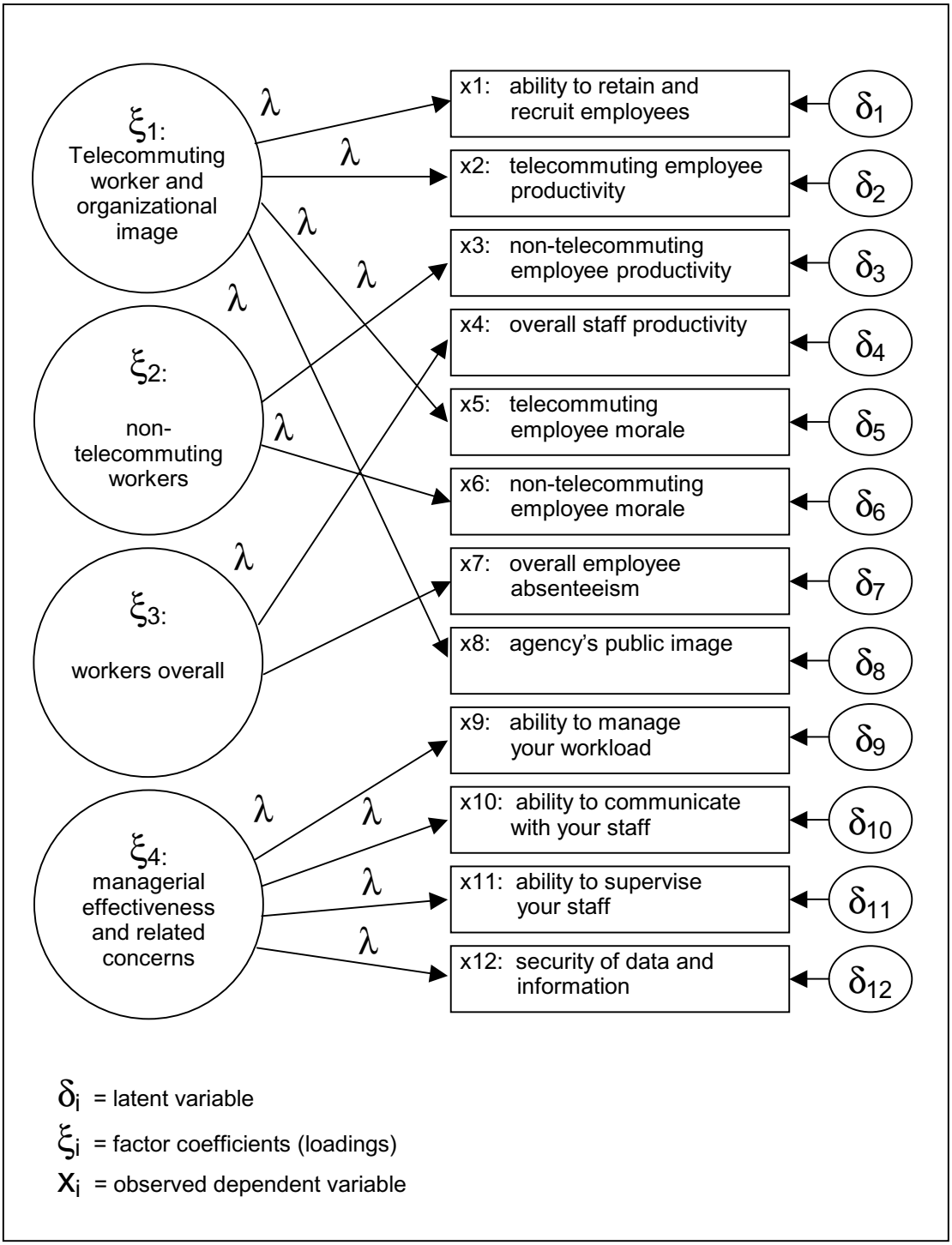

Figure 4.1 Confirmatory factor model of telecommuting attitudes.

affecting executives' attitudes toward telecommuting. The estimated correlation matrix (Φ) of the four factors is presented in Figure 4.3. The highest correlation exists between factors 1 and 3, indicating that the executives' attitudes toward telecommuting workers and image of the organization, and workers overall are almost perfectly correlated.

TABLE 4.8 ESTIMATED FACTOR PATTERN FROM THE CONFIRMATORY FACTOR ANALYSIS

Variable	***Factor 1***	***Factor 2***	***Factor 3***	***Factor 4***
Ability to retain and recruit employees (1)	0.64 (11.79)			
telecommuting employee productivity (2)	0.85 (17.35)			
non-telecommuting employee productivity (3)		0.61 (9.32)		
overall staff productivity (4)			0.82 (15.54)	
telecommuting employee morale (5)	0.61 (11.07)			
non-telecommuting employee morale (6)		0.85 (11.81)		
overall employee absenteeism (7)			0.62 (11.27)	
the agency's public image (8)	0.57 (10.12)			
ability to manage workload (9)				0.82 (16.89)
ability to communicate with staff (10)				0.89 (19.4)
ability to supervise staff (11)				0.90 (19.81)
security of data and information (12)				0.61 (11.22)

* The t-values in parentheses are significant at 5%

	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10	d11	d12
var 1	0.59 (11.2)											
var 2		0.27 (7.5)										
var 3			0.63 (8.9)									
var 4				0.33 (7.0)								
var 5					0.63 (11.3)							
var 6						0.28 (2.8)						
var 7							0.59 (11.2)					
var 8								0.68 (11.5)				
var 9									0.33 (10.2)			
var 10										0.2 (8.2)		
var 11											0.18 (7.7)	
var 12												0.63 (11.7)

* t-values in parentheses significant at 5%

Figure 4.2 Estimated uniqueness parameter coefficients ( ) from CFA.

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00			
Factor 2	0.40	1.00		
Factor 3	1.00	0.57	1.00	
Factor 4	0.80	0.55	0.86	1.00

Figure 4.3 Estimated factor correlation from the CFA.

4.5 STATED PREFERENCES FOR TELECOMMUTING ALTERNATIVES

Table 4.9 summarizes the responses to nine questions regarding the executive's preference for supporting an organizational telecommuting program, under different telecommuting scenarios. Each scenario is defined on the basis of who assumes additional telecommuting costs, and corresponding salary changes for telecommuters. Executives were asked to state their willingness to support telecommuting in their organization under each scenario from one of the following responses: yes, possibly, and no.

Under scenario 1, wherein telecommuter salary (TS) remains the same and employer-incurred cost for telecommuting (EICT) is none, 83% of the executives would support a telecommuting program. When TS is maintained and EICT is partial (scenario 2), this percentage decreases to 73%; and when EICT is full (scenario 3), the percentage decreases further to 62%. As expected, executives' willingness to support telecommuting decreases as their organization's cost responsibility increases. This relationship is maintained in the private sector study by Yen and Mahmassani (1994). The magnitude of support, however, is significantly less for the private sector for the first three scenarios (67%, 51%, and 41% respectively).

TABLE 4.9 EXECUTIVE STATED PREFERENCE RESPONSES FOR TELECOMMUTING PROGRAM SCENARIOS

	Responses (relative frequency in percent)		
Telecommuting Program Scenario	***Yes (1)***	***Possibly (2)***	***No (3)***
1. Employee salary stays the same; employer incurs no costs	45.96	37.13	16.91
2. Employee salary stays the same; employer assumes some costs	31.99	40.81	27.21
3. Employee salary stays the same; employer pays all costs	28.31	33.46	38.24
4. Employee salary decreases 5%; employer incurs no costs	6.27	24.72	69.00
5. Employee salary decreases 5%; employer assumes some costs	4.04	24.26	71.69
6. Employee salary decreases 5%; employer pays all costs	5.88	20.59	73.53
7. Employee salary increases 5%; employer incurs no cost	8.82	18.75	72.43
8. Employee salary increases 5%; employer assumes some costs	9.56	16.91	73.53
9. Employee salary increases 5%; employer pays all costs	8.82	13.60	77.57

Scenarios 4, 5, and 6 present telecommuting programs wherein TS is reduced by 5% and EITC is varied from none, partial, to full. Although these strategies would significantly decrease organizational costs, executives were reluctant to support such programs. Executive willingness to support scenarios 4, 5 and 6 dropped by more than half to 31%, 28%, and 26% respectively. These findings suggest that executives may recognize the inequity in decreasing telecommuter salary while requiring the same job tasks and performance, as well as the emergence of negative publicity and employee morale from such strategies.

In the private sector study, willingness to support telecommuting also dropped in scenarios 4, 5, and 6 to 40%, 34%, and 34% respectively, but not as significantly as in the public sector. A comparison of percentages of executives in the public and private sector who support a salary decreasing telecommuting program indicates fewer in the latter sector oppose salary cuts. This may be the case because profit maximization is a more important objective in the private sector.

As suggested by scenarios 7, 8, and 9, executives are equally if not more reluctant to support telecommuting wherein TS is increased by 5%. Under scenario 7 (TS increase of 5% and ECIT is none), 28% of the executives are willing to support telecommuting. When ECIT become partial and full (scenarios 8 and 9), the support decrease to 26% and 22% respectively. Private sector executive willingness to support telecommuting under these three scenarios is less than of the public sector (23%, 16%, and 16% respectively). This furthermore confirms the greater importance of the profit maximization objective for the private sector than the public sector. Both latter sets of scenarios (4-6 and 7-9) exhibit the tendency noted earlier of decreasing support for telecommuting by executives as employer costs increase.

Responses to telecommuting program scenarios are also cross-tabulated with respect to the executive and organizational characteristics listed in Tables 4.2 through 4.6. Results of the chi-square tests of independence between executive preferences and executive and organizational characteristics are presented in Table 4.10. Similar to attitudinal results, public sector executives' educational level and their willingness to support telecommuting under various scenarios are positively correlated. Few executives without a college degree indicated their support under scenarios 5, 7, and 8 (19%, 18%, & 19% respectively). Under the same scenarios, some executives with a bachelor degree indicated their support (31%, 28%, & 28% respectively) while even more executives with a masters or Ph.D. indicated support (36%, 43%, & 36% respectively).

In contrast to attitudinal results, gender did not play a role in executives' stated preferences; however, age did affect executives' willingness to support telecommuting. Many more young executives are willing to support telecommuting than their older counterparts as indicated by responses to scenarios 1, 2, 7, and 8. Table 4.11 presents the percent of executives in different

TABLE 4.10 RESULTS OF CHI SQUARE TESTS OF INDEPENDENCE BETWEEN EXECUTIVE RESPONSES TO STATED PREFERENCE QUESTIONS AND EXECUTIVE/ORGANIZATIONAL CHARACTERISTICS

	Stated Preferences Questions (see Table 4.8)								
Variable	1	2	3	4	5	6	7	8	9
socio-economic attributes									
age	*	*					#	*	
education level					*		#	o	
household subscribes o electronic database		*	*		o	*	o		o
telecommuting knowledge									
familiarity with telecommuting		o		*	o	o	*		
awareness of someone who telecommutes									*
organizational characteristics									
time employed in present agency	#								
subordinates directly supervised	*	#			#	*			
subordinates' education level		*							
number of personal computers per staff	#	#							o
method of supervision/management style									
supervision by time sheets		*					o		
evaluation is results, not activity oriented	*	*							o
clearly outline task expectations	*						#	*	

* significant at the 0.10 level but not at the 0.05 level
\+ significant at the 0.05 level but not at the 0.01 level
\# significant at the 0.01 level

age brackets who are willing to support telecommuting. Interestingly, none of the executive socio-economic attributes appeared (in similar analyses) to significantly influence the stated preferences of executives within the private sector.

