Southwest Region University Transportation Center

The Telecommuting Adoption Process: Conceptual Framework and Model Development

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16. Abstract

The substitution of travel by telecommunication has long been advocated as an approach that might alleviate congestion on transportation facilities and thereby reduce fuel consumption and air pollutant emissions. With increasing penetration of telecommunications in individual homes and businesses, coupled with the widespread availability of computing equipment, facsimile capabilities and the like, there is renewed interest in exploring and encouraging telecommuting arrangements. These include work-at-home schemes and workplace decentralization with satellite work centers, as well as many other non-traditional approaches to structure workplace activities and worker responsibilities.

The aim of this report is to propose a comprehensive framework of the interactions between telecommuting and travel behavior, and to develop a mathematical model of the telecommuting adoption process. The framework identifies two principal actors in the decision process, the employee and the employer. The employee faces a decision of whether to participate in a telecommuting program given the program features and his/her personal and household whether to characteristics and circumstances. The employer decides whether to offer a telecommuting program to employees and the features of such a program, given the employer's mission, activities and management concerns. Discrete choice models are employed to formulate the adoption process of both employee and employer.

The derived choice models are based on the ordered-response theory and the normality assumptions of the disturbances, known as the ordinal probit model. While existing ordinal probit models are limited by assumptions of deterministic utility thresholds and identical and independent disturbances of the latent variable, the generalized ordinal probit model derived in this research allows stochastic thresholds and a general variance covariance structure of the disturbances, which enables the model to analyze panel data with serial correlations or auto-correlations. The models are calibrated using stated-preference survey data from three Texas cities.

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THE TELECOMMUTING ADOPTION PROCESS: CONCEPTUAL FRAMEWORK AND MODEL DEVELOPMENT

by

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ABSTRACT

The substitution of travel by telecommunications has long been advocated as an approach that might alleviate congestion on transportation facilities. Among the variety of telecommunications applications such as telecommuting, teleshopping, and teleconferencing, telecommuting is considered one of the most promising substitutes of work trips, the major determinants of traffic congestion and air pollution during peak hours. Although positive effects from telecommuting have been demonstrated through small-scale pilot projects in the U.S.A.., systematic research is still limited.

The aim of this report is to propose a comprehensive framework of the interactions between telecommuting and travel behavior, and to develop a mathematical model of the telecommuting adoption process. The framework identifies two principal actors in the decision process (the employee and the employer), and the dynamic interactions between telecommuting and its environment. The employee faces a decision of whether to participate in a telecommuting program at work, given the program features and his/her personal and household characteristics and circumstances. The employer decides whether to offer a telecommuting program to his/her employees and the features of such a program, given the organization's mission and activities and the executives' management concerns. Discrete choice models are employed to formulate the adoption processes of both the employee and the employer.

The derived choice models are based on the ordered-response theory and the normality assumptions of the disturbances, known as the ordinal probit model. While existing ordinal probit models are limited by their assumptions of deterministic utility thresholds and identical and independent disturbances of the latent variable , the generalized ordinal probit model derived in this research allows stochastic thresholds and a general variance covariance structure of the disturbances, which enables the model to analyze panel data with serial correlations or auto-correlations. In addition, model estimation procedures are implemented by a newly developed computer code that is based on a monte carlo simulation approach and the properties of truncated distribution.

The empirical data are obtained from a survey in three cities. Stated preferences for telecommuting are elicited from both employees and employers for various telecommuting program scenarios. To address the possible auto-correlations existing among responses for the same individual, a general error structure is also specified in the choice model. The estimated results indicate that both the employee and the employer adoption processes are affected by their

attitudes toward telecommuting and the program design, defined on the basis of who assumes the additional costs of telecommuting and the corresponding salary changes for the telecommuter. The employee's choice of telecommuting is also influenced by his/her personal, household and job characteristics as well as commuting attributes (e.g. number of children under 16 and personal computers at home, number of hours communicating with co-workers face-to-face per day). On the other hand, the employer's adoption of telecommuting is mainly affected by management related considerations (e.g. number of subordinates directly supervised by the executive, data security).

In addition to the specification and estimation of the telecommuting choice models of the employee and the employer, an application of the estimated results to the prediction of the extent of potential telecommuting adoption is discussed.

Overall, the derived model formulation and estimation code are not limited to telecommuting research. They are applicable to other travel demand problems with ordered choice alternatives and problems that arise in other disciplines such as management science and sociology.

Executive Summary

Telecommuting is a work arrangement that allows workers to perform their job in a spatially distributed manner, i.e., without the need to be present at one common location. Telecommuting may take several forms, such as work-from-home or at satellite work centers, or at least a few days per week. The attractiveness of telecommuting as a peak-period trip reduction measure is evident, as telecommuters do not need to travel to a central work location, thereby reducing the traffic load on congested facilities during the busiest periods of the day. Telecommuting also offers advantages to workers by increasing their schedule flexibility, and freeing up time that would have otherwise been spent on commuting for other activities, e.g., tending to household matters. Employers also stand to gain in terms of reduced need for office space and parking accommodations, as well as potentially greater productivity due to fewer interruptions and higher employee morale. Nonetheless, certain concerns remain in management's perception, with regard to proper supervision and immediate worker availability in certain situations. Clearly, telecommuting is not for everyone, and not every job is readily telecommutable. However, flexible organizations that can re-engineer the workplace to leverage telecommuters' potential stand to make potentially significant gains, in addition to contributing to the solution of crippling urban congestion and degraded air quality in large metropolitan areas.

Critical to the attainment of any benefits from telecommuting is its adoption by employees and employers alike. This study provides the most thorough and systematic analysis to date of the telecommuting adoption process, and develops a set of mathematical tools to project the potential penetration of telecommuting and its likely impacts in terms of trip reduction and fuel savings. In addition, the model results obtained in this study provide indications and guidelines regarding which factors and associated policies are likely to increase telecommuting adoption by employers and participation by employees. These form the basis for specific implementation directions of the research results.

The results of the analysis suggest that under the most likely prediction scenario, if employers are willing to incur all direct telecommuting costs, possible adoption of some level of telecommuting costs is between 20% and 30% of the population of information workers; if the employer does not incur all additional costs, adoption is between 10% and 20%. Application of the methodology to three Texas cities, Austin, Dallas, and Houston, suggests that the predicted percentage of total workers who work from house every day is equivalent to 5.8% in Austin, 4.9% in Dallas, and 5.0%

in Houston. These percentages would translate into likely potential savings of about 2 to 3.7% of total automotive fuel consumed in these areas, which is equivalent to about 5 to 8% of fuel consumed during the peak period in freeways and main arterials.

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CHAPTER 1
INTRODUCTION

MOTIVATION AND PURPOSE

It is well recognized that travel demand is a derived demand. In microeconomics, a good which is transformed to a final product through some production process is called an intermediate good (Frank, 1991). The demand for an intermediate good is a derived demand because it is induced by the utility of the final good, not the intermediate good itself. Therefore, a trip can be considered an intermediate good in the sense that tripmaking, with time and costs as input, can be interpreted as a production process with the final product as its purpose (Lancaster, 1966). In general, tripmaking is motivated by activities, i.e. final goods, pursued by the tripmaker at the destination of each trip. Working and shopping, for example, provide the motivation for commuting and shopping trips, respectively. This recognition has led to an emerging approach to travel behavior research, broadly referred as activity-based analysis (Kitamura, 1990; Jones, 1990), and its application to transportation demand management (TDM).

The underlying rationale for TDM is that changes in tripmakers' activity types can induce changes in their travel demand patterns, such as the choices of departure time, route, mode, and destination. Flexible work hours is such a policy, aimed at diverting the commuter's departure time by allowing flexible activity schedules (work hours in this instance), thereby relieving traffic congestion during peak hours. While traditional TDM strategies seek to move trips from peak hours to off-peak periods, new schemes that involve the application of telecommunications technology have the potential to altogether eliminate a fraction of total trips. The basic idea of such schemes is to substitute the movement of people and goods on transportation networks with information flows on telecommunications networks. For instance, in-store shopping can be viewed as an information acquisition activity (Salomon and Koppelman, 1988) that could be attained via other communications media such as a mail-order catalog or a home-shopping computer network. The present study is motivated both by the recognition of travel demand as derived demand and by the potential of recent advances in telecommunications technology.

The possible substitution of transportation by telecommunications has long been advocated as an approach that might alleviate the demand for travel and congestion on transportation facilities and hence reduce energy consumption and air pollution. With the increasing popularity of telecommunications developments, approaches such as telecommuting, teleshopping, teleconferencing, telebanking, and tele-education have been proposed as potential substitutes of physical travel. Among these, telecommuting is considered one of the most promising substitutes of work trips, which are the major determinants of traffic congestion and air pollution during peak hours. It is also suggested that telecommuting offers the potential to increase social welfare by providing job opportunities to workers with disabilities who may not be able to work otherwise.

Several limited experiments and pilot programs have demonstrated some positive effects of telecommuting. However, there has been little in-depth investigation of the complex interactions between telecommuting and transportation. These interactions are essential to the success and effectiveness of telecommuting programs. In addition, the telecommuting adoption process itself has not been fully addressed. Thus, the purpose of this study is to address the apparent dearth of research in this area by systematically investigating the interactions of telecommuting and travel behavior and mathematically formulating the telecommuting adoption process. Specifically, a conceptual framework is first proposed. This framework identifies the relationships between telecommuting and its environment, the decision-makers involved in telecommuting adoption, and factors which affect this adoption process. Following this theoretical structure, a mathematical model of the choice process is developed to analyze the telecommuting adoption process, and a corresponding estimation procedure is also designed. Finally, the results of an empirical realization of the above model using survey data from three Texas cities are presented, including the prediction of telecommuting adoption and savings in fuel consumption due to telecommuting.

LITERATURE REVIEW

The concept of the "electronic homeworker" was first proposed in the automation literature in 1957 (Jones, 1957). It was not until the 1970's, however, that this idea received public attention, motivated primarily by the so-called energy crisis (Huws, 1991). The term "telecommuting" was initially coined by Nilles and defined as "the partial or total substitution of telecommunications for the daily work trip" (Nilles *et al.*, 1976; Nilles, 1988). Telecommuting was apparently first conceived as a full-time and home-based option, and presumed to be suitable only for information-related workers. It is now recognized that telecommuting does not need to be full time, and that jobs need not be necessarily information-related to be telecommutable, though such jobs will remain primary targets for telecommuting. It is also recognized that working from home is not the only possible type of telecommuting (Mokhtarian, 1992). For instance, Nilles defines four (spatial) types of telecommuting: (1) home based, (2) satellite centers, (3) local centers, and (4) neighborhood centers (Nilles, 1988). Home based telecommuting refers to an individual working from home instead of a traditional office. Satellite centers are buildings set up by organizations to accommodate their own employees who commute fewer miles to the (suburban) centers than to the main offices. Local centers are set up to accommodate telecommuters from different organizations. Local centers serve the same function as satellite centers, but are shared by different companies or agencies, while the latter are sponsored by a single organization. Neighborhood centers are similar to small satellite or local centers but consist of facilities intended to accommodate fewer workers who live just a few blocks from the center.