As expected, executives who are familiar with telecommuting (group 1) are more willing to support telecommuting than those who are somewhat or not familiar (group 2) with this concept. Over scenarios 2, 4, 5, 6, and 7 the percentages of executives in group 1 to support telecommuting are 90%, 47% , 47%, 50%, and 40% respectively; whereas the percentages of executives in group 2 are much less at 71%, 29%, 26%, 24%, and 28% respectively. Similar to the attitudinal results, the penetration of relevant technology within the organization has a positive effect on executives' willingness to support telecommuting. As indicated by responses to

scenarios 1, 2, and 9, more executives (88%, 81%, and 27% respectively) in organizations with a personal computer to staff ratio greater than 0.5 are willing to support telecommuting than other executives (72%, 56%, and 15% respectively).

TABLE 4.11 PERCENTAGE OF EXECUTIVES WILLING TO SUPPORT TELECOMMUTING BY AGE

	Percentage of Executives Willing to Support Telecommuting			
Executive Age	Scenario 1	Scenario 2	Scenario 7	Scenario 8
under 30	100	100	67	56
30 - 50	84	75	31	30
over 50	79	62	17	15

The management span of executives also influences their willingness to support telecommuting. As indicated by responses to scenarios 2, 5, and 6, more executives (83%, 35%, and 31% respectively) with five or fewer subordinates are willing to support telecommuting than executives (66%, 24%, and 24% respectively) with greater than five subordinates. Management style, as in attitudinal results, also affects executives' willingness to support telecommuting. Executives who evaluate by results rather than activity (group 1) are more willing to support telecommuting than others (group 2). Of the executives from group 1, 84%, 76% and 21% supported telecommuting scenarios 1,2 , and 9 respectively. These percentages for group 2 drop to 73%, 40%, and 13%.

4.6 PRIVATE AND PUBLIC SECTOR COMPARISON OF ATTRIBUTES

Sections 4.4 and 4.5 have identified characteristics which influence telecommuting attitudes and preferences of public sector executives, and compared these to the results of a previous survey of private sector executives. Four categories were identified to influence attitudes toward and preferences for telecommuting: socio-economic attributes, telecommuting knowledge, organizational characteristics, and method of supervision and management style. To further aid in interpreting the comparison results in the previous two sections, the present section compares public and private sector survey respondents' attributes within these categories. Statistics available for both the public and private sector sample characteristics that influence attitudes and preferences are summarized in Table 4.12.

Socio-economic characteristics that are expected to influence telecommuter attitudes and preferences are gender, age, and educational level of executives. Younger individuals, and individuals with a higher educational level are expected to be more supportive of telecommuting

than their counterparts. Of the private sector respondents, 22% are under the age of 30 and 40% have a Master or Ph. D. degree. These figures are 3% and 15% for the public sector, suggesting that the private sector respondents should exhibit a greater propensity for telecommuting.

More executives in the private sector sample are familiar with telecommuting and aware of someone telecommutes than their counterparts in the public sector, suggesting more favorable attitudes toward and greater preferences for telecommuting. Organizational characteristics are approximately comparable between the public and private sector sample respondents.

Supervision by time-sheets and written reports is expected to be more suitable for telecommuting than on-site supervision. Although approximately the same percentage (within 10%) of executives use on-site supervision, a much greater percentage of private sector executives use time sheets (64% vs 49%) and written reports (74% vs 47%). This suggests a more favorable telecommuting adoption environment among private sector respondents.

However, comparisons made in Sections 4.4 and 4.5 of private sector attitudes and preferences with those of the public sector respondents appear to contradict the assessment that the private sector responses suggest is a more favorable telecommuting adoption environment. Several reasons can be suggested for this disparity. It is likely that public sector executive responses to attitudes toward and preferences for telecommuting were somewhat more favorable toward telecommuting because of participation in an orientation session on telecommuting benefits. Also, the survey of public sector executives was conducted two years after that of the private sector by Yen and Mahmassani (1994). Within this time span, general attitudes toward telecommuting may have improved due to increased public attention and awareness of policy consideration that motivate telecommuting. In particular, TxDOT employees are highly likely to be well aware of the growing concerns about air quality, congestion, and fuel consumption. Sampling processes may also contribute to this difference.

4.7 SUMMARY

This chapter has presented an exploratory analysis of the attitudinal and stated preference data obtained from a survey of executives in TxDOT. In general, characteristics which influence executive attitudes toward telecommuting also influence executive willingness to support telecommuting. In the former, household and socio-economic characteristics play an almost equal role as organizational and management characteristics; in the latter, organizational and management characteristics are more significant. Attributes of greatest significance in capturing these characteristics for the public sector include age, familiarity with telecommuting, household database subscription, personal computer to staff ratio, and results oriented evaluation (see

Tables 4.7 and 4.10). The set of significant characteristics is the same as that for the private sector; however, the specific attributes employed to capture these characteristics may be different.

TABLE 4.12 COMPARISON OF PUBLIC AND PRIVATE SECTOR CHARACTERISTICS

		Relative Frequency (%)	
	Category	***Public Sector***	***Private Sector***
socio-economic attributes			
gender	male	79.4	77.1
	female	20.6	22.9
Age	under 30	3.3	21.7
	31-50	71.8	71.1
	above 50	24.9	7.2
education level	finished high school	25.9	7.2
	finished college/university	59.0	53.1
	Master, Ph.D. or equivalent	15.1	39.7
telecommuting knowledge			
familiarity with telecommuting	very familiar	11.7	16.0
	somewhat familiar	54.0	60.5
	not familiar	34.3	23.5
awareness of someone who telecommutes	yes	29.7	36.6
	no	70.3	63.4
organizational characteristics			
number of subordinates directly supervised	0-5	37.2	34.6
	>=6	62.8	65.4
number of personal computers available to staff	0	3.0	6.2
	1-4	50.2	40.7
	>=5	46.8	53.1
method of supervision			
on-site supervision	Yes	82.6	77.8
supervision by time-sheets	Yes	49.0	64.2
supervision by written report	Yes	47.3	74.1

Comparisons between private and public sector attitudes toward telecommuting indicate more executives in the private sector believe telecommuting impacts to be negative than in the private sector. For example, 24% of public sector executives expect telecommuter productivity to decrease, whereas 50% of the private sector executives expect the same. Private sector executives are also less willing to support telecommuting than public sector executives, except in the case where salaries are decreased by 5%, confirming that private sector is more strongly

driven by profit motives. The public and private sectors overwhelmingly prefer telecommuting scenarios wherein telecommuter salaries remain the same and no additional organizational cost is incurred.

Comparisons are also made of attributes that influence telecommuting attitudes and preferences. These comparisons, contrary to the attitude and preference comparison results, suggest the private sector may have greater propensity toward telecommuting adoption than the public sector. This disparity is attributed to the two year difference in survey implementation, differences in the sampling strategy, as well as greater public sector awareness of the policy consideration that motivate telecommuting.

Factor analysis identified the underlying dimensions of executive attitudes toward telecommuting. This analysis transformed the twelve attitudinal questions into four general attitudes toward telecommuting. Analyses in this chapter provide a useful guide for the specification of telecommuting preference models in the following chapter.

CHAPTER 5: PREFERENCE MODELING

5.1 INTRODUCTION

The telecommuting adoption process includes two principal decision-makers: the employer and the employee. The former decides whether or not to initiate a telecommuting program and the latter decides whether or not to participate in a given telecommuting program. This work addresses the adoption process of the first of the employer, specifically executives in a public sector agency (TxDOT) empowered with the decision to offer employees in their divisions the option to telecommute. The stated preference data described in Chapter 4 forms the basis of the model development.

This chapter first presents the conceptual framework for the employer telecommuting adoption choice and briefly discusses the adoption process. In the next section, the conceptual framework is applied to formulate mathematical models. Three specifications are proposed that model the willingness of executives to support telecommuting. The first two capture ordinal and dynamic nature of the choice process being modeled, respectively. The third captures simultaneously the ordinal and dynamic nature of the preference data. Each model is calibrated using maximum likelihood estimation procedures; the latter two evaluate choice probabilities based on a Monte Carlo simulation approach. Estimation results and substantive implications of the three models are compared.

5.2 CONCEPTUAL FRAMEWORK

Figure 5.1 presents the framework of the employer adoption process suggested by Yen and Mahmassani (1994), and describes the relationships within the choice process and between the environment and adoption choice. The decision to adopt telecommuting is complex because it results from the interaction of environmental and organization-related factors. Differences in culture, structure, business activity, and size among organizations further enhance this complexity. Depending on organizational rigidity, the decision process may be impromptu or dictated by protocol. This process may involve an individual or a team. Depending on the decision-making structure, a model for individual or group choice behavior needs to be formulated to represent the adoption process.

The employer's decision to adopt telecommuting, regardless of the decision process or the size of the decision group, is influenced by five major factors: executive characteristics, perceptions and attitudes toward telecommuting, organizational characteristics, the telecommuting program's economic implications, and task suitability. These factors, identified in

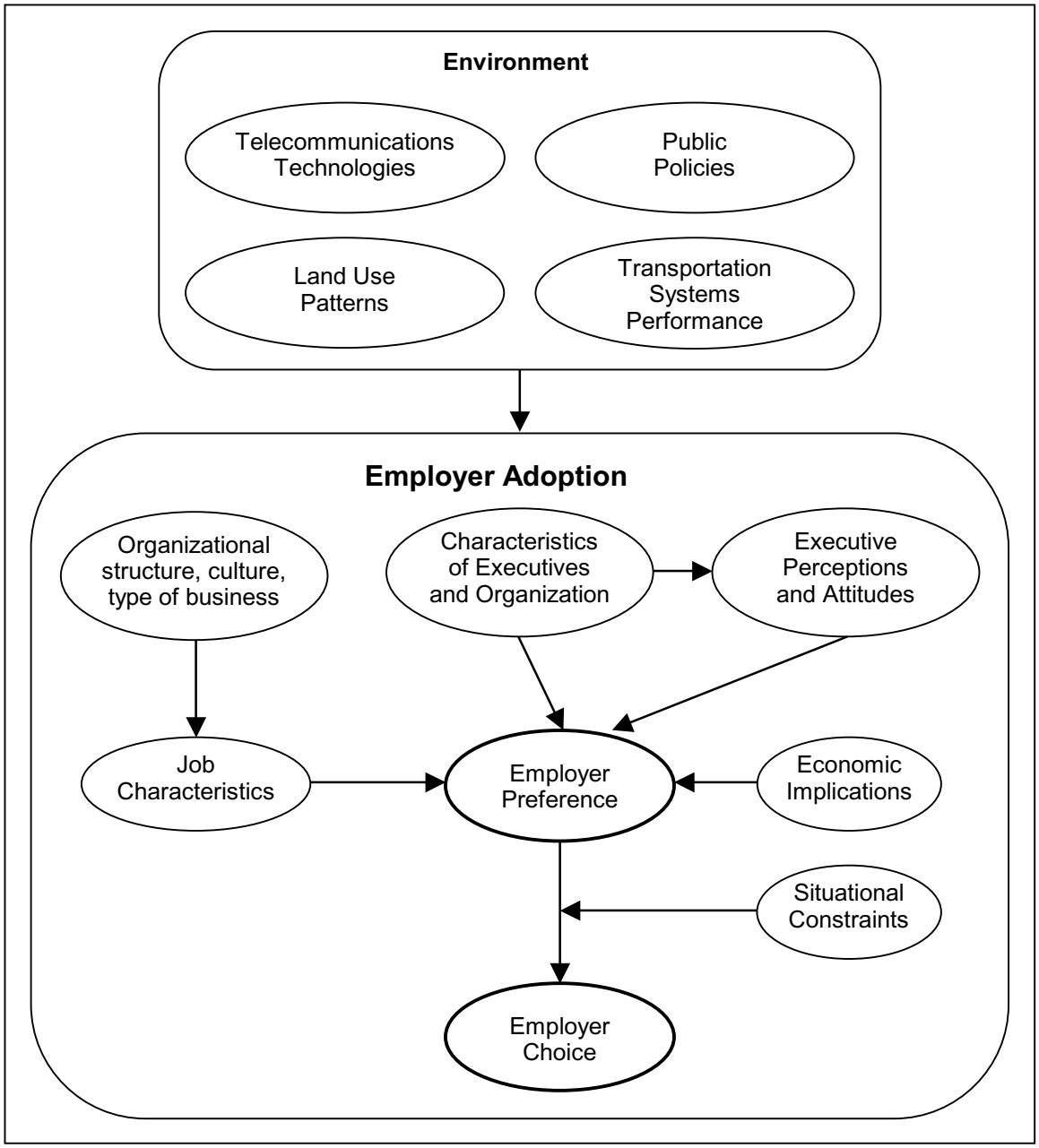

Figure 5.1 The employer adoption process.

the analysis conducted by Yen and Mahmassani (1994), are confirmed by the exploratory analysis of Chapter 4 to significantly influence telecommuting preferences. These factors form the basis for the explanatory components incorporated in the choice modeling.

5.3 MODELS AND SPECIFICATIONS

Of the 300 executive surveys included in the exploratory analysis, 272 could be used for model estimation. The stated response to the telecommuting preference questions, as presented in Chapter 4, is discrete and ordered. Responses to nine telecommuting program scenarios are elicited from each respondent, indicating his/her willingness to support a telecommuting program of given characteristics (corresponding to each scenario) within his/her organization.

The executive willingness to support telecommuting is a continuous latent variable (Y) whose outcome is measured by a discrete ordered variable, y, ($y \in$ {no, possibly, yes}). The transformation from the observed ordinal indicator variable to the underlying continuous latent variable is given in terms of an unknown threshold vector, m, given by equation 5.1 (Golob, 1990; McKelvey and Zavoina, 1975).

$$y = \begin{cases} \text{yes} & \text{if } \mu_3 \leq Y \\ \text{maybe} & \text{if } \mu_2 \leq Y < \mu_3 \\ \text{no} & \text{if } \mu_2 > Y \end{cases} \qquad 5.1$$

This latent variable is assumed to be a function of specific attributes and random disturbances. The attributes included in the specification for the systematic component of the latent variable and are those which were identified in Chapter 4 to significantly influence executives' preferences for telecommuting. The systematic components of latent variables in each model are assumed to be linear both in variables and in parameters.

The models are common in their specification of the systematic component. They differ in the treatment of the observed variable (ordinal versus binary) and in the ability to capture correlation which exist in the data. In the following sections the three models are presented and specified for estimation.

5.3.1 Ordinal Probit Model with Constant Thresholds

The ordinal probit model proposed by McKelvey and Zavoina (M-Z) (1975) is presented as follows. Let Y^t_n be a latent random variable which is a measure of the utility or attractiveness of promoting telecommuting associated with a particular telecommuting program scenario t (t = 1, ..., T; T = 9) as perceived by an individual n (n = 1 to N, N = 272) who is faced with J ordered choice

alternatives (J = 3; no, possibly, and yes). Assume that Y^t_n has a measurable systematic component V^t_n and an unobservable random disturbance u^t_n. The systematic component is a function of a vector of known attributes (X^t_1, X^t_2, ..., X^t_m) to be specified according to hypothesized relations, and a vector of unknown parameters (β_0, β_1, ..., β_m) to be estimated. Also, let μ_{0n}, μ_{1n}, ... , μ_{jn} be a set of utility thresholds constant across individuals. We assume then, that the latent variable, , and associated thresholds are specified as:

$$Y^t_n = V^t_n + u^t_n \qquad 5.2$$

$$\mu_{jn} = a_j \qquad 5.3$$

where

$$V^t_n = \beta_0 + \beta_1 X^t_1 + \beta_2 X^t_2 + ... + \beta_m X^t_m \qquad 5.4$$

and aj, j = 1, 2, ..., J are constant thresholds to be estimated. It is assumed that the error terms are independently and identically normally distributed as follows:

$$u^t_n \sim N(0, \sigma^2) \qquad 5.5$$

The term σ^2 is the variance of the disturbance term. Equation 5.5 suggests that the error terms u^t_n are independently and identically distributed across decision scenarios and the decision makers. In effect, the data set can be viewed as NT decisions rather than N decision sets.
Since Y^t_n is unobservable and only discrete choices made by individuals are revealed, let Z^t_{jn} be an observed variable with value 1 or 0 such that for a given t and (j=1, 2,..., J):

$$Z^t_{jn} = \begin{cases} 1 & \text{if individual n chose alternative i} \\ 0 & \text{otherwise} \end{cases} \qquad 5.6$$

The assumption of ordered response implies that $Z^t_{jn} = 1$ if and only if $\mu_{j-1,\,n} < Y^t_n < \mu_{jn}$ and that $Z^t_{jn} = 0$, otherwise, where μ_j is the upper threshold associated with alternative j and mj-1 is the lower threshold associated with alternative j. As the utility thresholds are constant across decision instance (scenario) and individuals, the subscripts n and t are not required for the thresholds and thus is removed henceforth. Then for 1 < j < J, the probability function of the observed dependent variable, Z, can be written as:

$$\Pr\left[Z^t_{jn} = 1\right] = \Phi\left[\frac{\mu_j - V^t_n}{\sigma}\right] - \Phi\left[\frac{\mu_{j-1} - V^t_n}{\sigma}\right] \Leftrightarrow$$

$$\frac{\mu_{j-1} - V^t_n}{\sigma} \le \frac{u_n}{\sigma} < \frac{\mu_j - V^t_n}{\sigma} \Leftrightarrow \mu_{j-1} \le V^t_n + u_n < \mu_{jn} \qquad 5.7$$

$$L^* = \log L = \sum_{n=1}^{N}\sum_{t=1}^{T}\sum_{j=1}^{J} Z^t_{jn} \log\left(\Phi\left[\mu_j - V_n\right] - \Phi\left[\mu_{j-1} - V_n\right]\right) \qquad 5.8$$

where $\Phi(x)$ is the standard normal cumulative distribution function evaluated at x. To remove the problem of under-identification in equation 5.6, it is assumed without loss of generality that $\mu_1 = 0$ and $\sigma = 1$. The corresponding log likelihood function is presented in equation 5.8.

The ordinal probit model shown by equations 5.2 to 5.8 assumes that for a particular decision situation the utility thresholds are constant and identical across the population and that the disturbance of the latent variables are assumed to be independently and identically distributed. Furthermore, the model does not account for the serial correlation of responses by each decision maker; thus, rather than 275 decision sets, 2448 (272 X 9) choices are available in the estimation process. These assumptions, although unrealistic, are often made in the literature, and are imposed to facilitate estimation. Estimation results are presented and discussed in section 5.3.

5.3.2 Binary Dynamic Probit Model

The second model is calibrated by relaxing the assumption that responses from a given individual across different scenarios are independent of each other. Thus, it attempts to capture auto-correlation of the responses. The response set of a given individual across different scenarios is treated as a vector, similar to a sequence of responses over time. The procedure proposed by James Heckman (1981) for the longitudinal analysis of unidimensional binary choice data is utilized along with the auxiliary alternative method of implementation suggested by Daganzo and Sheffi (1982), and previously implemented by Chang (1988), Mahmassani (1990), and Jou (1994) in the analysis of commuter day to day choices. This model specification does not recognize the ordered nature of responses; thus, the choice set is transformed from 'yes,' 'possibly,' and 'no' to 'yes' (alternative 1 = yes) and 'no' (alternative 0 = possibly/no). The binary dynamic probit model specification is presented as follows.

Let the choice set for individual n (n = 1, ..., N; N = 272) and scenario t (t = 1, ..., T; T = 9) be represented by alternatives 0 and 1. Using a random utility maximization (RUM) framework for analysis, let Y^t_n be latent random variable which is a measure of the utility or attractiveness of promoting telecommuting as perceived by individual n in the binary choice for scenario t. Assume that Y^t_n has a deterministic component V^t_n and a random component u^t_n such that:

$$Y^t_n = V^t_n + u^t_n \qquad 5.9$$

Since Y^t_n is unobservable and only discrete choices made by individuals are revealed, let δ^t_n be an indicator variable with values 1 or 0 such that:

$$d_n^t = \begin{cases} 1 \text{ if individual n chooses alternative 1for scenario t} \\ 0 \text{ if individual n chooses alternative0 for scenario t} \end{cases} \quad 5.10$$

Also, given that the modeling of a random variable crossing a threshold is identical for the binary case to the modeling under the RUM principle, the respective probabilities that individual n chooses alternative 0 or 1 can be expressed by the following:

$$Pr^t_n [1] = Pr[Y^t_n \quad 0] = Pr[V^t_n + u^t_n \quad 0] \quad 5.11a$$

$$Pr^t_n [0] = Pr[Y^t_n < 0] = Pr[V^t_n + u^t_n < 0] \quad 5.11b$$

Equations 5.11a and 5.11b can be written more compactly by the use of the indicator variable:

$$Pr[\delta^t_n] = Pr[(1-2\delta^t_n)(V^t_n + u^t_n) \leq 0] \quad 5.12$$

Extending this to the implementation of the auxiliary alternative the time dimensionality is removed. Suppose $Y^*_n (0^*)$ is the utility associated with an auxiliary alternative 0^* for individual n and that $Y^*_n (0^*) = 0$. Similarly, the utility associated with the chosen alternative (c_t) during scenario t is $Y^*_n (c_t)$ where:

$$Y^*_n (c_t) = (1-2\delta^t_n)(V^t_n + u^t_n), \ \forall \ t = 1, ..., T \quad 5.13$$

Thus, there are T+1 alternatives, of which one is the auxiliary alternative, 0^*, with zero utility. Equation 5.12 can then be rewritten as:

$$Pr[\delta^t_n, \ \forall \ t = Pr[Y^*_n (0^*) > Y^*_n (c_t) , t=1, ..., T] = Pr_n[0^*] \quad 5.14$$

Under the assumption of multivariate normal error terms ε^t_n , the model can be estimated as a multinomial probit with T+1 choice alternatives, and the choice probabilities are formed by a T dimensional integral. As such, this is the probability of observing a particular sequence by an individual. Making the assumption that individuals in the sample make decisions independently of each other, the log likelihood L* will be:

$$\sum_{n=1}^{N} \log(Pr [\delta^t_n, \ \forall \ t = 1, \ ..., \ T]) \quad 5.15$$

This specification is estimated using the multinomial probit code (Lam, 1991) adapted for the above dynamic binary specification by Jou (1994). In order to estimate the dynamic probit model two components must be specified: the systematic component of the latent variable (V^t_n) and the variance-covariance structure of the random component $\sum_u$. Following are these specification:

$$Y^t_n = \beta X^t_n \quad 5.16$$

$$\sum_u = \begin{cases} \sigma^2_{ii} \text{ for i = 1, 2, ..,9} \\ \rho_{ij} \text{ for i} \neq \text{j} \end{cases} \quad 5.17$$

where $X_n^t = \left[X_{1,n}^t \; X_{2,n}^t \; \ldots \; X_{m,n}^t\right]$

$\beta = \left[\beta_0 \; \beta_1 \; \ldots \; \beta_m\right]$

m = number of explanatory variables used in systematic component

σ^2_{ii} = variance of disturbance component for program scenario i

ρ_{ij} = correlation between disturbance components i and j.