Telecommuting received public attention again in the 1980's due to increasing concerns over urban traffic congestion and air quality. Since then, telecommuting has been proposed as one element of a broader array of measures aimed at reducing work trips and auto emissions during peak hours. In addition, it is advocated as an opportunity for parents with young children or workers with disabilities to more fully participate in the labor force (Yap & Tng, 1990; Woelders, 1990) and thus may have potential to increase the work force and social welfare. Furthermore, some managers believe that a properly designed telecommuting program may enhance their company's image as providing a good work environment, thereby improving their ability to recruit and retain qualified employees (Katz, 1987). Other advantages of telecommuting are also mentioned in the literature (DeSanctis, 1984; Katz, 1987; Salomon & Salomon, 1984). For participating employees, the major advantages include: (1) less travel time and costs, (2) fewer distractions during work hours, (3) more scheduling flexibility to meet family needs, and (4) greater opportunities to participate in community activities. For organizations with a telecommuting program, the major purported advantages include: (1) lower overhead costs for offices, (2) less turnover, (3) higher employee productivity, and (4) better morale of telecommuters.

Several possible disadvantages are also identified (DeSanctis, 1984; Katz, 1987; Salomon & Salomon, 1984). For employees, these include: (1) less opportunity for social interaction with co-workers, (2) fewer opportunities for on-the-job learning from senior workers, (3) possibly lower salary under some scenarios, and (4) fewer opportunities for promotion. For companies, the major possible disadvantages include: (1) potentially high initial investment, (2) difficulty of performance measurement, (3) resistance from management, (4) resistance from workers' unions, and (5) less data security. Also, some researchers have indicated that telecommuting should not only be viewed as a transportation or management issue, but also as a psychological and sociological issue because it affects the life styles of both telecommuters and their household members (Salomon & Salomon, 1984; Christensen, 1988).

In addition to identifying advantages and disadvantages of telecommuting, efforts have been made to conceptualize the interactions between transportation systems and telecommunications applications. Among these, three possible relationships between telecommunications and travel (i.e. substitution, enhancement, and complementarity) and three expected impacts of telecommunications on the demand for transportation (short-term direct, short-term indirect, and long-term) have been proposed in the literature (Salomon, 1985; Salomon, 1986; Mokhtarian, 1990). The first relationship (substitution) assumes that some demand for travel will be replaced by telecommunications. The second (enhancement), in contrast with the first, anticipates the introduction of telecommunications technology to increase the use of transportation systems. The third possible relationship, complementarity, refers to the situation where both transportation and telecommunications systems will enhance the efficiency of each other (Salomon, 1985; Salomon, 1986). In terms of potential impacts of telecommunications on transportation, Mokhtarian (1990) considers short-term direct impacts as the possible substitution or stimulation of travel due to telecommunications. Short-term indirect impacts would arise if time-savings from the replacement of travel by telecommunications are used to generate other trips. Long-term impacts are associated with the changes of land use patterns facilitated by telecommunications.

Notwithstanding limited qualitative speculation on possible implications of telecommunications on transportation and management, as well as preliminary quantitative analyses of results from small-scale pilot projects, no theoretical framework for investigating the interactions between telecommuting and transportation has been reported to date. Similarly, no effort to establish a mathematical model of the telecommuting adoption process appears to have been reported. Limited systematic inquiry and conceptual framework development has been reported in the literature for other branches of telecommunications applications (e.g. teleshopping and teleconferencing). Salomon and Koppelman (1988), for example, developed a framework for teleshopping behavior research. Manski and Salomon (1986) employed a random utility model to analyze experimental data and investigate attributes which affect the choice of teleshopping. Moore (1987) and Moore and Jovanis (1988) constructed a conceptual framework of organizations' communication media choices and used this structure as the foundation for an empirical study.

RESEARCH OBJECTIVES

Recognizing the need to systematically investigate the interactions between telecommuting and travel behavior, and mathematically model the telecommuting adoption process, this study attempts to build a comprehensive conceptual framework as a guide to future research. This research also seeks to develop a model of the adoption of telecommuting that can be used to predict the potential impacts of telecommuting on both transportation systems and organizations. Specifically, the objectives of the present research are:

1) to synthesize current results of telecommunications related studies scattered in different disciplines such as travel behavior, organizational behavior, management, economics, psychology, and geography,
2) to develop a conceptual framework (in which the interactions of telecommuting and travel behavior are identified) as a guideline for mathematical model development,
3) to derive a mathematical formulation for modeling the telecommuting adoption process,
4) to propose an estimation procedure, including a method of evaluating the individual choice probability function for the specific structure of the derived model,
5) to systematically examine the survey data obtained from employees and executives and estimate two corresponding choice models based on the derived formulation, and
6) to apply the estimated choice models to the prediction of employee and employer adoption of telecommuting, and savings in fuel consumption.

Although not defined in the initiation of the study, a secondary objective has been achieved in the present research. Specifically, to formulate the telecommuting adoption process, this research derives a new class of discrete choice models and develops a procedure to estimate model parameters. While the prevalent discrete choice models are based on the utility maximization assumption, the new model is based on the ordered-response theory, which is discussed in the following sections. In addition, the model formulation and the estimation code developed in this research are not limited to telecommuting research. They are applicable to other travel demand problems with ordered choice alternatives and problems that arise in other disciplines such as management science, education, and sociology.

RESEARCH APPROACH

To achieve the objectives listed in the previous section, a conceptual framework of the interactions between telecommuting and travel behavior is proposed. The framework identifies two principal actors in the telecommuting adoption process (the employee and the employer), and the dynamic interactions between telecommuting and its environment. Following the proposed framework of telecommuting adoption, an empirical study is conducted based on data obtained from a survey in three Texas cities (Austin, Dallas, and Houston). Two sets of data are obtained to represent the respective decision-makers (the employee and the employer) involved in the telecommuting adoption process. An exploratory analysis of the survey data is conducted to identify important factors that affect the decision makers' attitudes and preferences toward telecommuting.

The results of the exploratory analysis and the causal relationship recognized in the telecommuting adoption framework provide the basic rationale for the specification of the telecommuting adoption models for both employee and employer. The model formulation and estimation are based on the derived ordered-response model discussed in the following section. While the employee choice model is aimed at modeling his/her own participation in a telecommuting program, the employer model is to formulate his/her decision to support such a program in the organization.

In addition to the specification and estimation of the telecommuting choice models, application of the estimated results is discussed. First, the extent to which telecommuting will be adopted for both employees and employers is predicted based on some aggregate scenarios. The elasticity of telecommuting demand is also calculated and interpreted from the perspective of microeconomics theory, including price elasticity, cross-price elasticity, and generalized income elasticity. Finally, savings in fuel consumption due to telecommuting in three Texas cities are predicted.

SPECIAL FEATURES OF THE DERIVED ORDERED-RESPONSE MODEL

Telecommuting adoption is formulated as the outcome of discrete choice processes. Most of the discrete choice models in the literature are grounded in random utility maximization, which assumes that the decision maker facing a finite set of discrete choice alternatives will choose the alternative from which he/she derives the greatest perceived utility. Depending on the assumed error structure, two models forms are widely known in the literature: the multinomial logit (MNL) model, with the assumption of independently and identically Gumbel distributed disturbances, and the multinomial probit (MNP) model with a general multivariate normally distributed error structure.

Though the MNL and MNP models have been successfully applied to transportation problems such as the choice of mode or route, they may not be suitable for decision problems with ordered alternatives where random utility maximization may not be applicable. For example, a customer's response to a five-score measurement of attitudes toward the quality of import cars (say very bad, bad, fair, good, and very good) cannot be formulated by either the MNL or MNP models. It appears that an alternative approach is necessary to model choice problems with ordered responses. The ordered-response model maps the range of a continuous latent variable onto a set of discrete outcomes. For instance, for a given decision situation, a latent variable represents the decision maker's perceived utility or attractiveness toward the decision object of interest. A set of ordered thresholds for the latent variable associated with each decision maker define ranges corresponding to each discrete decision outcome. The decision-maker's choice then depends on the corresponding interval within which the perceived utility or attractiveness lies.

The derived model of the telecommuting adoption process is based on the ordered-response theory and the normality assumption of the disturbances of the latent variable and utility thresholds, and known as the ordinal probit model. The first ordinal probit model with multiple-alternatives was proposed by McKelvey and Zavonia (M-Z) (1975). The M-Z model assumes that for a particular decision situation the decision maker's utility thresholds are constant and identical across the population, and the disturbances of latent variables are independently and identically distributed (IID). These two strong assumptions are believed to be unrealistic in general because different decision-makers may have different utility thresholds, and latent variables may not be independent of utility thresholds.

A generalized ordinal probit model is developed in this study to capture possible stochastic features of utility thresholds and allow a more general specification of the latent variables. First, in the proposed formulation, utility thresholds can be specified as a function of attributes of the decision content or characteristics of the decision maker and thus are no longer constant. Secondly, the model assumes random utility thresholds and allows the existence of correlations among utility thresholds and the latent variable. Finally, this model is able to analyze both cross-section data and observations with serial correlation or autocorrelation such as panel data (time-series data) or stated-preferences elicited from the same individual.

In addition to the derivation of the model formulation, a maximum likelihood procedure is also developed and coded to estimate the parameters specified in both the systematic components and the variance-covariance matrix of the generalized ordinal probit model. This estimation procedure includes a Monte Carlo simulation approach to evaluate the choice probability of each individual and the BFGS Quasi-Newton method with a backtracking line search method in the nonlinear optimization procedure.

STRUCTURE OF THE REPORT

This report is organized as follows. A conceptual framework is presented in chapter 2 in which the interactions between telecommuting and travel behavior are identified. Environmental factors that influence telecommuting decisions and possible impacts from the adoption of telecommuting are also discussed. Chapter 3 presents the concepts of proposed telecommuting choice models. Chapter 4 summarizes the survey method, general characteristics of the empirical data used in this study, and the exploratory results. The specification and estimation of the employee telecommuting choice model are presented in chapter 5, followed by a discussion of the employer's model in chapter 6. Chapter 7 applies the estimation results of both choice models to the prediction of the extent of potential telecommuting adoption, the elasticity analysis of telecommuting demand, and potential savings in fuel consumption. Finally, chapter 8 concludes the report and points out some desirable future research.