Telecommuter salary is expected to be the single most important factor in willingness to support telecommuting. Salary remains the same for scenarios 1, 2, and 3 (block 1), increases for scenarios 4, 5, and 6 (block 2), and decreases for scenarios 7, 8, and 9 (block 3); thus, correlations within each block of three are expected to be positive and between blocks to be negative. Furthermore, for simplicity and due to estimability constraints, it is assumed that for each individual the variances are the same across the t scenarios, and the correlations are the same within each block set. Equation 5.19 presents the suggested variance-covariance matrix for estimation. Estimation results are presented in section 5.3.

$$\sum_u = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{array} \\ \begin{bmatrix} \sigma^2 & \alpha^2 & \alpha^2 & \alpha\zeta & \alpha\zeta & \alpha\zeta & \alpha\gamma & \alpha\gamma & \alpha\gamma \\ \alpha^2 & \sigma^2 & \alpha^2 & \alpha\zeta & \alpha\zeta & \alpha\zeta & \alpha\gamma & \alpha\gamma & \alpha\gamma \\ \alpha^2 & \alpha^2 & \sigma^2 & \alpha\zeta & \alpha\zeta & \alpha\zeta & \alpha\gamma & \alpha\gamma & \alpha\gamma \\ \alpha\zeta & \alpha\zeta & \alpha\zeta & \sigma^2 & \zeta^2 & \zeta^2 & \zeta\gamma & \zeta\gamma & \zeta\gamma \\ \alpha\zeta & \alpha\zeta & \alpha\zeta & \zeta^2 & \sigma^2 & \zeta^2 & \zeta\gamma & \zeta\gamma & \zeta\gamma \\ \alpha\zeta & \alpha\zeta & \alpha\zeta & \zeta^2 & \zeta^2 & \sigma^2 & \zeta\gamma & \zeta\gamma & \zeta\gamma \\ \alpha\gamma & \alpha\gamma & \alpha\gamma & \zeta\gamma & \zeta\gamma & \zeta\gamma & \sigma^2 & \gamma^2 & \gamma^2 \\ \alpha\gamma & \alpha\gamma & \alpha\gamma & \zeta\gamma & \zeta\gamma & \zeta\gamma & \gamma^2 & \sigma^2 & \gamma^2 \\ \alpha\gamma & \alpha\gamma & \alpha\gamma & \zeta\gamma & \zeta\gamma & \zeta\gamma & \gamma^2 & \gamma^2 & \sigma^2 \end{bmatrix} \end{array} \qquad 5.19$$

5.3.3 Dynamic Generalized Ordinal Probit Model

The dynamic generalized ordered probit (DGOP) model approach developed by Yen and Mahmassani (1994) in their analysis of employer stated preferences for telecommuting is appropriate for the problem addressed here for three reasons: (1) unlike conventionally ordinal probit, the DGOP specification allows stochastic rather than constant utility thresholds (2) it allows correlation among disturbances of latent variables and (3) like the dynamic probit, it considers observations with serial correlation. This model structure, although most appropriate theoretically, is problematic in terms of calibration because of the complexities in decomposition of large variance-covariance matrices, and because the corresponding log-likelihood function is not

globally concave and often leads to local optima in the search for parameter values in the estimation procedure.

Three major components need to be specified in order to estimate the choice model using the DGOP framework: the systematic components of the latent variable and the utility thresholds, and the variance-covariance structure of the disturbances of both the latent variable and the utility thresholds. The specification of the systematic component of the latent variable is of the same form as the ordinal probit model (see equations 5.9 and 5.10) with the addition of one alternative. The specification of the utility threshold is different from that of the ordinal probit in that thresholds are not constants. The probability that an individual n will select a specific set of alternatives for the nine scenarios is given by equation 5.20, and the corresponding log likelihood is given by equation 5.21 (Yen and Mahmassani, 1994).

$$P(\mu^t_{k^t-1} \le Y^t_n < \mu^t_{k^t} \mid \mu^t_0 < \mu^t_1 < \ldots < \mu^t_j, t = 1,2,\ldots,T) \times$$
$$P(\mu^t_0 < \mu^t_1 < \ldots < \mu^t_j, t = 1,2,\ldots,T) \qquad 5.20$$

$$L = \sum_{n=1}^{N} \sum_{k^{tn}=1}^{J} \delta_{k^{tn}} \ln[P(\mu^t_{k^t_n-1} \le Y^t_n < \mu^t_{k^t_n} | \mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{jn}, t = 1,2,\ldots,T)]$$
$$+ \sum_{n=1}^{N} \ln[P(\mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{jn}, t = 1,2,\ldots,T)] \qquad 5.21$$

Specifications of the utility threshold and variance-covariance components are discussed below in turn.

5.3.3.1 Utility Threshold Specification: The respondent's attitudes toward telecommuting are believed to affect his/her preferences for supporting telecommuting programs (Yen 1994). The influence of these attitudes is reflected in the utility thresholds of the model shown by equation 5.22 through the four factors developed in Section 4.4.2. Table 5.1 lists the regression weights for each factor, from which the directly measured twelve attitude scores of each executive can be transformed to the four factor scores suggested for the systematic specification of the utility thresholds.

Three alternatives are possible in the executive survey; thus, four utility thresholds (labeled from 0 to 3) require specification. It is assumed that the systematic component of the utility threshold is the same across the nine scenarios for each threshold. Moreover, because only relative magnitudes of the utility thresholds matter, the lowest utility threshold (μ_{0n}) is set to negative infinity, the highest threshold (μ_{3n}) is set to positive infinity, and the mean value of the second threshold (μ_{1n}) is set to zero (McKelvey and Zavoina, 1975). These assumptions leave

only the systematic component of μ_{2n} to be specified. This component is also taken as a linear function of known attributes. In equation 5.22, F_{2n} is a function of specific attributes and α_2 is the parameter set corresponding to F_{2n}.

$$\begin{aligned} \mu_{0n} &= -\infty \\ \mu_{1n} &= \varepsilon_{1n} \\ \mu_{2n} &= \alpha_2 F_{2n} + \varepsilon_{2n} \\ \mu_{3n} &= +\infty \end{aligned} \qquad 5.22$$

TABLE 5.1 FACTOR SCORE REGRESSION COEFFICIENTS ON THE MEASURED EXECUTIVE ATTITUDES

	General Attitudes (Factors)			
Variable	1	2	3	4
1. agency's ability to retain and recruit employees	0.118	-0.013	0.115	0.017
2. telecommuting employee productivity	0.341	-0.037	0.332	0.049
3. non-telecommuting employee productivity	-0.011	0.207	0.032	0.011
4. overall staff productivity	0.265	0.081	0.175	0.056
5. telecommuting employee morale	0.105	-0.011	0.103	0.015
6. non-telecommuting employee morale	-0.036	0.659	0.101	0.036
7. overall employee absenteeism	0.107	0.033	0.070	0.022
8. the agency's public image	0.091	-0.010	0.088	0.013
9. your ability to manage your workload	0.039	0.028	0.055	0.178
10. your ability to communicate with your staff	0.070	0.051	0.099	0.322
11. your ability to supervise your staff	0.079	0.057	0.111	0.359
12. security of data and information	0.015	0.011	0.021	0.069

5.3.3.2 Variance-Covariance Structure Specification: The above assumptions require the specification of two disturbances (ε_{1n} and ε_{2n}) associated with the utility thresholds and one random component (u^t_n) for the latent variable. The DGOP model assumes that u^t_n and ε_{in} are multivariate normally distributed. Thus, the general variance-covariance structure of the telecommuting model disturbances is a 27 by 27 matrix, with three elements for each of the nine scenarios. This variance-covariance matrix, Σ, is presented by equation 5.23

$$\sum = \begin{array}{c} \\ u \\ \varepsilon_1 \\ \varepsilon_2 \end{array} \begin{array}{c} \begin{array}{ccc} u & \varepsilon_1 & \varepsilon_2 \end{array} \\ \begin{bmatrix} \Sigma_{uu} & \Sigma_{u\varepsilon_1} & \Sigma_{u\varepsilon_2} \\ \Sigma_{u\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_2} \\ \Sigma_{u\varepsilon_2} & \Sigma_{\varepsilon_1\varepsilon_2} & \Sigma_{\varepsilon_2\varepsilon_2} \end{bmatrix} \end{array} \qquad 5.23$$

The following two assumptions are made regarding the variance-covariance structure:

1. The covariances of ($u^t_{n,}$ ε^τ_{jn}) and of (ε^τ_{in}, ε^τ_{jn}) are assumed to be zero for all $i \neq j$, and t, $\tau \in$ (1, 2, ..., 9).
2. For each individual, variances and covariances of disturbances of two thresholds or of the latent variable are assumed to be the same across the nine scenarios.

With these restrictions, six parameters need to be estimated in the 27¥27 symmetric variance-covariance matrix. The form of the diagonal sub-matrices shown in equation 5.23 is presented in equation 5.24; off-diagonal sub-matrices are zero. Estimation results are presented and discussed in Section 5.3.

$$\sum_u = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{array} \\ \begin{bmatrix} \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i \\ & \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i \\ & & \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i \\ & & & \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i & \gamma_i & \gamma_i \\ & & & & \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i & \gamma_i \\ & & & & & \sigma_i^2 & \gamma_i & \gamma_i & \gamma_i \\ & & & & & & \sigma_i^2 & \gamma_i & \gamma_i \\ & & & & & & & \sigma_i^2 & \gamma_i \\ & & & & & & & & \sigma_i^2 \end{bmatrix} \end{array} \qquad 5.24$$

5.4 ESTIMATION RESULTS

This section presents the results of parameter estimation of the models specified in Section 5.2 using the survey data described in Chapter 4. Tables 5.2, 5.3, and 5.4 present the estimation results of the ordinal probit, dynamic probit, and DGOP models respectively. Estimation results for each of the three models are discussed in the following sections.