CONTRIBUTIONS OF THE STUDY

The major contribution of this study is two-fold. In the theoretical part, this research derives the generalized ordinal probit model, proposes, and implements the estimation procedure. Unlike traditional discrete choice models, the derived mathematical model is based on the ordered-response theory and therefore is suitable for decision problems with ordered alternatives, which may not be consistent with utility maximization. In addition, the derived model allows the specification of random utility thresholds and can analyze observations with serial correlation or autocorrelation, which is a major limitation of existing ordinal probit models in the literature, yet a very important feature to capture the dependence within the dynamic behavior phenomenon or the autocorrelations among stated preferences elicited from the same individual.

In the application part, the present research proposes a comprehensive framework of the interactions between telecommuting and travel behavior and the telecommuting adoption process, which is currently not available in telecommuting literature. The derived ordered-response model is successfully applied to the empirical data from a telecommuting survey in three Texas cities. The estimation results have policy implications in that they identify factors that influence employee and employer preferences for telecommuting, as well as the relative importance of these factors. The ability to predict telecommuting adoption achieves the ultimate and most important objective of telecommuting research because the extent to which telecommuting is adopted determines the potential impacts of telecommuting on transportation systems. Finally, fuel savings are estimated according to predicted telecommuting penetration.

CHAPTER 2
CONCEPTUAL FRAMEWORK: INTERACTION BETWEEN TELECOMMUTING ADOPTION AND THE ENVIRONMENT

INTRODUCTION

A comprehensive conceptual framework is proposed in this chapter to address the complex interactions between the telecommuting adoption process and its environment. This framework serves as the basis for the subsequent model development and empirical study in this research. It could also provide an organizing framework to guide future telecommuting research. The dynamic nature of the telecommuting adoption process is recognized in this conceptual structure. The adoption process is dynamic in that telecommuting adoption, a joint outcome of employee and employer decisions, is influenced by four environmental (exogenous) factors: telecommunications technologies, transportation systems performance, public policies, and land use patterns. The consequences of telecommuting adoption typically induce changes in the travel behavior of telecommuters and their household members, household activity allocation and car ownership decisions, as well as the location choices of residences and organizations. These impacts will in turn affect the environmental factors. Figure 2.1 illustrates the interaction taking place over time.

The following section discusses the interactions between telecommuting and its environment, including external factors that affect telecommuting adoption and the impacts resulting from this adoption process. After that, the telecommuting adoption process itself and its two primary types of decision-makers (employees and employers) are described .

INTERACTIONS BETWEEN TELECOMMUTING AND THE ENVIRONMENT

The dynamic structure proposed in Figure 2.1 is further refined in Figure 2.2, which depicts a modulized framework aimed at modeling the complex interactions between telecommuting adoption and its environment. Three main modules are incorporated in this framework. The environmental module includes three sub-modules: activity system sub-module, transportation system sub-module, and land use pattern sub-module. The telecommuting adoption module consists of two sub-modules: the employee adoption model and the employer adoption model. The telecommuting impact module contains three sub-modules corresponding to three different levels of telecommuting impacts on the environment: short-term, medium-term, and long-term.

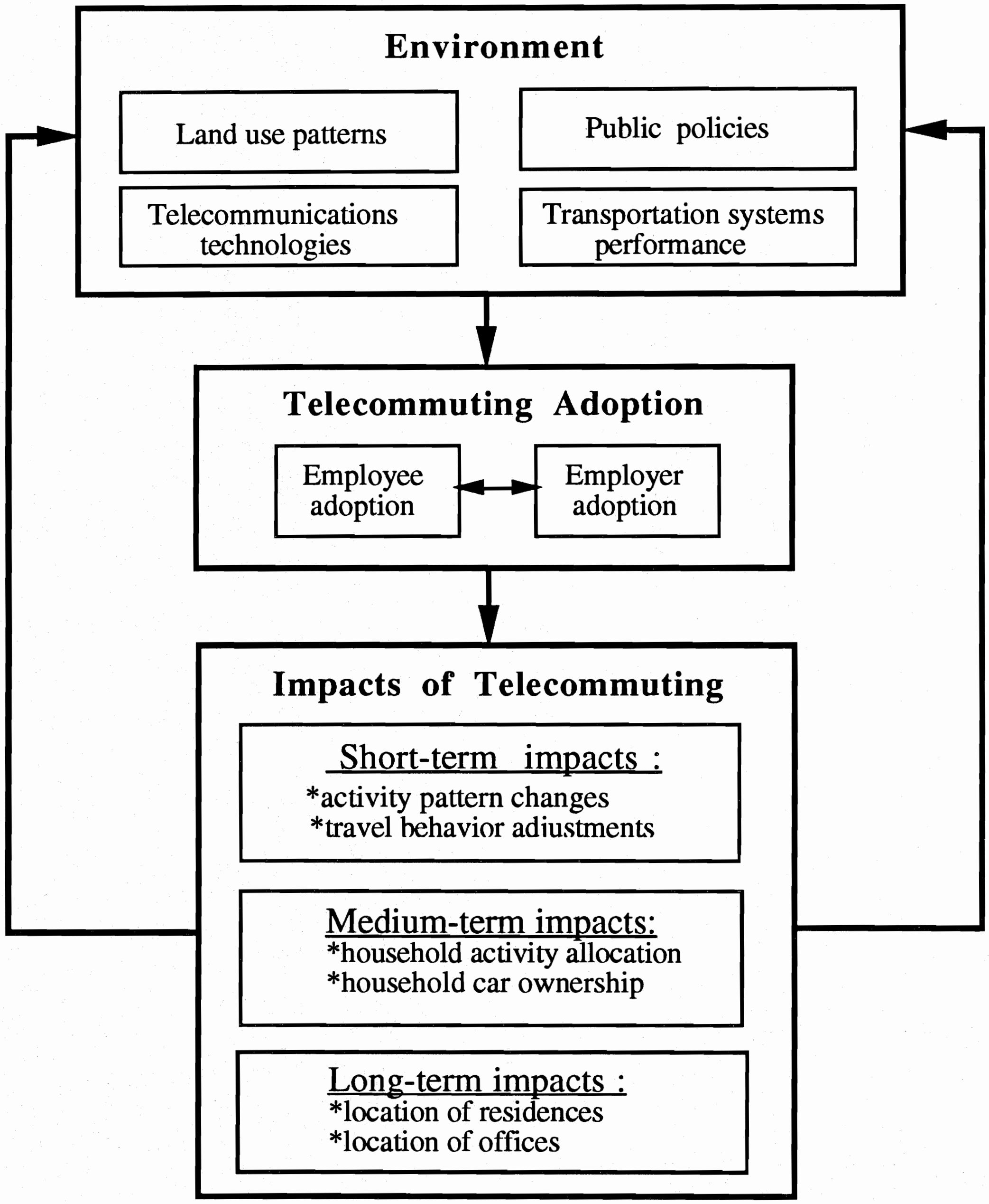

Figure 2.1 Interaction between Telecommuting Adoption Process and External Environment

The Environment of Telecommuting Adoption

As discussed in chapter one, travel demand is derived from the need or desire to participate in activities at the destination. The derived nature of transportation demand is highlighted by the strong interaction among the transportation system, the activity system and the land use pattern recognized in the transportation planning literature (Meyer and Miller, 1984). Figure 2.2 illustrates this relationship. Conceptually, the aggregate travel demand on transportation systems derived from each individual's activities motivates capacity addition to the transportation infrastructure and/or policy measures to manage the resulting congestion. These changes in the transportation system influence the land use pattern in the community, which in turn affects individuals' activities. Empirically, in order to predict travel demand and the associated performance of the transportation system, traditional transportation planning procedures use different types of land use models to predict future economic activities in the area of interest. The results of land use models and demographic data then provide the input to the four-stage transportation planning process intended to project the performance of the transportation system for the particular land use pattern under consideration (Manheim, 1979; Paquette *et al.*, 1982; Meyer and Miller, 1984).

Although a plethora of critiques of the traditional four-stage procedure can be found in the literature, it remains well entrenched in transportation planning practice. Recent policy concerns such as air quality, congestion management and advanced technologies have led to renewed interest in alternative transportation planning methodologies. In practice, activity-based approaches to travel demand analysis appear particularly attractive. Their basic premise is that the activities (motivated demand and final goods) instead of trips (derived demand) should be at the center of demand analysis procedures. Activity-based approaches are particularly appropriate to analyze the transportation impacts of telecommunications technology applications. The latter can directly and indirectly influence activity patterns as they have the potential to transform the movement of people and goods on transportation networks by information transmission on telecommunications networks.

A wide variety of telecommunications applications with potential impacts on transportation have been reported in the literature: telecommuting, teleconferencing, teleshopping, telebanking, tele-entertainment, and tele-education (Mokhtarian, 1990). Different relationships between these applications and transportation have also been proposed. As discussed in chapter one, substitution involves the replacement of travel by telecommunications, enhancement refers to the generation of additional trips due to the introduction of