5.4.1 Constant Threshold Ordinal Probit Estimation Results

The SST ordered probit estimation procedure (Dubin and Rivers, 1988) was applied to derive parameter estimates. All variables intended to capture the economic aspects of the telecommuting program are statistically significant. As expected, employer responsibility for some (SC) or all (AC) additional telecommuting costs has a negative effect on executive preference. Full cost responsibility exerts a greater negative effect than partial cost responsibility as suggested by the parameter estimates of -0.406 and -0.236 respectively. Similarly, the coefficient value of -1.744 indicates that an increase in telecommuter salary (SI5) significantly reduces the probability that executives will support such a program, ceteris paribus. A decrease in telecommuter

salary (SD5) also exerts a negative influence on executive willingness to support telecommuting, indicating that programs suggesting salary decreases will not increase the likelihood of executive support. Although salary decreases would reduce organizational costs, executives may perceive it as an unfair policy if the telecommuter maintains or improves job performance.

TABLE 5.2 ORDINAL PROBIT ESTIMATION RESULTS OF EXECUTIVE TELECOMMUTING SUPPORT MODEL

		Parameter	
Attribute Specified in the Latent Term		***Estimates***	***t-statistics***
Constant		-2.115	-9.85
Economic implications			
SI5:	telecommuter salary increase (1 if 5% increase; 0 otherwise)	-1.744	-24.54
SD5:	telecommuter salary decrease (1 if 5% decrease; 0 otherwise)	-1.317	-20.54
SC:	employer responsibility for some telecommuting costs (1 if some cost; 0 otherwise)	-0.236	-3.67
AC:	employer responsibility for all telecommuting costs (1 if total cost; 0 otherwise)	-0.406	-6.19
Executive personal and household characteristics			
AGE:	age (1 if age above 40 years; 0 otherwise)	-0.267	-4.10
DB:	household subscribes to electronic database (1 if yes; 0 otherwise)	0.148	2.12
FT:	familiarity with telecommuting (1 if familiar; 0 otherwise)	0.182	4.42
Executive management/organizational characteristics			
PC:	personal computer to staff ratio (PCR) (1 if PCR > 0.5; 0 otherwise)	0.259	5.66
ER:	manage by evaluating results rather than activity (1 if response 3; 0 otherwise)	0.575	4.47
Executive attitudes and interactive effects			
F1:	effect on telecommuting workers and organizational image (factor regression score; mean=4.0, standard deviation=0.96)	0.529	13.10
IT:	interaction term	-0.468	-7.13
Constant threshold value			
TH:	threshold between possibly and yes	1.091	26.87
Overall Statistics			
Number of observations		2448	
Log likelihood value at zero		-2345.1	
Log likelihood value at convergence		-1722.3	
Rho-square value		0.266	
Adjusted rho-square value		0.264	

It is hypothesized that executives who believe that telecommuting exerts a negative effect on telecommuters and organizational image would be more willing to support salary reduction

programs than those who believe the effect to be positive. Equation 5.25 presents the interaction term developed to test this hypothesis. The general attitudinal factor measuring expected telecommuting impacts on the telecommuter and organizational image is shifted such that its mean is zero, and is multiplied by the indicator variable for salary decrease.

$$IT = SD \times (\text{General attitude } F1 - 4.0) \qquad 5.25$$

TABLE 5.3 DYNAMIC PROBIT ESTIMATION RESULTS OF EXECUTIVE TELECOMMUTING SUPPORT MODEL

		Parameter	
Attributes Specified in the Latent Term		***Estimates***	***t-statistics***
Constant		-2.237	-9.29
Economic implications			
SI5:	telecommuter salary increase (1 if 5% increase; 0 otherwise)	-1.744	-24.54
SD5:	telecommuter salary decrease (1 if 5% decrease; 0 otherwise)	-1.317	-20.54
SC:	employer responsibility for some telecommuting costs (1 if some cost; 0 otherwise)	-0.236	-3.67
AC:	employer responsibility for all telecommuting costs (1 if total cost; 0 otherwise)	-0.406	-6.19
Executive personal and household characteristics			
AGE:	age (1 if age above 40 years; 0 otherwise)	-0.267	-4.10
DB:	household subscribes to electronic database (1 if yes; 0 otherwise)	0.148	2.12
FT:	familiarity with telecommuting (1 if familiar; 0 otherwise)	0.182	4.42
Executive management/organizational characteristics			
PC:	personal computer to staff ratio (PCR) (1 if PCR > 0.5; 0 otherwise)	0.259	5.66
ER:	manage by evaluating results rather than activity (1 if response 3; 0 otherwise)	0.575	4.47
Executive attitudes and interactive effects			
F1:	effect on telecommuting workers and organizational image (factor regression score; mean=4.0, standard deviation=0.96)	0.529	13.10
IT:	interaction term	-0.468	-7.13
Constant threshold value			
TH:	threshold between possibly and yes	1.091	26.87
Overall Statistics			
Number of observations		272	
Log likelihood value at zero		-1405.09	
Log likelihood value at convergence		-614.12	
Rho-square value		0.563	
Adjusted rho-square value		0.532	

The interaction term is zero in all scenarios except those with salary decreases, and thus will have no utility impact except in the three salary decrease scenarios. The interaction variable will be positive when the expected impacts on an executive are greater than the sample average and negative when the expected impacts are lesser than the sample average. This interaction term multiplied by the statistically significant negative parameter estimate of -0.468 confirms that executives with poor impact expectations will derive a lesser negative utility from programs with a salary decrease, than executives with positive impact expectations. Due to the presence of this interaction term, the magnitudes of SI5 and SD5 cannot be compared to reach conclusions as to which variable exerts a greater negative effect on willingness to support telecommuting.

The relative magnitudes of cost-related components (SI5, SD5, SC, AC, and IT) indicate that an employee salary change exerts a much stronger effect on executive willingness to support telecommuting than changes in cost responsibility structures. A change in telecommuter salary is less tolerated by executives than the organization having to assume some or all telecommuting costs.

In terms of executive characteristics, the estimated coefficient of age (AGE, -0.267) confirms that respondents over 40 years of age have a lower probability of supporting telecommuting. Age in itself may not affect telecommuting preference, but rather, may act as a proxy variable for factors such as familiarity and comfort with telecommunications technologies or willingness to adopt change. Executives who are familiar with telecommuting or who subscribe to an electronic database within their homes are more likely to support telecommuting as confirmed by the significant positive coefficients (0.182 and 0.148 respectively).

The variable describing executive management style significantly affects executive support for a telecommuting program. The positive coefficient of management by results, ER, (0.575) implies that all else being equal, those who manage by evaluating results are more willing to support telecommuting than those who rely on task or activity observation based management.

One organizational characteristic, the personal computer to staff ratio (PCR), has a significant effect on the executive propensity to support telecommuting. The positive value of the coefficient estimate (0.259) indicates that executives from organizations with a PCR greater than 0.5 have a greater propensity toward telecommuting support than others.

One of the executive's four general attitudes toward telecommuting is found to significantly affect the executive likelihood of supporting telecommuting. This attitude pertains to the effect of a telecommuting program in telecommuting workers and the image of the organization. As expected, executives who believe impacts to be positive are more willing to support telecommuting programs than those who believe impacts to be negative.

The results in Table 5.2 also indicate that the utility threshold is significant. Model fit statistics such as the adjusted rho-square value (0.264) indicate this specification to be acceptable.

TABLE 5.4 DGOP ESTIMATION RESULTS OF EXECUTIVE TELECOMMUTING SUPPORT MODEL

		Parameter	
Attributes Specified in the Latent Term		***Estimates***	***t-statistics***
Constant		1.759	6.0
Economic implications			
SI5:	telecommuter salary increase (1 if 5% increase; 0 otherwise)	-3.530	-26.0
SD5:	telecommuter salary decrease (1 if 5% decrease; 0 otherwise)	-3.241	-5.6
SC:	employer responsibility for some telecommuting costs (1 if some cost; 0 otherwise)	-0.456	-2.3
AC:	employer responsibility for all telecommuting costs (1 if total cost; 0 otherwise)	-1.383	-1.9
Executive personal and household characteristics			
AGE:	age (1 if age above 40 years; 0 otherwise)	-1.007	-18.0
FT:	familiarity with telecommuting (1 if familiar; 0 otherwise)	0.443	4.2
Executive management/organizational characteristics			
PC:	personal computer to staff ratio (PCR) (1 if PCR > 0.5; 0 otherwise)	0.049	1.4
ER:	manage by evaluating results rather than activity (1 if response 3; 0 otherwise)	-1.758	-3.5
Specification of Utility Thresholds			
Constant			
F1:	effect on telecommuting workers and organizational image (factor regression score; mean=4.0, standard deviation=0.96)	-0.076	-6.4
Specification of Variance-covariance Terms			
σ_u	standard deviation of latent variable disturbance	1.304	13.0
γ_u	Covariance of latent variable disturbance	0.810	4.8
$\sigma_{\varepsilon 1}$	standard deviation of first threshold disturbance	0.434	18.0
$\gamma_{\varepsilon 1}$	Covariance of first threshold disturbance	0.030	0.30
$\sigma_{\varepsilon 2}$	standard deviation of second threshold disturbance	1.134	42.0
$\gamma_{\varepsilon 2}$	Covariance of second threshold disturbance	0.005	0.05
Overall Statistics			
Number of observations		272	
Log likelihood value at zero		-2505.20	
Log likelihood value at convergence		-1419.96	
Rho-square value		0.433	
Adjusted rho-square value		0.406	

5.4.2 Dynamic Probit Estimation Results

The dynamic probit code was a modification of the multinomial probit code developed by Lam (1991) made by Jou (1994). It was applied to obtain the parameter estimates for the model described in Section 5.2.2. Results from this model corroborate the findings of the ordinal probit model with regard to the significance and magnitude of influence of specific attributes on the executive probability to support telecommuting. Model fit statistics such as the adjusted rho-square value (0.532) suggest this model to capture executive behavior and preferences adequately.

The dynamic probit model provides improvement/benefit over the constant threshold ordinal model by the following:

1. Salary increase and decrease actions are shown to exert an equivalent negative effect on executive willingness to support telecommuting (-3.29 versus -3.30) in the dynamic probit model, whereas this could not be shown for the constant threshold ordinal model.
2. Executives from agencies without personal computers are less likely to support telecommuting by a factor of five than executives with a PCR less than 0.5. Although the variable was shown to be significant, the segmentation was not proven significant in the ordinal probit model.
3. The correlation of responses by each individual, not captured in the ordinal probit model, is isolated by this specification and found to be significant.

The positive correlation imposed for salary neutral scenario responses is shown to be significant (α^2 = 0.581, t_α = 4.30). Correlations within and between the set of salary increase scenarios and salary decrease scenarios are positively correlated, and are found to be of the same magnitude (β^2 = 0.0225). Responses within the first three scenarios appear to have much greater correlation than within the last six scenarios. Also, correlations between the first three scenarios and last six are negative ($\alpha\beta$ = -.114). This is because those that are willing to support a salary neutral telecommuting program generally change their disposition when salary changes are involved.

5.4.3 DGOP Estimation Results

The DGOP code, developed by Yen and Mahmassani (1994), was applied to calibrate parameter estimates. Results from this model corroborate the findings of the ordinal probit model with respect to the significance and magnitude of influence of specific variables on the executive probability to support telecommuting.