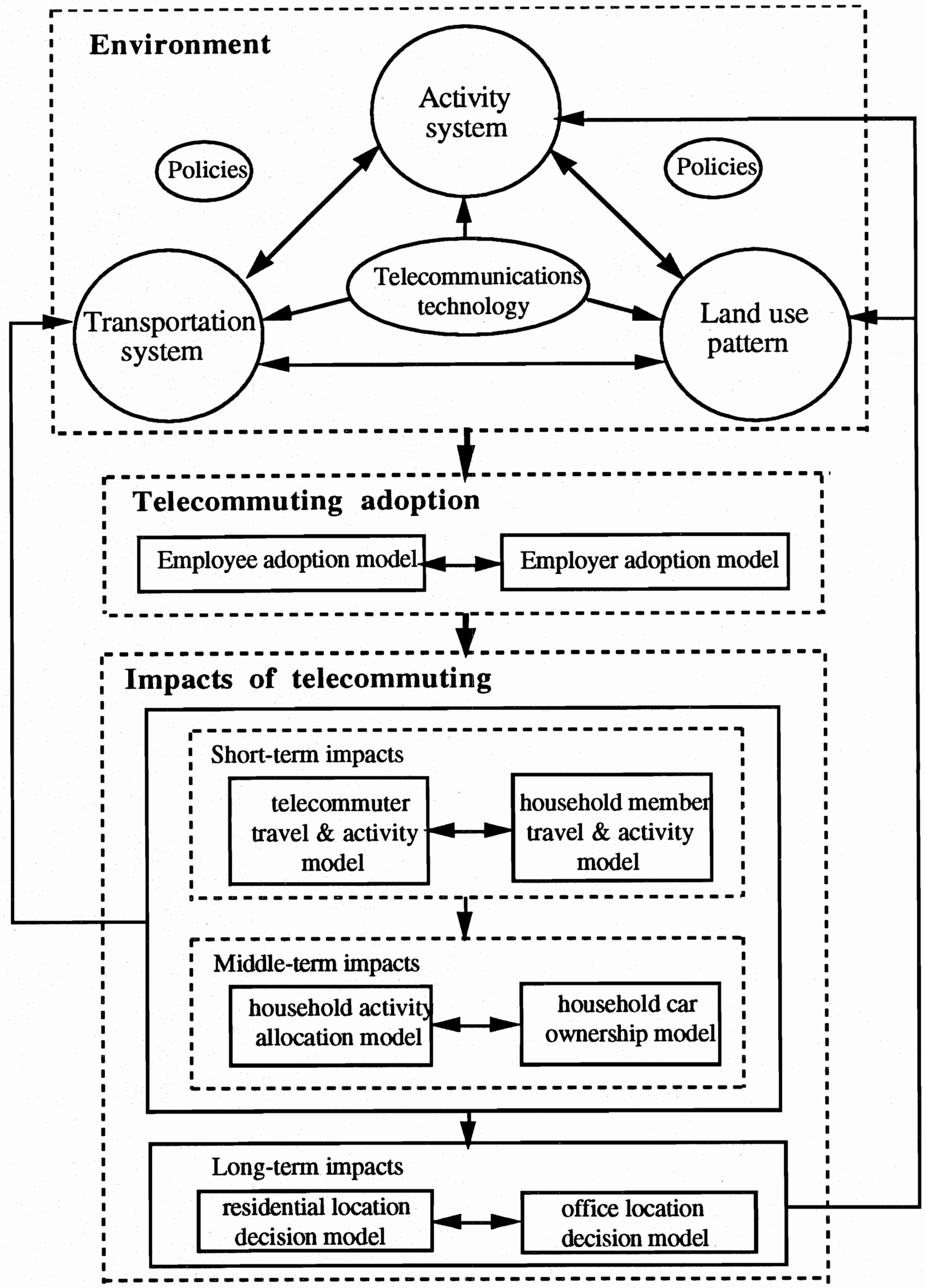

Figure 2.2 Formulation of the Interactions between Telecommuting Adoption Process and the Environment

telecommunications, while complementarity implies increased efficiency of both telecommunications and transportation (Salomon, 1985; Salomon, 1986). Findings to date in this regard are very limited and somewhat contradictory. For example, Mokhtarian (1988) reported an increase of travel as a result of a pilot teleconference, while Kitamura *et al.* (1990), Pendyala *et al.* (1991) and Nilles (1991) documented replacement of travel in some pilot telecommuting projects. Essentially, long-term data are insufficient to reach firm conclusions, and the nature of the relationship undoubtedly depends on the type of application (e.g. telecommuting or teleconferencing). However, results to date indicate the existence of these relationships; hence it is important to include the implications of telecommunications technology in transportation planning procedures.

In addition to the need for theoretical development and empirical investigation of the net relationships between telecommunications and transportation at the individual tripmaker or household level, network-wide effects need to be addressed. The latter have not received enough attention in the literature to date. Network impacts are pertinent in terms of two advocated advantages from telecommunications applications: energy savings and congestion/delay reduction during peak hours. It has long been recognized that transportation infrastructure improvements tend to generate additional demand for travel that is attracted by better service levels (Adler, 1987). Therefore, it may not be unreasonable to expect at least part of the potential savings from telecommunications applications to be offset by induced demand.

The development of telecommunications technologies may also affect land use patterns and hence the economic and social activity system. For example, Kutay (1986) argued the importance of communication networks as a determinant of office location, paralleling the role of transportation systems in regional economic development (Adler, 1987). To the extent that telecommunications networks might be a substitute for transportation systems in the future, they may be expected to play a role in the growth of economic activities and spatial distribution of industry. Thus businesses today with high information-related activities may be located where easy access to telecommunications networks is available (Salomon, 1988).

Policies and regulations enacted by the public sector may target telecommunications technologies, the transportation system, or the land use pattern. Intervention by governments is primarily on the supply side of these factors, and may include control of market structure, pricing, and level of service (through standards). Such supply side actions will affect the demand side as well. Control of market structure refers to governmental regulation of ownership in the industry. Different ownership control policies may lead an industry to a market with perfect competition, monopoly, monopoly competition, or oligopoly and hence affect the efficiency of suppliers as well as their actions in areas such as pricing. Control of prices and level of service influences market demand and the revenue of suppliers. As a result, public policies have a bearing on the supply of and demand for telecommunications technologies, transportation facilities, and land development and therefore affect the telecommuting adoption process.

Impacts of Telecommuting Adoption: Transportation Aspects

The impacts of telecommuting derive primarily from the changes of travel behavior (e.g. frequency, departure time, trip chaining) and activity patterns of the telecommuter. Some pilot projects indicate that such changes may also be expected by household members of the telecommuting adopter (Kitamura *et al.*, 1990). These travel behavior and activity modifications may take place immediately after the start of telecommuting and are thus labeled short-term impacts in Figure 2.1. Models addressing both telecommuters and their household members are necessary to capture these short-term impacts (Figure 2.2).

It is expected that telecommuting households may reallocate activities among their members in order to adapt to the new work and travel pattern of the telecommuter. For example, a former commuter who usually drops a child off at school on the way to the office and purchases groceries on the way back home would no longer do so during telecommuting days, unless he/she makes morning and evening trips specifically for these purposes. These duties may be transferred to other household members who still drive to work, or the pattern of some these activities (e.g. shopping), namely frequency, time of day, or day of week may change. The reallocation of household activities may interact with the relative priority of car use among household members and perhaps lead to a reduction of household car holdings. These medium-term effects emphasize the possible influence of telecommuting adoption on household activity allocation and car ownership. Figure 2.2 illustrates that these effects could be formulated through two interdependent models.

The kinds of changes described above may also cause eventual reconsideration of household residential location. It has been argued that the tendency to move farther from work results from a combined influence of the increase of private transportation and the motivation to live in suburbs (Nilles, 1991), i.e. the increase of mobility tends to reinforce the household's impetus to move farther. To the extent that telecommuting increases mobility, it is believed to influence household residential location decisions. Furthermore, a household might move closer to the workplace location of a non-telecommuting household member. Insufficient evidence is available to confirm the impact of telecommuting on household residential location. During a two-year telecommuting pilot project in California, about 50% of the respondents who either relocated or were thinking about it reported that telecommuting influenced their residential location decisions. However, a formal statistical test did not reject the hypothesis that the household shift patterns are not significantly different between telecommuters and non-telecommuters (the control group) (Nilles, 1991).

Office location decisions of organizations are affected by information and communication technologies as well. This phenomenon has two aspects. The first is concerned with the impacts from the broad penetration of telecommunications technology and has been discussed in the previous section, focusing on the need for certain organizations to locate where they can access telecommunications networks. The second refers to the influence of telecommuting adoption on the location choice of an individual organization. By implementing a telecommuting program, the organization has the opportunity to locate its offices in areas where infrastructure costs are generally less than traditional office locations such as downtown areas. Consequently, telecommuting provides the organization with greater flexibility to locate its offices. The possible relocation of telecommuting households and the offices of organizations with telecommuting programs form the long-term impacts indicated in Figure 2.2.

As indicated in Figure 2.2, it is mainly the short-term and medium-term impacts, i.e. the changes of travel patterns and activities at individual and household levels, that affect the performance of the transportation system. To the extent that work trips have been recognized as the major determinants of energy consumption by vehicles, the change in commuting travel behavior has a bearing on energy savings as well. The long-term impacts, on the other hand, influence land use patterns and the activity system through the location decisions of households and organizations.

Impacts of Telecommuting Adoption: Management Aspects

Though not of principal concern in this study, a brief discussion of the impacts of telecommunications technology from a management perspective is worthwhile for the investigation of employer telecommuting adoption addressed in the next section.

Major management implications of telecommuting can be categorized into short-term and long-term influences. The former are concerned with the impacts on employee productivity, morale, and turnover. The latter refer to the possible modification of organizational structures and strategic decision processes due to the adoption of telecommuting programs in the organization.

Several results from pilot telecommuting projects indicate positive influences in terms of an increase in productivity and morale and a decrease in turnover associated with telecommuters. No long-term results are currently available in the literature. Yen (1992) proposed that organizations with telecommuting alternatives will tend to have more formal structure and will become more decentralized in terms of spatial dispersion but more centralized in terms of the decision-making process.

The impacts of telecommunications media on group decisions have been reported in the literature as well. The results, however, vary depending upon the type of communication media. Rawlines (1989), for example, found that small groups in a face-to-face decision-making meeting required less time than an audio-only teleconference with the same decision context. In addition, leaders were perceived to play a bigger role in the face-to-face decision process than in teleconferencing. On the other hand, Kiesler and Sproull (1992) reported that while a "computer-mediated" discussion might take longer than a face-to-face meeting, it allows "more equal participation among group members."

TELECOMMUTING ADOPTION PROCESS

The telecommuting adoption module includes two principal decision-makers, the employee, who decides whether or not to participate in a given telecommuting program, and the employer, who decides whether or not to initiate such a program. Two choice models are included in this module: the employee adoption model and the employer adoption model. Figure 2.2 depicts the telecommuting adoption process under the dynamic telecommuting-environment interaction framework, and Figure 2.3 illustrates these two choice processes.

The Employee Adoption Process

The employee faces the decision situation of whether to work from home or to drive to work, given the characteristics of the available telecommuting program, the nature and requirements of his/her work, his/her characteristics and those of his/her household as well as his/her perceptions and attitudes toward telecommuting. Situational constraints such as facility and work space availability at home also affect the employee's preferences toward telecommuting, which in turn guide his/her choice. The conditions associated with the telecommuting program, such as decrease (or increase) in salary or compensation are also expected to influence the employee's willingness to telecommute. The detailed framework of this adoption process is shown in Figure 2.3. To summarize, several groups of factors may influence employee

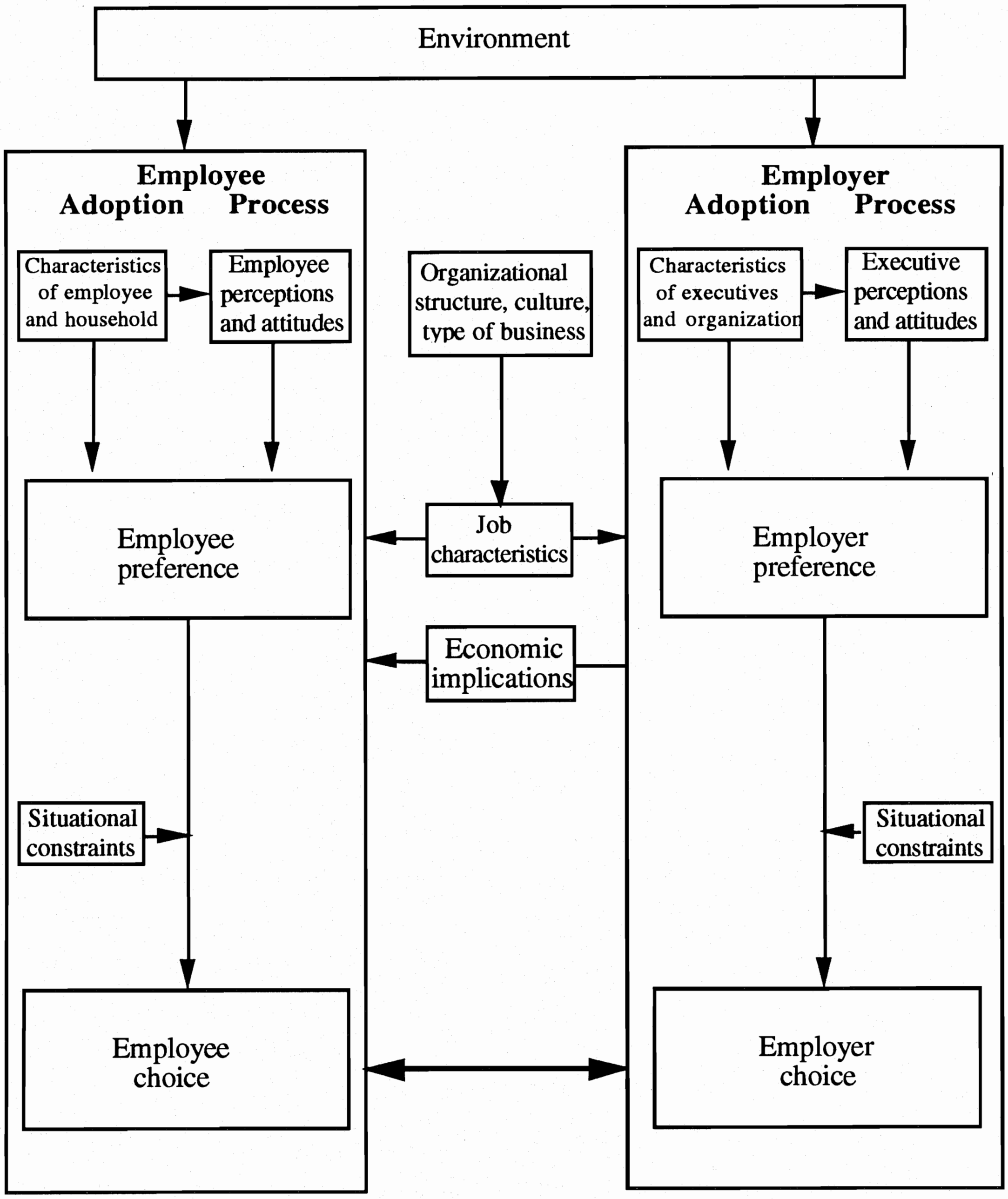

Figure 2.3 The Telecommuting Adoption Process

telecommuting adoption: (1) commuting trip attributes experienced by the employee, (2) employee characteristics, (3) employee activity patterns, (4) household characteristics, (5) household situational constraints, (6) household residential location, (7) employee perceptions and attitudes toward telecommuting, (8) employee job characteristics, and (9) possible economic implications from telecommuting. These are discussed in turn hereafter.

Commuting trip attributes experienced by the employee reflect influence of the transportation system performance on telecommuting adoption. Travel time, average speed, and delay are the most common indices of system performance perceived by the employee. It may be assumed that people who incur worse trip attributes have greater motivation to telecommute (Yap and Tng, 1990; Mahmassani *et al.*, 1993). The empirical findings vary, however. For example, Mahmassani and his co-authors (1993) found that travel time did affect employee telecommuting adoption in a stated-preference survey in Texas, USA, while Yap and Tng (1990) did not find significant correlation between travel time and telecommuting attitudes based on a survey in Singapore. However, the latter authors suspected that their results reflected the fact that 90% of the respondents did not incur long travel times.

Employee personal characteristics such as gender, age, marital status, educational achievement, and computer proficiency level are believed to have a bearing on telecommuting adoption, too. Age and marital status serve as lifecycle indicators, and educational achievement is an index of lifestyle in the activity-based analysis literature (Bhat, 1991). It is assumed that both personal educational attainment and computer proficiency have positive effects on telecommuting adoption, namely people with higher education or computer proficiency are more likely to telecommute. Lifecycle is an important index, too. For example, married employees have been reported to be more likely to prefer telecommuting (Yap and Tng, 1990). Gender has also been identified as an important factor in telecommuting adoption. Prevailing findings indicate that women tend to have a higher motivation to telecommute (DeSanctis, 1984; Mahmassani *et al.*, 1993).

The employee's activity patterns reflect his/her current household responsibility allocation which influences his/her travel behavior and eventual decision to telecommute. In activity-based analysis, trip chaining is generally used to gain insight into the trip-maker's activity pattern. The frequency and duration of stops for different purposes on the way to work and on the way back home are two essential aspects of trip chaining. Since the idea of telecommuting is to substitute the activity (work) that induces commuting trips, the employee may find it more difficult to telecommute if work is only one of several activities associated with the commuting trip.

Household characteristics that affect the employee's telecommuting decision include lifecycle, lifestyle, car ownership and the number of household members with a driver's license. Household lifecycle reflects factors such as number of adults and number of children (especially under 16) in the household, while household lifestyle combines attributes such as household income, spouse's employment status and occupation. Lifecycle and lifestyle are primary determinants of household activity behavior (Kitamura, 1988), and are expected to influence the employee's telecommuting adoption process. Household car ownership and the number of household members with a driver's license affect the activity allocation among household members as well (Bhat, 1991), and hence the activity patterns of the employee. In addition to the separate effects of employee and household characteristics, joint or interaction effects can be expected. For instance, it has been pointed out that the joint presence of working women and pre-school children strongly influences telecommuting adoption (Hamilton, 1987).

Household situational constraints include the number of different telephone lines, possession of FAX equipment, subscription to electronic database services, and the availability of personal computers. On one hand, these factors reflect the availability (or lack) of facilities at home to support or enable telecommuting. On the other hand, they reflect the adoption of new telecommunications technologies at the household level. Therefore, it is expected that greater availability of telecommunications equipment at home increases the probability that the employee will adopt telecommuting.

The trip distance from an employee's residence to the work place can be used as a proxy of location patterns. Little is found in the literature with regard to how location patterns affect employees' choices of telecommuting. The interaction between household location and telecommuting adoption may be two-fold. On the one hand, people who live farther from work would be more likely to telecommute because of greater travel cost savings than those who live closer to work. On the other hand, telecommuting availability has been suggested as a possible factor that encourages employees to live in the suburbs and move farther away from their offices. As a result, telecommuting may contribute to urban sprawl (Nilles, 1991).

The linkage between a person's attitudes and behavior has long been addressed in the psychology literature. According to Fishbein and Ajen's (1975) general attitude-behavior model, people's behavior is affected by intentions which are in turn influenced by their attitudes. Within this framework, Samuelson and Biek (1991) reviewed energy consumption research and concluded that individuals' actual energy conservation behavior is related to their attitudes toward energy use. Thus, employee perceptions and attitudes toward telecommuting may be considered one of the major determinants of the telecommuting adoption process.

Employees' job characteristics affect their decision to telecommute through their own perceptions or speculation about their supervisors' attitudes. An employee who needs to frequently communicate face-to-face with customers or co-workers every day may think that his/her job is not suitable for telecommuting. In addition, this employee may feel that his/her supervisor is not likely to allow him/her to telecommute. Clearly, changes in salary or job compensation resulting from telecommuting may also affect their preferences for telecommuting. The present study shows that employees are not likely to be interested in trading off salary for the opportunity to telecommute (Mahmassani *et al.*, 1993). Therefore, the success of telecommuting programs will be highly dependent on the economic implications of the program for telecommuters.

The Employer Adoption Process

The employer decides whether or not to let employees telecommute from the organization's viewpoint, which is generally dominated by executives' characteristics such as personal management style and inclination to adopt new policies, as well as their perceptions and attitudes toward telecommuting. Other management considerations which also influence the employer's decision of providing a telecommuting program in the organization may include the arrangement of work hours, the difficulty of communication with and supervision of telecommuters, productivity measurement, and data security. Figure 2.3 depicts the framework of the employer's adoption process.

The complexity of the employer's telecommuting adoption process is evident, as decision processes differ among organizations depending on the organization's culture, structure, and other characteristics such as type of business activity. Some organizations may have only one decision-maker, the chief executive officer (CEO), while others may have a decision team consisting of various executives. In addition to the variation of decision rules among organizations, different processes may occur within the same organization. If only the CEO is involved in the telecommuting decision process, a model for individual choice behavior can be used to formulate the employer's adoption of telecommuting, recognizing that factors that influence the employer's choice are different from those that influence the employee's choice. On the other hand, if the organizational decision process includes more than two decision-makers, group-decision concepts need to be employed in the adoption process.

Regardless of the size of the decision group and the underlying decision mechanism, several categories of factors are expected to influence the employer's adoption of telecommuting: (1) executive characteristics, (2) executive perceptions and attitudes toward telecommuting, (3) organizational characteristics, (4) business type of the organization, and (5) situational constraints of the organization.

The executive's characteristics such as career experience, number of subordinates directly supervised (management span), and awareness of or previous experience with telecommuting are expected to influence his/her role as an advocate or opponent in initiating a telecommuting program in the organization. In addition, the executive's perceptions and attitudes toward telecommuting are believed to affect his/her actual behavior. The perceptions and attitudes emphasized here primarily focus on the possible impacts of telecommuting on management concerns such as data security, the productivity, morale, and absenteeism of telecommuters or non-telecommuters as well as the executive's ability to communicate with and supervise telecommuting subordinates.