The dynamic probit model differs from the ordinal and dynamic probit models in the following

ways:

1. Employee responsibility for all telecommuting costs is perceived with over three times as much negativity than partial cost responsibility. This ratio for the ordinal and dynamic probit is much less.
2. The personal computer to staff ratio is significant at the .20 level. Its magnitude is relatively small. In both earlier models this variable proved significant and of much greater magnitude. This is possibly because of the greater number of variables required estimation in this specification.
3. Individual utility threshold is significantly influenced by general attitudes pertaining to telecommuting. This influence is captured by F1 within the specification of the utility threshold.

Of the four general attitudes toward telecommuting, the one pertaining to the effect of telecommuting on telecommuting workers and organizational image is found to significantly affect the utility threshold. The estimated coefficient of -0.076 for F1 indicates that the effect of the attitude is negative, implying that a positive attitude toward telecommuting will reduce the executive's utility threshold, thereby increasing the probability that the executive supports a telecommuting program.

The results in Table 5.4 indicate that all estimates of the specified standard deviations are statistically significant. The correlation coefficients, however, do not prove significant for the utility thresholds. This may not be the case, but may result from poor estimation precision. Model fit statistics such as the adjusted rho-square value (0.406) suggest this model to capture executive behavior and preferences adequately.

5.5 PUBLIC AND PRIVATE SECTOR DGOP MODEL COMPARISONS

Yen and Mahmassani (1994) developed the DGOP framework and estimated the model for private sector executive preferences. This section compares the private sector model results to the public sector model estimated in this work. Table 5.5 presents the results of the private sector DGOP model by Yen (1994). The form of both models is similar in that variables related to economic implications, executive personal characteristics, executive management and organizational characteristics are incorporated in both models, and the utility thresholds maintain the same specification. The variance-covariance structures are similar except that the private sector model included covariances of $u^t_{n,}$ ε^τ_{jn} and of ε^τ_{in}, ε^τ_{jn} when $t = \tau$. These covariances were assumed to be the same across the nine scenarios. Thus, rather than six, nine parameters required estimation for the private sector model.

TABLE 5.5 DGOP ESTIMATION RESULTS OF PRIVATE SECTOR EXECUTIVE TELECOMMUTING SUPPORT MODEL

		Parameter	
Attributes Specified in the Latent Term		***Estimates***	***t-statistics***
Constant		0.229	6.0
Economic implications			
SI5:	telecommuter salary increase (1 if 5% increase; 0 otherwise)	-1.031	-3.5
SD5:	telecommuter salary decrease (1 if 5% decrease; 0 otherwise)	-0.676	-37.0
SC:	employer responsibility for some telecommuting costs (1 if some cost; 0 otherwise)	-0.414	-32.0
AC:	employer responsibility for all telecommuting costs (1 if total cost; 0 otherwise)	-0.572	-22.0
Executive personal and household characteristics			
EA:	executive's educational achievement (1 if master or Ph.D. Degree; 0 otherwise	0.493	12
AW:	awareness of telecommuting (1 if executive knows a telecommuter; 0 otherwise	0.537	19.0
Executive management/organizational characteristics			
JT	executive's job title (1 if president or vice president; 0 otherwise	-0.772	-38.0
SOM:	number of subordinates directly supervised by executive (1 if <=5; 0 otherwise)	0.451	23.0
Specification of Utility Thresholds			
Constant		3.923	
F1:	effect on telecommuting workers and organizational image (factor regression score of executive attitudes)	-0.488	-60.0
F2:	effect on managerial effectiveness and related concerns (factor regression score of executive attitudes)	-0.118	-22.0
Specification of Variance-covariance Terms			
σ_u	standard deviation of latent variable disturbance	1.10	72.0
γ_u	covariance of latent variable disturbance	0.700	19.0
$\sigma_{\varepsilon 1}$	standard deviation of first threshold disturbance	0.773	81.0
$\gamma_{\varepsilon 1}$	covariance of first threshold disturbance	0.755	54.0
$\sigma_{\varepsilon 2}$	standard deviation of second threshold disturbance	0994	100.0
$\gamma_{\varepsilon 2}$	covariance of second threshold disturbance	0.236	27.0
cov(u,e1)	covariance of disturbances of the latent variable and threshold 1	0.192	27.0
cov(u, e2)	covariance of disturbances of the latent variable and threshold 2	0.180	21.0
cov(e1,e2)	covariance of disturbances of threshold 1 and threshold 2	0.281	27.0
Overall Statistics			
Number of observations		272	
Log likelihood value at zero		-2505.20	
Log likelihood value at convergence		-1419.96	
Rho-square value		0.433	
Adjusted rho-square value		0.406	

Variables related to economic implications maintain the largest effect on executive preferences according to both models. Relative magnitudes differ in that private sector executives perceive salary increases with greater negativity than salary decreases. Negative impacts on the propensity to support telecommuting are about the same for salary increase and decrease for the public sector executives. Executive attributes significant for the private sector are not so for the public sector respondents. Executive educational achievement influences private sector executive willingness to support telecommuting. For the public sector executive, age appears to have a significant impact on the probability of supporting telecommuting programs. Familiarity with telecommuting is significant in both cases; however for private sector executives this factor is manifest through awareness of someone who telecommutes, whereas for public sector executives it is manifest through familiarity with telecommuting. In both cases, the coefficient estimates are relatively equivalent magnitude.

Management and organizational attributes also differ between the public and private sector in their willingness to support telecommuting. For the public sector, management style (ER) and penetration of telecommunications technologies (PCR) proved significant, whereas for the private sector executive job title (JF) and management span proved significant (SOM). Job title and management span did not significantly affect preferences of public sector executives. In the utility threshold estimation of the private sector executives, two general attitudes prove significant, F1 and F2. Only F1 proved significant in the public sector executive preference model.

In both models variances of the latent variable and utility threshold disturbances prove significant. The correlation coefficient of disturbances of latent variables under different scenarios prove significant and of relatively similar magnitude for both the public and private sector executive model. The correlations related to the threshold disturbances; however, do not prove significant in the public sector model. This indicates that thresholds are independent across program scenarios.

Overall, both models are comparable. However, executive and organizational characteristics which provide good explanatory power in modeling executive preferences differ across survey groups. This indicates that although the categories of variables are consistent for both the public and private sector, adoption model explanatory variables are rather dependent on the data set. The variable set difference could also occur if perceptions and interpretations of the same attributes by private versus public sector managers may be different.

5.6 SUMMARY

This chapter introduced the telecommuting adoption modeling framework and discussed the adoption process of executives. Ordinal probit, dynamic probit, and DGOP models of executive preference for telecommuting programs were specified and calibrated. All models suggest the same set of attributes to significantly influence adoption preference of executives. Results prove the robust nature of the explanatory variables included in the specification..

The set of explanatory variables includes telecommuting program characteristics such as salary and cost responsibility changes, executive characteristics such as age and telecommuting awareness, and management/organizational characteristics such as the PCR and management by results rather than activity. Correlation of responses to different program scenarios by individual is found to be significant by both models with capabilities to capture correlation.

The DGOP model estimates for the public sector executives were compared to a DGOP model estimate for a sample of private sector executives. Both models indicate economic factors to be of greatest importance in executive preferences. In the private sector salary increases are perceived to have greater negativity than salary decreases whereas salary increases and decreases are perceived with equal negativity for the public sector. Other explanatory attributes differ between the two models, although attribute categories are equivalent.

CHAPTER 6: CONCLUSIONS

The objectives of this study are to develop a systematic process by which telecommuting impacts can be assessed, to implement this process through a telecommuting program, to model the executive telecommuting adoption process, and to compare and contrast telecommuting-related characteristics of public and private sector executives. The first of these objectives has been achieved by performing a comprehensive literature review of hypothesized impacts and empirical tests corresponding to the identified impacts; and consequently, by proposing an evaluation framework that defines the relationships among measurement instruments, time frames, impact categories, and participation groups for a telecommuting program. To meet the second objective, the framework was implemented within the TxDOT Telecommuting Pilot Program. The executive willingness to support telecommuting programs was modeled using three model types: the ordinal probit, the dynamic probit, and the dynamic generalized ordinal probit. Comparisons are performed for the data acquired through the evaluation framework implementation with similar data from Yen (1994). The following presents a summary of the results obtained from this study.

The literature review in Chapter 2 identified three categories of telecommuting impacts (telecommuter and household, organization, and societal) and linked impacts over time frames, adoption penetration and various telecommuter, organizational, and telecommuting program characteristics. The framework developed in Chapter 3 identified three stages for telecommuting program execution, (planning the prototype; implementation; and monitoring, reporting and final roll-out) and concurrent with the latter two stages defined the evaluation framework. The proposed evaluation framework entails a three-phase data acquisition plan wherein information is obtained from the telecommuter, his/her household, his/her supervisor, his/her non-telecommuting co-worker, and various departments within the organization. The first phase documents baseline characteristics associated with the telecommuting program and program participants whereas the second and third phases document changes in these base characteristics corresponding to short-term and stabilized impacts respectively.

The first phase of the evaluation framework was implemented, and partial implementation of the second phase was achieved. Data is acquired by measurement instruments such as telecommuter, supervisor, and executive surveys, as well as travel logs, and accounting processes. Telecommuter and supervisor surveys, and travel logs from the TxDOT pilot program illustrated the identification of factors relevant to telecommuting, and the process of impact analyses. The case study showed travel impacts from telecommuting to be beneficial;

organizational and telecommuter impacts were not assessed.

Chapter 4 addressed the implementation, data acquisition, and data analyses of the executive survey, one of four measurement instruments developed in this work. The exploratory analyses revealed that executive attitudes and preferences toward telecommuting are significantly influenced by personal characteristics and management concerns such as age, management style, familiarity with telecommuting, and organizational telecommunications penetrations. Executives appear to be most favorable toward telecommuting programs wherein telecommuter salaries remain the same and additional telecommuting costs and shared between the organization and the telecommuter.

A comparisons is performed between public and private sector characteristics, attitudes toward telecommuting, and telecommuting adoption preferences. Private sector executive and organizational characteristics appear to be more favorable to telecommuting than similar public sector characteristics. These characteristics include executive age, education level, management style, familiarity with telecommuting, and telecommunications penetration. Attitudes and preferences toward telecommuting of the public sector respondents are overall more favorable than those of the private sector respondents. This may be attributed to the fact that the private sector sample was conducted two years prior to the public sector sample and that telecommuting has in that time gained popularity. Also, the public sector sample was briefed on the benefits of telecommuting. Awareness of the policy considerations that motivate telecommuting may also contribute to this difference as TxDOT employees are highly likely to be aware of the growing concern about air quality, congestion, and fuel consumption.

Models of executive willingness to support telecommuting programs were calibrated based on stated preference responses to a set of telecommuting program scenarios. The estimated model provide the opportunity to identify the significance of specific factors to the attractiveness of telecommuting to executives. Correlation among the disturbances of the latent variable of individual response over the nine scenarios was shown to be significant through the DGOP and dynamic probit model.