It has been recognized in the organizational decision-making literature that characteristics such as culture, structure, type of business, and the organization's general role as a defender, analyzer, prospector, or reactor will affect the organization's strategic decision process (Miles *et al.*, 1978). These characteristics, therefore, are expected to influence the organization's telecommuting adoption as well. Based on a qualitative analysis of the relationship between the strategic decision process and the organizational characteristics, combined with the properties of telecommuting itself, it is proposed that organizations with more formal structure in terms of information processing, with more complex spatial dispersion, or with higher motivation to be an "analyzer" are more likely to adopt telecommuting (Yen, 1992). An analyzer is "an organization that attempts to minimize risk while maximizing the opportunity for profit" (Miles *et al.*, 1978).

Telecommuting employees work at home or satellite centers through faxes, telephones or computer networks. The information they need or provide should be more formal or organized because there is little face-to-face communication between telecommuters and their supervisors or subordinates. Therefore, it would be easier for organizations with a more formal information processing structure to implement a telecommuting program. In addition, one advantage of telecommunications is its potential to overcome physical distances by using information technology. For organizations with wide spatial dispersion, it is difficult to have regular face-to-face meetings among middle-class managers. Hence, these organizations are more likely to adopt new telecommunications technologies such as computer networking and teleconferencing. As a result, they are expected to have higher motivation and more facilities available to initiate a telecommuting program.

In addition to its culture and structure, the organization's type of business activity is expected to affect the employer's willingness to adopt telecommuting. It is believed that organizations with highly information-intensive business activities such as data entry and computer programming are more likely to initiate a telecommuting program because employee performance is easier to evaluate in these organizations than in others (Dresch, 1991). On the other hand, organizations with business activities that need to be performed in the field such as construction, or to communicate face-to-face with customers such as banking are more reluctant to adopt telecommuting.

The current level of telecommunications technology penetration into the organization may affect its choice of telecommuting as well. The availability of telecommunications equipment such as fax, personal computers, terminals, and computer networks are examples of situational constraints on the organization. It is expected that organizations with higher level of telecommunications accessibility are more likely to set up and adopt a telecommuting program.

Other constraints such as office space, overhead, and public policies of the surrounding community may also affect the employer's adoption process. Pacific Bell's first telecommuting program, for example, was initiated when the local government asked businesses to reduce traffic during the 1984 Summer Olympics in the Los Angeles area (Bailey and Foley, 1990). On the other hand, the Interactive System Corporation, a computer software company in Santa Monica, California, adopted telecommuting because it could not afford to lease an office (SCAG, 1985). As illustrated in Figures 2.1 and 2.2, these constraints, namely telecommunications penetration, office space, and government intervention, also reflect the impacts of telecommunications technology, land use patterns, and public policies, respectively, on the telecommuting adoption process.

Interactions between Employee and Employer Adoption

The interactions between employee and employer telecommuting decisions are fundamental to the joint adoption and the actual implementation of telecommuting programs. Participation by employees in telecommuting programs is generally on a voluntary basis. Most of the pilot projects reported that voluntary telecommuters required the approval of their supervisors. At the present stage, the employer's decision (either from the chief executive officer or from a group of executives) plays a decisive role in the initiation and adoption of a telecommuting program. The employee's decision is relatively passive. This situation may change in the future, however, depending on the degree of acceptance of telecommuting in the community. As telecommuting becomes more prevalent in the future, companies may need to compete for better workers by providing such an option. Therefore, employee willingness and preferences would be more actively reflected in the availability of telecommuting options.

SUMMARY

A comprehensive framework of the interaction of telecommuting and its environment as well as the interaction between telecommuting and travel behavior has been proposed in this chapter, which identifies four external factors (telecommunications technologies, transportation systems performance, public policies, and land use pattern) and two primary actors (employees and employers) in the adoption process. Specifically, the impacts of telecommuting are categorized into three levels. Short-term impacts include the changes in the activity pattern and travel behavior of telecommuters and their household members. Medium-term impacts refer to the changes in household activity allocation and car ownership. Long-term impacts include the location decisions of households and organizations. Additionally, impacts on management concerns such as employee absenteeism and group decisions are discussed.

Within the telecommuting adoption process, factors that influence employees and employers are articulated in detail. The characteristics of individuals and households that influence employee telecommuting adoption are discussed from the activity-based travel demand analysis perspective. In particular, several groups of factors such as commuting trip attributes, employee and household characteristics, employee job characteristics and attitudes toward telecommuting, as well as possible economic implications from telecommuting are discussed. On the other hand, factors that are expected to influence the employer's support of telecommuting include executive characteristics and attitudes toward telecommuting, and organizational characteristics such as structure, culture, and type of business activities.

CHAPTER 3
MODEL DEVELOPMENT

INTRODUCTION

The conceptual framework presented in the previous chapter identified several major modules involved in the dynamic interaction between telecommuting and its environment. This study focuses on modeling the telecommuting adoption process itself. In chapter 2, this process was qualitatively described in detail, and the principal factors likely to affect it were identified. Based on this framework, a mathematical formulation is developed in this chapter as a vehicle to establish two telecommuting adoption models associated with two respective decision makers, the employee and the employer. The theory of ordered-response analysis forms the foundation of the model formulation derived in the following sections. The ordered-response model maps the range of a continuous latent variable onto a set of discrete outcomes. For instance, for a given decision situation, the latent variable represents the decision maker's perceived utility or attractiveness toward the decision object of interest (telecommuting in this research). A set of ordered thresholds for the latent variable associated with each decision maker define ranges corresponding to each discrete decision outcome. The decision-maker's choice then depends on the corresponding interval within which the perceived utility or attractiveness lies.

The next section reviews existing ordered-response models, including their underlying assumptions and limitations, which is followed by a description of the concepts of a more generalized ordered-response developed in this study. The mathematical formulation of the ordered-response model employed in this study is derived in Appendix A. To estimate the derived ordered-response model, a maximum likelihood estimation procedure is also proposed in Appendix B. The procedure includes a Monte Carlo simulation approach to evaluate choice probabilities in the likelihood function.

THE ORDERED-RESPONSE MODEL

The ordered-response model is suitable for the analysis of decision problems where alternative choices are ordered (Maddala, 1983). The choices may be ordered "in nature" or under some *a priori* assumptions. For instance, the responses to a five-score measurement of employee attitudes toward a car-pool program in the organization (from strongly disagree, disagree, neutral, agree, to strongly agree) are ordered by the question design. On the other hand, when an individual is asked to indicate the number of days (between three and five) he/she prefers to work per week for a given fixed salary, the alternatives can be viewed as ordered from high to low attractiveness only if it is assumed that individuals derive greater utility from leisure than from work, all else being equal.

Traditional ordered-response analyses rely on linear regression models and generally have low accuracy of prediction (McKelvey and Zavoina, 1975). In addition to linear regression, researchers have proposed a mathematical formulation, the ordinal probit model, as an extension of the dichotomous probit model (Aitchison and Silvey, 1957). McKelvey and Zavoina (M-Z) (1975) extended the ordinal probit model with only two choice alternatives to more than two alternatives, and made the case that ordinal probit is more suitable than linear regression for ordered-response analysis.

The M-Z model assumes that for a particular decision situation, the decision maker's utility thresholds are constant and identical across the population, and the disturbances of latent variables are independently and identically distributed (IID). These two strong assumptions are believed to be unrealistic in general because different decision-makers may have different utility thresholds, and the latent variables may not be independent of the utility thresholds. An extension of the M-Z model was proposed by Terza (1985) to address the variation of utility thresholds among the population, though still under the assumptions of deterministic utility thresholds and IID disturbances of latent variables.

Despite the limitation of its underlying assumptions, the M-Z model is widely used in ordered-response analysis because of its closed mathematical form and straightforward estimation (McKelvey and Zavoina, 1975). It has been applied to problems in a variety of disciplines, including the movement of transaction stock prices (Hausman, Lo, and MacKinlay, 1991), educational mobility (Winship and Mare, 1984), and voting behavior (Mckelvey and Zavoina, 1975).

THE GENERALIZED ORDINAL PROBIT MODEL

A generalized ordinal probit model is developed in this study to capture the possible stochastic features of the utility thresholds and allow a more flexible specification of the latent variable. First, the utility thresholds can be specified as functions of the attributes of the decision object or of the decision maker and thus are no longer constant. Secondly, the thresholds are modeled as random variables, with possible correlations among the thresholds and between the latent variable and the thresholds. Finally, the model can be used to analyze observations with serial correlation or autocorrelation such as panel data (time-series data) or stated-preferences elicited from the same individual. Specifically, the ordered-response model developed in this study assumes that there is a latent variable, a measure of utility, attractiveness, or propensity associated with each individual when he/she is faced with a set of J ordered alternatives. The latent variable is not directly measurable; only choices made by individuals can be observed. It is also assumed that each individual has a set of J+1 ascendantly ordered thresholds labeled from 0, 1, to J such that the individual will choose alternative i when the associated latent variable is greater than threshold (i-1) and less than utility threshold i, assuming no ties.

The mathematical details of the model are included in Appendix A, and procedures for parameter estimation are described in Appendix B, as these details are not essential to understand the substantive conclusions of the study. In the next chapter, the survey conducted to obtain the data for the analysis is described. This data forms the basis for calibrating the models discussed in Chapter 5.

CHAPTER 4
SURVEY DATA AND EXPLORATORY ANALYSIS

INTRODUCTION

With revealed preference data from actual telecommuters limited due to the relatively limited extent of formal telecommuting in the country, this study relies on stated preference information from survey respondents to investigate the telecommuting adoption processes of employees and employers. The present study takes advantage of two features of stated preference data that may not be available from revealed preference observations. First, stated preference observations provide useful information on trade-offs among the attributes of choice alternatives that may not be observed in revealed preference data. Secondly, stated preference data yield information on preferences for non-available services and thus may have important policy implications regarding the introduction of such services. Based on the review of telecommunications-related research presented in chapters 1 and 2, telecommuting is not currently available in most organizations and thus respondents' stated preferences are important to gain insight into the underlying adoption processes of both employees and employers for this evolving work arrangement.

After a description of the survey method and the general characteristics of the respondents, an exploratory analysis is conducted. First, a cross-tabulated analysis of responses from a survey conducted in Texas is performed to identify the principal characteristics that affect the respondents' attitudes and stated preferences toward telecommuting. In addition, a confirmatory factor analysis is presented to further investigate the attitudinal information obtained from employees and employers. To the extent that telecommuting is not currently prevalent, the substantive findings from the exploratory analysis enrich the body of existing knowledge on telecommuting and its adoption in organizations. In addition, these results provide useful information for the specification of telecommuting choice models discussed in chapters 5 and 6.