Factors associated with economic implications of telecommuting are found to be most important, followed by executive and organizational characteristics. These results are promising for the telecommuting policy maker as control or modifications of cost factors is more feasible than of executive or organizational characteristics.

A major limitation encountered during this research is the absence of adequate telecommuting program participants. For this reason the complete evaluation framework was not implemented. Inferences made from this sample can not be directly projected to the population

as responses originate from a single agency and as all respondents were briefed on telecommuting benefits. Additional research on the individual and aggregate impacts resulting from telecommuting needs to be performed to confirm the findings of limited work to present. Processes to assess longer term impacts related to land use and household structure also need to be developed as such impacts may significantly change the form of shorter term impacts on the transportation system and on energy consumption. Another worthwhile direction for further work would be to compare the models and findings of the adoption preference analysis to results based on actual adoption choice behavior.

APPENDICES

APPENDIX A: EXECUTIVE SURVEY

EXECUTIVE SURVEY

Thank you for participating in our survey. This research is being conducted by the Center for Transportation Research at the University of Texas at Austin. Please answer all questions to the best of your knowledge. All answers, of course, will be kept strictly confidential.

The following questions are related to your occupation and your commute to work.

1. What is your job title ? _____

2. How long have you been employed in your present organization ? ___ years and ___ months

3. How long have you been in your present position? ___ years and ___ months

4. Approximately how many people are employed by your agency at this location ? _____

5. How many employees do you supervise ? _____

6. What is the primary business activity conducted by your unit? _____

7. Approximately what percentage of the people you supervise have completed the following education levels ?
   ____ high school ____ some college
   ____ finished college ____ Master
   ____ Ph. D.

8. Which of the following means of supervision you regularly rely on ? (please check all that apply)
   ____ review meetings ____ activity logs do
   ____ review completed task ____ time-sheets
   ____ on-site supervision ____ written reports

9. Please indicate the number of units of computer hardware available to your staff.
   ____ personal computers
   ____ dedicated word processors
   ____ mainframe terminals

10. How many terminals are inter-connected through an internal network ?
    ____ all ____ more than 75%
    ____ less than 50% ____ none

11. How familiar were you with telecommuting before you received this survey ?

____ very familiar
____ somewhat familiar
____ not familiar

12. Do any employees at your organization telecommute at least part-time ?

____ Yes ____ No ____ Don't know

13. Have you ever worked in an organization that had a telecommuting program ?

____ Yes ____ No

14. Do you know anyone who telecommutes ?

____ Yes ____ No

15. Does your agency sponsor a flexible hours work schedule program ? (i.e. flex-time)

____ Yes ____ No ____ Don't know

16. Would you have the authority to initiate a telecommuting program for your staff ?

____ Yes ____ No ____ Don't know

In the following questions, please circle your response to each question. Numbers 1 to 5 represent your feelings about each item from very negative (1) to very positive (5):

1. Suppose your staff were part of a voluntary telecommuting program in which eligible employees worked from their homes twice a week. What effect do you think such a telecommuting program would have on:

	very negative		neutral		very positive
(a) the firm's ability to retain and recruit employees ?	1	2	3	4	5
(b) telecommuting employee productivity ?	1	2	3	4	5
(c) non-telecommuting employee productivity ?	1	2	3	4	5
(d) overall staff productivity ?	1	2	3	4	5
(e) telecommuting employee morale ?	1	2	3	4	5
(f) non-telecommuting employee morale ?	1	2	3	4	5
(g) overall employee absenteeism ?	1	2	3	4	5
(h) the firm's public image ?	1	2	3	4	5
(i) your ability to manage your workload ?	1	2	3	4	5
(j) your ability to communicate with your staff ?	1	2	3	4	5
(k) your ability to supervise your staff ?	1	2	3	4	5
(l) security of data and information ?	1	2	3	4	5

2. How receptive do you think upper management would be to a voluntary telecommuting program ? 1 2 3 4 5

3. What effect do you think telecommuting could have on improving traffic conditions in your community ? 1 2 3 4 5

4. Do you think a voluntary telecommuting program would be cost-effective ? ___ Yes ___ No ___ Possibly

5. If you had the opportunity to telecommute from home at least part-time would you ? ___ Yes ___ No ___ Possibly

6. Has your work group discussed the potential impacts of telecommuting? ___ Yes ___ No

   If yes, does your work group support the telecommuting program? (please circle your response) 1 2 3 4 5 (not at all – definitely)

7. In what ways would telecommuting affect your task of supervising employees?

_____
_____
_____
_____

8. Do you manage by evaluating results rather than activity? (please circle one)

1	2	3	4	5
not at all				definitely

9. Do you clearly outline your expectations for project priorities, approaches, and expected time lines? (please circle one)

1	2	3	4	5
not at all				definitely

The following questions ask you to think about various work arrangements for your staff in the future. For each question please consider the described situation and check one answer.

1. Would you support a voluntary telecommuting program if,

(a) employee salaries stay the same and the firm incurs no extra costs of working from home?

___ Yes
___ Possibly
___ No

(b) employee salaries stay the same and the firm assumes some costs of working from home ?

___ Yes
___ Possibly
___ No

(c) employee salaries stay the same and the firm pays all costs of working from home ?

___ Yes
___ Possibly
___ No

(d) employee salaries decrease 5% and the firm incurs no extra costs of working from home ?

___ Yes
___ Possibly
___ No (If you answer "No", please go to question 2)

(e) employee salaries decrease 5% and the firm assumes some costs of working from home ?

___ Yes
___ Possibly
___ No

(f) employee salaries decrease 5% and the firm pays all costs of working from home ?

___ Yes
___ Possibly
___ No

(g) employee salaries increase 5% and the firm incurs no extra costs of working from home ?

___ Yes
___ Possibly
___ No

(h) employee salaries increase 5% and the firm assumes some costs of working from home ?

___ Yes
___ Possibly
___ No

(i) employee salaries increase 5% and the firm pays all costs of working from home ?

___ Yes
___ Possibly
___ No

2. Would you support a telecommuting program in which employees worked at a satellite office instead of working from home ?

___ Yes
___ Possibly
___ No

3. Which one of the following statements best describes your feelings about telecommuting ?

___ A. Telecommuting is a valuable tool that allows workers greater flexibility and creates savings potential for firms. Telecommuting should be done as often as possible.

___ B. Telecommuting is an attractive option for some workers and also contains possible benefits for employers. Telecommuting should be considered in some cases.

___ C. Telecommuting might be effective for some workers but carries uncertain benefits for firms and should be approached carefully.

___ D. Telecommuting involves too many constraining elements both for employees and management and should be avoided.

___ E. Other (please comment _____)

4. Do you have any concerns about telecommuting that you wish to discuss with your employees? _____
_____

5. Are you willing to try telecommuting in your work group? (please circle one)

1	2	3	4	5
not at all				definitely

The following questions will be used only in determining our sample demographics

1. What is your gender ? ___ male ___ female
2. What is your age ? ___ under 30 ___ 31- 40 ___ 41 - 50
   ___ 51 - 60 ___ above 60
3. What is your educational level ? ___ finished high school
   ___ some college or university
   ___ finished college or university
   ___ Master
   ___ Ph. D.
   ___ other (specify _____)
4. How many passenger cars (including pick-ups) do you have in your household ? ___
5. Do you subscribe to any electronic data-base or home-shopping service for your home personal computer ? ___ Yes ___ No
6. How far is your residence from your work place ? ___ miles

APPENDIX B: TELECOMMUTER SURVEY

TELECOMMUTING SURVEY

Thank you for participating in our survey. This research is being conducted by the Center for Transportation Research at the University of Texas at Austin. Please answer all questions to the best of your knowledge. All answers, of course, will be kept strictly confidential.

The following questions are related to your occupation and your commute to work.

1. What is your job title ?
   (Examples: Planner, Engineer, Data Entry Clerk) _____

2. How long have you been employed in your present organization ? ___ years and ___ months

3. How long have you been in your present position ? ___ years and ___ months

4. Which of the following best describes your knowledge of your job?
   ___ new to the job and still learning how to do it
   ___ know much of what the job requires, but still need instruction in some areas
   ___ know the job very well

5. How would you best describe your work hours?
   ___ regular work hours
   (from ___:___to ___:___)
   ___ scheduled shift work
   (___ hours per day)
   ___ flexible hours
   (___ hours per week)
   ___ other
   (specify _____)

6. Do you usually work at the same workplace outside the home every day ? (e.g. office, laboratory) ___ Yes ___ No

7. Do you work from home instead of a workplace outside the home ?

___ Yes, everyday.
___ No, not at all.
___ I work from home ___ days per week.

8. Do you currently have the option to work at your home rather than your office either part-time or full-time ?

___ Yes ___ No

9. If you have more than one workplace outside the home, how many days per week do you spend at the main location ?

___ day(s)

10. Do you currently have the option of using another work site that is closer to your home than the central office (such as neighborhood work center)?

___ Yes ___ No

11. Does your job involve fieldwork, and if so how frequent are your field visits?

___ No
___ day(s) per month

12. How far is your residence from your workplace ?

_____ miles

13. On a typical day,

(a) What time do you leave home for work ? ___: ____
(b) What is your travel time from home to your workplace ? _____ minutes
(c) How many stops do you make on your way to work ? _____
(d) How do you commute to work ? (check one)
___ car (alone)
___ car/van pool
___ bus
___ park & ride
___ other (specify _____)

14. On a typical day,

(a) What time do you leave work for home ? ___:_____

(b) What is your travel time from the workplace to home ? _____ minutes

(c) How many stops do you make on your way home ? _____

(d) How do you return home? (check one)

___ car (alone)

___ car/van pool

___ bus

___ park & ride

___ other (specify _____)

15. If you were to telecommute, and you currently car pool, how would it affect your travel?

___ drop out of the car pool

___ arrange car pool schedule to fit telecommuting schedule

___ Other (please explain _____)

16. On your way from home to your workplace, How many times per week do you stop for the following purposes? (please answer all that apply)

___ pick up/ drop off people

___ shopping

___ personal business

___ food

___ work-related errand

___ recreation / social

___ other (specify _____)

17. On your way from your workplace to home, How many times per week do you stop for the following purposes ? (please answer all that apply)

___ pick up/ drop off people

___ shopping

___ personal business

___ food

___ work-related errand

___ recreation / social

___ other (specify _____)

18. If you were to telecommute on certain days, which of the following trips would you still have to make on those days?

___ pick up/ drop off people
___ shopping
___ personal business
___ food
___ work-related errand
___ recreation / social
___ other (specify _____)

19. On a typical work day, how much time do you spend in communication with:

(a) customers or clients	___ hours	and	___ minutes
(b) your supervisor(s)	___ hours	and	___ minutes
(c) your co-worker(s)	___ hours	and	___ minutes
(d) your subordinate(s)	___ hours	and	___ minutes

20. How often do you use the following means of communication with customers or clients:

	not used	1 to 4 times per week	once or twice per day	several times per day
(a) face to face	___	___	___	___
(b) telephone	___	___	___	___
(c) fax	___	___	___	___
(d) electronic mail / computer networks	___	___	___	___
(e) regular mail	___	___	___	___

21. How often do you use the following means of communication with your supervisor(s):

	not used	1 to 4 times per week	once or twice per day	several times per day
(a) face to face	___	___	___	___
(b) telephone	___	___	___	___
(c) fax	___	___	___	___
(d) electronic mail / computer networks	___	___	___	___
(e) regular mail	___	___	___	___

22. How often do you use the following means of communication with your co-worker(s):

	not used	1 to 4 times per week	once or twice per day	several times per day
(a) face to face	___	___	___	___
(b) telephone	___	___	___	___
(c) fax	___	___	___	___
(d) electronic mail / computer networks	___	___	___	___
(e) regular mail	___	___	___	___

23. How often do you use the following means of communication with your subordinate(s):

	not used	1 to 4 times per week	once or twice per day	several times per day
(a) face to face	___	___	___	___
(b) telephone	___	___	___	___
(c) fax	___	___	___	___
(d) electronic mail / computer networks	___	___	___	___
(e) regular mail	___	___	___	___

24. On a typical work day, how much time do you use:

(a) a typewriter ___ hours and ___ minutes

(b) a computer ___ hours and ___ minutes

(c) other equipment ___ hours and ___ minutes (specify _____)

25. Would you like to telecommute? ___ Yes ___ No

If yes, how often would you like to telecommute?