SURVEY METHOD

Data used in this study are obtained from a survey of employees and executives in selected organizations in three Texas cities, Austin, Houston, and Dallas. The employee questionnaire, included in Appendix C, is comprised of four sections. The first section is intended to capture the employee's commuting information and job characteristics, including the travel distance and travel time for the daily commuting trips, as well as the job title, how much time he/she spends in communication with the customers, supervisor(s), subordinate(s), or co-workers, and what form of media is used. The second section addresses the employee's attitudes toward telecommuting, measured by Likert's five-score, bipolar scales (Fishbein and Ajen, 1975). The third section seeks the employee's stated preferences for alternative telecommuting scenarios, defined in terms of different combinations of out-of-pocket costs incurred by the employee in order to work from home and the corresponding salary changes. The last section addresses the employee's socio-economic characteristics, such as gender, age, household income, and computer proficiency level.

The executive questionnaire, included in Appendix D, also consists of four sections. The first section is an attempt to capture the general characteristics of executives and their organizations, including the executive's job title and management-related information such as the number of subordinates directly supervised by the executive (span of management) and methods of supervision. Also included is the current availability of telecommunications and computer network facilities in the company. The second section addresses the executive's attitudes toward telecommuting in terms of management concerns such as employee productivity, morale, absenteeism and data security. The third and fourth sections are similar to those of the employee questionnaire except that the stated preferences elicited from the executive represent his/her willingness toward supporting a telecommuting program in the organization instead of his/her own telecommuting.

Questionnaires were sent to selected organizations and distributed to their employees and executives through personnel officers. These organizations were selected on the basis of four criteria: (1) the potential for telecommuting, (2) firm size, measured by number of employees or total billings per year, so as to reflect different firm scales in the survey sample, (3) geographical location, including organizations in both central business districts and suburbs, and (4) business activity, such as computer software, engineering consultancy, or accounting.

GENERAL CHARACTERISTICS OF THE RESPONDENTS

According to the selection criteria, 72 organizations were chosen and 3814 questionnaires were sent for distribution to employees, of which 694 usable questionnaires were received. In terms of the executive survey, 397 questionnaires were mailed to 68 organizations, with 83 questionnaires received from 31 firms. Tables 4.1 and 4.2 list the respective sample distributions of employees and executives across the business activities of firms for each city.

The characteristics of employees and their households are presented in the next section, followed by a description of the attributes of executives and their organizations in section 4.3.2.

Employee, Household, and Commuting Characteristics

Table 4.3 summarizes the characteristics of surveyed employees and their households. About 56% of them are female and 75% are between 18 and 40 years of age. Most of the respondents (91%) have achieved a high level of educational attainment: 66% completed college or university and 18% obtained a master's or Ph.D. degree. Household annual income is approximately normally distributed, with the mode in the range of $25,000 to $50,000. In terms of the availability of home telecommunications facilities, only 13% of the employees have more than 1 phone line and 2% have a FAX machine at home. Personal computers are more prevalent, with 47% of the respondents having at least 1 unit at home and 5% reporting at least 2. However, only 7% of the employees use electronic databases or computer-based teleshopping. To the extent that workers with good computer skills have been identified as a likely target group for telecommuting, employees were asked about their proficiency levels in various computer-related skills. Among them, 76% have at least a medium level proficiency in the use of word processing packages, 50% for spreadsheets, 30% for data processing packages, 22% for computer language programming, and 33% for computer graphics packages. Overall, 84% of the sampled employees have at least one computer skill at the medium or high level.

For the purpose of telecommuting research, the 34 job titles mentioned are grouped in 12 categories, shown in Table 4.4, based on three criteria: power in the organizational strategic decision process, schedule flexibility, and suitability for telecommuting. Categories 1 (president/vice president) and 2 (manager/supervisor) have the most power in the decision making process. Categories 3 (writer/editor), 4 (accountant/attorney), and 5 (agent) are assumed to have more schedule flexibility. While categories 6 (computer programmer), 7 (data processing worker), and 8 (engineer/researcher) may have the most potential for telecommuting, categories 9 (field worker) and 10 (receptionist/secretary) probably have the least. According to Table 4.4, general employee (19%), engineer/researcher (18%), and manager/ supervisor (16%) are the largest three job categories in the employee sample.

Commuting information in Table 4.3 indicates that respondents in general encounter longer travel and make more stops in the PM trip than in the AM trip, which is consistent with the finding in other studies conducted in the same state (Mahmassani, Caplice, and Walton, 1990). On average, surveyed employees encounter 28.5 minutes of travel and make 3.5 stops in the PM

Table 4.1 Number of Employee Questionnaires Sent and Received, by Business Sector, by City

Primary Activity	# of organizations selected				# of questionnaires delivered				# of questionnaires received			
	A	D	H	T*	A	D	H	T	A	D	H	T
Accounting	1	2	1	4	25	150	100	275	7	42	0	49
Advertising	1	1	2	4	30	100	107	237	17	0	29	46
Architecture	1	1	1	3	15	50	100	165	7	31	12	50
Banking	0	0	1	1	0	0	100	100	0	0	0	0
Computer/software	4	3	3	10	275	235	59	569	109	11	7	127
Engineering	1	2	1	4	75	100	50	225	23	24	0	47
General consultant	2	0	1	3	32	0	10	42	0	0	2	2
Government	0	1	1	2	0	30	100	130	0	19	40	59
Hospital/medical	2	1	1	4	150	50	40	240	11	0	3	14
Insurance	1	2	2	5	12	110	120	242	4	0	1	5
Law	1	2	2	5	25	115	180	320	2	24	0	26
Manufacturing	1	1	2	4	25	100	125	250	3	0	14	17
Oil	0	3	2	5	0	93	18	111	0	31	10	41
Publishing/translating	2	0	0	2	210	0	0	210	110	0	0	110
R & D	3	0	0	3	255	0	0	255	35	0	0	35
Real estate	1	1	1	3	25	10	50	85	4	0	12	16
Stocks	1	1	1	3	60	50	40	150	18	2	0	20
Telecommunications	1	1	2	4	3	100	55	158	3	0	20	23
Travel	1	1	1	3	30	10	10	50	7	0	0	7
Total	24	23	25	72	1247	1303	1264	3814	360	184	150	694

* A: Austin
D: Dallas
H: Houston
T: Total

Table 4.2 Number of Executive Questionnaires Sent and Received, by Business Sector, by City

Primary Activity	# of organizations selected				# of questionnaires delivered				# of questionnaires received			
	A	D	H	T*	A	D	H	T	A	D	H	T
Accounting	1	2	3	6	5	7	66	78	3	3	10	16
Advertising	1	1	2	4	5	30	6	41	4	10	1	15
Architecture	0	1	1	2	0	2	11	13	0	0	7	7
Banking	0	0	1	1	0	0	4	4	0	0	0	0
Computer/software	4	3	3	10	17	8	21	46	4	0	4	8
Engineering	1	2	0	3	5	8	0	13	1	6	0	7
General consultant	1	0	1	2	3	0	4	7	0	0	0	0
Government	0	1	1	2	0	2	6	8	0	2	0	2
Hospital/medical	2	1	0	3	8	30	0	38	2	6	0	8
Insurance	1	2	3	6	1	16	8	25	1	0	1	2
Law	1	2	1	4	2	37	1	40	0	3	0	3
Manufacturing	1	1	2	4	2	5	8	15	0	0	1	1
Oil	0	2	3	5	0	8	9	17	0	0	1	1
Publishing/translating	2	0	0	2	7	0	0	7	6	0	0	6
R & D	3	0	0	3	15	0	0	15	0	0	0	0
Real estate	1	1	0	2	2	2	0	4	1	0	0	1
Stocks	1	1	1	3	4	3	2	9	1	1	0	2
Telecommunications	1	1	2	4	1	3	7	11	1	0	1	2
Travel	1	1	0	2	5	1	0	6	2	0	0	2
Total	22	22	24	68	82	162	153	397	26	31	26	83

* A: Austin
D: Dallas
H: Houston
T: Total

trip, but only 26.5 minutes and 2.0 stops in the AM trip.

Executive and Organization Characteristics

Characteristics of the sampled executives and their organizations are listed in Table 4.5. Most of the executives (77%) are male and 71% are between 31 and 50 years of age. About 97% of the executives have achieved a high level of education, with 89% completing college or university, and 36% attaining a master's or Ph.D. degree. Compared with employees surveyed in the same organizations, executives in general have higher educational levels and a greater fraction of them are male. As expected, the majority of sampled executives are presidents/vice presidents (24%) and general managers (52%). Other reported job titles include accountant/attorney (19%), agent (1%), engineer/researcher (2%), and general employee (1%).

To the extent that managerial characteristics are believed to affect executives' preferences for initiating a telecommuting program in the organization, related questions were also included in the survey. The span of management, for example, varies from 0 to 145, with a mean of 16.8 and a standard deviation of 23.2 employees. In terms of supervision methods , review meetings (88%), completed task review (84%), on-site supervision (78%), and written reports (74%) were mentioned by most executives, while activity logs (33%) were used by relatively fewer respondents. Because telecommuting is not widespread in Texas, executives' familiarity with it is expected to influence their attitudes or preferences toward supporting such a program. Only 16% of the executives are very familiar with telecommuting, though 61% reported being somewhat familiar, suggesting that a substantial number of the sampled executives may have only limited appreciation of telecommuting. In addition, about 40% of the respondents know someone who telecommutes.

With regard to the current availability of optional work arrangement in the organization, 32% of the executives mentioned that there is a flex-time program and about 17% reported that they have employees who telecommute at least on a part-time basis. For the penetration of technologies normally associated with telecommuting, about 53% of the executives indicated at least 5 personal computers are available to their staff, with 35% indicating at least 10; 44% of the executives reported the availability of at least 1 mainframe terminal and 28% reported at least 2. Statistically, the average number of personal computers among sampled organizations is 18.9 and 4.3 for mainframe terminals. Additionally, as on a per-employee basis, the average number of personal computers per supervised staff member is 1.1 across the organizations, dropping to 0.2 for mainframe terminals.