___ twice per month ___ three days per week

___ one day per week ___ four days per week

___ two days per week ___ other (specify _____)

26. If you were to telecommute, could you schedule face to face meetings to free up the number of days checked in Question 25? (please circle your response)

1	2	3	4	5
not at all				definitely

27. If you were to telecommute, could you organize your work so that you do not need equipment, files, or other stationary resources located at the central office on the number of days checked in Question 25? (please circle your response)

1	2	3	4	5
not at all				definitely

28. Do your projects have discrete time lines and deadlines? (please circle your response)

1	2	3	4	5
not at all				definitely

29. How often do your co-workers, managers, clients, or customers call you with questions or request which can only be responded to while at the central office?

___ seldom
___ twice per month
___ one day per week
___ two days per week
___ three days per week
___ four days per week
___ daily

30. Could someone at your central office resolve, or be trained to resolve, the matters mention in Question 29? ___ Yes ___ No

31. Does your job require that you work with confidential information or materials? ___ Yes ___ No

If yes, could you arrange your schedule to accomplish this confidential work on the days when you would work in the office, or could you arrange to take this information with you on telecommuting days? (please circle your response)

1	2	3	4	5
not at all				definitely

32. Has your work group discussed the potential impacts of telecommuting? ___ Yes ___ No

If yes, does your work group support the telecommuting program? (please circle your response)

1	2	3	4	5
not at all				definitely

33. If you were to telecommute, which of the following tasks could you perform on those days?

___ analysis ___ maintaining data bases
___ auditing reports ___ meeting with clients
___ batch work ___ preparing budgets
___ calculating ___ preparing/monitoring contracts
___ reading ___ computer programming
___ record keeping ___ project management
___ data entry ___ conducting business by phone
___ research ___ design work planning
___ dictating ___ sending/receiving E-mail
___ drafting ___ spreadsheet analysis
___ editing ___ thinking
___ evaluations ___ typing
___ field visits ___ word processing
___ graphics ___ writing
___ other (please list _____)

34. Do you currently have enough space to work from home? ___ Yes ___ No ___ Possibly

35. If you were to telecommute, which of the following equipment would you need, and/or currently have at home?

	Would Need	Already Have	
computer (specify type e.g. Pentium, laptop, MAC)	___	___	Type _____
software used at central office	___	___	Software _____ (please list) _____ _____
printer	___	___	
modem	___	___	
additional telephone line	___	___	
call waiting	___	___	
voice mail	___	___	
answering machine	___	___	
facsimile machine	___	___	
other (please list)	___	___	_____

36. How many employees do you supervise? ___ employee(s)

37. If you were to telecommute and currently supervise others, how would it affect your supervision of employee(s)?

_____
_____
_____
_____

38. If you were to telecommute, in what ways would it change the way you do your job?

_____
_____
_____
_____

39. Do you have any concerns about telecommuting that you wish to discuss with your supervisors or co-workers?

_____
_____
_____
_____

In the following questions, please circle your response to each question if applicable. Numbers 1 to 5 represent your feelings about each item from negative (1) to positive (5).

1.	Do you find commuting to work stressful?	1	2	3	4	5
		not at all				definitely
2.	On a typical day, how would you describe the traffic you encounter on your way from home to your workplace?	1	2	3	4	5
		too congested				very smooth
3.	On a typical day, how would you describe the traffic you encounter on your way from your workplace to home?	1	2	3	4	5
		too congested				very smooth
4.	How important is flexibility of your work schedule for accomplishing your household duties?	1	2	3	4	5
		not important				important
5.	Would you like to work independently during more of your work time?	1	2	3	4	5
		dislike				like
6.	How do you feel about learning to use new home equipment for your job?	1	2	3	4	5
		dislike				like
7.	How essential to your work is frequent input from your supervisor or your co-workers?	1	2	3	4	5
		not essential				essential
8.	How important is it for you to attend short-notice meetings during your work hours?	1	2	3	4	5
		not important				important
9.	How important is it for you to have immediate access to information or references which are available only at the office?	1	2	3	4	5
		not important				important
10.	How important to you are social interactions with your co-workers at work?	1	2	3	4	5
		not important				important

11. How important to you are social interactions with your co-workers outside of work?	1 not important	2	3	4	5 important
12. How comfortable are you at discussing problems with co-workers and supervisors?	1 not at all	2	3	4	5 completely
13. How comfortable does your supervisor seem with discussing problems with you?	1 not at all	2	3	4	5 completely
14. How comfortable are you with the way your supervisor communicates with you? (planned or impromptu meetings, telephone, E-mail)	1 not at all	2	3	4	5 completely
15. How comfortable are you with frequency of communication and feedback between you and your supervisor?	1 not at all	2	3	4	5 completely
16. Does you supervisor manage you by evaluating results rather than activity?	1 not at all	2	3	4	5 definitely
17. Do you understand your supervisor's expectation for project priorities, approaches, and expected time lines?	1 not at all	2	3	4	5 definitely
18. How willing is your supervisor to try out telecommuting in your work group?	1 not at all	2	3	4	5 completely
19. Do you think your job is suitable for working from home every day?	1 not suitable	2	3	4	5 very suitable
20. Do you think your job is suitable for working from home several days per week?	1 not suitable	2	3	4	5 very suitable
21. Do you think your supervisor would approve your working from home every day?	1 not at all	2	3	4	5 definitely

22. Do you think your supervisor would approve working from home several days per week?	1 not at all	2	3	4	5 definitely
23. If you could work from home, do you think you could get more work done?	1 not at all	2	3	4	5 definitely
24. If you could work from home, what effect do you think this would have on your chance for promotion?	1 decrease	2	3	4	5 increase
25. If you could work from home, how do you think this would affect your relationship with other household members?	1 adversely	2	3	4	5 beneficially
26. If you could work from home, how supportive would your family (or household members) be?	1 not at all	2	3	4	5 definitely
27. If you could work from home, would potential distractions be a concern?	1 not at all	2	3	4	5 definitely

APPENDIX C: SUPERVISOR SURVEY

SUPERVISOR SURVEY

The following questions pertain to individual staff members under your supervision who have shown interest in a telecommuting work option. Please fill one form for each of these staff members.

1. Please write your employee's name and job title.

   _____ employee name
   _____ employee job title

2. Would you like your employee to telecommute? ___ Yes ___ No
   If yes, how often would you like your employee to telecommute?
   ___ twice/month ___three days/week
   ___ one day /week ___ four days /week
   ___ two days/week ___ other (specify (_____)

3. How often do your employee's co-workers, managers, clients, or customers call him or her with questions or request which he or she can only respond to while at the central office?
   ___ seldom ___ three days/week
   ___ twice / month ___ four days /week
   ___ one day /week ___ daily
   ___ two days /week

4. Could someone at your central office resolve, or be trained to resolve, the matters mention in Question 3? (please circle your response)

1	2	3	4	5
not at all				definitely

5. Could your employee schedule face to face meetings to free up the number of days checked in Question 3? (please circle your response)

1	2	3	4	5
not at all				definitely

6. Could your employee organize his or her work so that he or she does not need equipment, files, or other stationary resources located at the central office on the number of days checked in Question 1? (please circle your response)

1	2	3	4	5
not at all				definitely

7. Do your employee's projects have discrete time lines and deadlines that help him or her assess progress? (please circle your response)

1	2	3	4	5
not at all				definitely

8. Does your employee's job require that he or she work with confidential information or materials? ___ Yes ___ No

   If yes, could your employee arrange his or her schedule to accomplish this confidential work on the days when he or she would work in the office, or can he or she arrange to take this information home on telecommuting days? ___ Yes ___ No

9. Which of the following best describes your employee's knowledge of his or her job?
   ___ new to the job and still learning how to do it
   ___ knows much of what the job requires, but still needs instruction in some areas
   ___ knows the job very well

10. If your employee were to telecommute, which of the following tasks could he or she perform on those days?

___ analysis	___ maintaining data bases
___ auditing reports	___ meeting with clients
___ batch work	___ preparing budgets
___ calculating	___ preparing/monitoring contracts
___ reading	___ computer programming
___ record keeping	___ project management
___ data entry	___ conducting business by phone
___ research	___ design work planning
___ dictating	___ sending/receiving E-mail
___ drafting	___ spreadsheet analysis
___ editing	___ thinking
___ evaluations	___ typing
___ field visits	___ word processing
___ graphics	___ writing
	___ other (please list _____)

11. If your employee were to telecommute, which of the following equipment would he or she need, and/or currently have at home?

	Would Need	Already Have	
computer (specify type e.g. Pentium, laptop, MAC)	___	___	Type_____
software used at central office (please list)	___	___	Software_____ _____ _____
printer	___	___	
modem	___	___	
additional telephone line	___	___	
call waiting	___	___	
voice mail	___	___	
answering machine	___	___	
facsimile machine	___	___	
other (please list)	___	___	_____

12. Is your employee a supervisor? ___ Yes ___ No

If yes, how would his or her telecommuting affect his or her supervision of employee(s)?

_____
_____
_____
_____

13. In what ways would telecommuting change the way your employee does his or her job?

_____
_____
_____
_____

14. What criteria do you use to evaluate your employee's work? Please elaborate.

_____
_____
_____
_____

In the following questions, please circle your response to each question. Numbers 1 to 5 represent your feelings about each item from very negative (1) to very positive (5):

15. Would your employee feel isolated on telecommuting days without the social interaction at the central office?	1 not at all	2	3	4	5 definitely
16. Does your employee fully understand the procedures and policies of your agency?	1 not at all	2	3	4	5 definitely
17. Is your employee comfortable discussing problems with you and his or her co-workers?	1 not at all	2	3	4	5 completely
18. Are you comfortable with the ways your employee communicates with you? (planned or impromptu meetings, telephone, E-mail)	1 not at all	2	3	4	5 completely
19. Are you comfortable with the frequency of communication and feedback between you and your employee?	1 not at all	2	3	4	5 completely
20. Are you comfortable discussing problems with your employee?	1 not at all	2	3	4	5 completely
21. Based on your assessment of your employee's job performance would you be comfortable having him or her telecommute?	1 not at all	2	3	4	5 definitely