Table 4.3 Employee and Household Characteristics

Characteristics	Categories	Relative frequency (%)
Gender	Male	44.3
	Female	55.7
Age	Under 18	0.0
	18-30	35.6
	31-40	39.8
	41-50	17.4
	51-60	5.5
	above 60	1.7
Educational level	Finished high school	4.2
	Some college or university	25.0
	Finished college or university	48.6
	Master	16.3
	Ph.D.	1.4
	Other	4.5
Household income/year	Less than 25,000	12.7
	25,000-50,000	44.0
	50,000-75,000	28.9
	More than 75,000	14.3
Number of telephone lines at home	0	2.0
	1	85.3
	2	11.5
	3	1.0
	4	0.1
With FAX at home	Yes	1.9
	No	98.1
Subscription to electronic home-shopping	Yes	6.5
	No	93.5
Number of personal computers at home	0	53.1
	1	42.4
	2	3.5
	3	1.0
Proficiency level in word processing	high	40.3
	medium	35.3
	low	13.0
	non-existent	11.4

Table 4.3 Employee and Household Characteristics (continued)

Characteristics	Categories	Relative frequency (%)
Proficiency level in spreadsheets	high	22.0
	medium	28.0
	low	22.0
	non-existent	28.0
Proficiency level in data processing packages	high	10.0
	medium	20.2
	low	25.4
	non-existent	44.4
Proficiency level in computer programming	high	13.7
	medium	8.2
	low	21.2
	non-existent	56.8
Proficiency level in computer graphics packages	high	14.5
	medium	18.8
	low	24.9
	non-existent	41.9
Distance from home to the workplace (miles)*	mean	14.0
	standard deviation	10.8
AM travel time from home to the workplace (minutes)*	mean	26.5
	standard deviation	15.8
PM travel time from the workplace to home (minutes)*	mean	28.8
	standard deviation	17.0
AM stops on the way from home to the workplace, per week*	mean	2.0
	standard deviation	3.0
PM stops on the way from the workplace to home, per week*	mean	3.8
	standard deviation	3.5

* Numbers for these items are not relative frequencies.

Table 4.4 Employee Job Category

Job category	Frequency	Percentage
1. President / vice president 10	1.5	
2. Manager / supervisor	108	15.7
3. Writer / editor	60	8.7
4. Accountant / attorney	72	10.5
5. Agent	15	2.2
6. Computer programmer	57	8.3
7. Data processing	14	2.0
8. Engineer / researcher	122	17.8
9. Field worker	39	5.7
10. Receptionist / secretary	49	7.1
11. Coach / trainer	8	1.2
12. General employee	132	19.2
Total	686	100.0

Table 4.5 Executive and Organizational Characteristics

Characteristics	Categories	Relative frequency (%)
Gender	Male	77.1
	Female	22.9
Age	Under 30	21.7
	31-40	32.5
	41-50	38.6
	51-60	6.0
	above 60	1.2
Educational level	Finished high school	2.4
	Some college or university	4.8
	Finished college or university	53.0
	Master	31.3
	Ph.D.	4.8
	Other	3.6
Familiarity of telecommuting	very familiar	16.0
	somewhat familiar	60.5
	not familiar	23.5
Awareness of someone who telecommutes	yes	36.6
	no	63.4
Number of subordinates directly supervised	0-5	34.6
	>= 6	65.4
Methods of supervision (check all that apply)	review meetings	87.7
	written reports	74.1
	activity logs	33.3
	on-site supervision	77.8
	time-sheets	64.2
	review completed task	84.0
Number of personal computer available to the staff	0	6.2
	1-4	40.7
	>= 5	53.1
Number of dedicated word processors available to the staff	0	55.6
	1-4	30.8
	>= 5	13.6

Table 4.5 Executive and Organizational Characteristics (Continued)

Characteristics	Categories	Relative frequency (%)
Number of mainframe terminals available to the staff	0	55.6
	1	16.0
	2	3.7
	>= 3	24.7
Number of terminal inter-connected through an internal network	all	45.8
	more than 75%	15.7
	less than 50%	20.5
	none	18.1
Existence of employees who telecommute in the organization	yes	16.9
	no	66.3
	not aware	16.9
Existence of flex-time programs in the organization	yes	31.7
	no	67.1
	not aware	1.2

In addition to statistics based on individual executives, information from each organization as a unit is analyzed. Among the 16 organizations with only one executive questionnaire received, three indicated a flex-time program (FTP) and four reported that telecommuting is available. Within the other 15 organizations with more than one questionnaire, six have a consensus among the sampled executives on the availability of a FTP, with only one indicating yes and five indicating no; there is a consensus among executives in seven organizations that telecommuting is not available. For organizations without consensus, six have more than half of the executives responding yes to the availability of a FTP and three have more than half answering no; two have more than half answering yes to the availability of telecommuting, and six have more than half answering no. The results reveal that about half of the organizations with more than one sampled executive have a consensus on their current offering of a FTP or telecommuting, and the consensus is overwhelmingly on the lack of availability of such programs. Further investigation shows that six organizations have inconsistent responses on both questions; all of them have more than 200 employees, indicating that the inconsistency may result from the relatively large size of the organization.

ATTITUDES TOWARD TELECOMMUTING

Employee Attitudes toward Telecommuting

The employee responses to the attitudinal questions are shown in Table 4.6. With regard to attitudes toward the transportation system in the first three questions, 33% of the commuters think the traffic is smooth from home to the workplace, while 41% think it is congested. On the other hand, while only 24% of the respondents believe it is smooth on the way back home, 54% believe it is congested, also consistent with other studies that commuters experience a longer commute in the evening (Mahmassani, Caplice, and Walton, 1990). In terms of the importance of working in the office (questions 7 to 9), 60% of the employees feel frequent input from the supervisor or co-workers is essential, 44% believe it important for them to attend short-notice meetings during the work hours, and 70% find it important to have immediate access to information or references available only at the office.

With respect to the job's suitability for telecommuting (questions 12 to 15), only 21% of the employees feel their jobs are suitable for working from home every day, which increases to 38% when the frequency is limited to several days per week. Interestingly, most employees believe their assessment of this matter is not likely to be shared by their supervisors: only 4% feel the supervisors will approve of their working from home every day and 9% indicate so when working from home takes place only several days per week. For the effects on job performance and relationship with the family (questions 16 to 18), 34% of the respondents feel they could get more work done by working from home and 40% feel they could not; while 43% of the respondents feel working from home has a beneficial effect on their relationships with other household members, only 15% feel it is adverse. However, 65% of the respondents feel the chance for promotion will decrease if they work from home, while only 4% feel it will increase. This important element needs to be carefully addressed to encourage employee participation in telecommuting.

In order to identify the factors that influence employee attitudes toward telecommuting, chi-squared tests were performed to examine the independence of the distributions of responses to each attitudinal question and the levels of each individual and household characteristics listed in Table 4.3. Fourteen of the above variables, shown in Table 4.7, exert significant effects on the responses to at least one question. Specifically, more female respondents than male believe working from home will benefit their relationship with the family, and respondents with at least a medium level of computer proficiency are more inclined to believe their jobs are suitable for working from home. As expected, the number of children at home influences the respondent's attitudes too: about 65% of respondents with more than 2 children under 16 at home believe working from home has a positive effect on their relationship with the family, while only 37% of other respondents so believe.

Compared with others, employees with such an experience are more likely to have positive assessment of their job's suitability for telecommuting and the effect of telecommuting on their productivity. Also, a larger portion of the telecommuters than non-telecommuters believe they can get more work done by working from home. Interestingly, none of the full-time telecommuters think telecommuting will increase their chance for promotion, while 17% of the part-time telecommuters and 4% of the non-telecommuters think so. Job category also affects the respondent's attitudes. A smaller percentage of president/vice president, manager/supervisor, and receptionist/ secretary respondents believe their jobs are suitable for working from home, while a higher percentage of respondents with job titles as writer or editor, agent, computer programmer, and data processing indicate their jobs are suitable.

Table 4.6 Employee Responses to Attitudinal Questions

Questions	Responses (relative frequency, in percent) 1	2	3	4	5
1. Do you find commuting to work stressful ?	19.7 *not at all*	27.6	22.4	16.1	14.2 *definitely*
2. On a typical day, how would you describe the traffic you encounter on your way from home to your workplace ?	14.7 *too congested*	26.7	26.1	19.7	12.8 *very smooth*
3. On a typical day, how would you describe the traffic you encounter on your way from your workplace to home ?	25.9 *too congested*	27.7	22.8	14.7	8.8 *very smooth*
4. How important is flexibility of your work schedule for accomplishing your household duties ?	16.3 *not important*	11.8	25.5	23.1	23.4 *important*
5. Would you like to work independently during more of your work time ?	2.8 *dislike*	5.2	21.8	24.3	45.9 *like*
6. How do you feel about learning to use new office equipment for your job ?	1.4 *dislike*	2.6	8.7	23.0	64.3 *like*
7. How essential to your work is frequent input from your supervisor or your co-workers ?	5.7 *not essential*	12.9	21.3	25.8	34.3 *essential*
8. How important is it for you to attend short-notice meetings during your work hours ?	15.3 *not important*	21.0	19.8	19.9	24.0 *important*
9. How important is it for you to have immediate access to information or references which are available only at the office ?	4.5 *not important*	9.1	16.6	22.1	47.7 *important*
10. How important to you are social interactions with your co-workers at work ?	11.0 *not important*	12.9	26.0	27.6	22.5 *important*
11. How important to you are social interactions with your co-workers outside of work ?	35.6 *not important*	29.9	21.8	9.2	3.5 *important*
12. Do you think your job is suitable for working from home every day ?	45.3 *not suitable*	18.3	15.2	12.7	8.5 *very suitable*

Table 4.6 Employee Responses to Attitudinal Questions (Continued)

Questions	Responses (relative frequency, in percent) 1	2	3	4	5
13. Do you think your job is suitable for working from home several days per week ?	31.9 *not suitable*	15.0	14.9	17.2	21.1 *very suitable*
14. Do you think your supervisor would approve your working from home every day ?	71.6 *not at all*	16.5	8.3	2.8	0.9 *definitely*
15. Do you think your supervisor would approve your working from home several days per week ?	51.5 *not at all*	21.1	18.2	6.1	3.0 *definitely*
16. If you could work from home, do you think you could get more work done ?	24.5 *not at all*	15.1	26.0	15.5	18.9 *definitely*
17. If you could work from home, how do you think this would affect your relationship with other household members ?	5.9 *adversely*	9.0	42.1	18.8	24.2 *beneficially*
18. If you could work from home, what effect do you think this would have on your chance for promotion ?	39.4 *decrease*	25.7	31.2	1.8	1.9 *increase*

Employer Attitudes toward Telecommuting

The executives' responses to attitudinal questions are summarized in Table 4.8. With regard to the possible effects of telecommuting on the organization and the employee (questions 1 to 6), about 54% of the executives believe instituting such a program would help their retaining and recruiting qualified employees. Additionally, while 67% of executives indicated the effect on telecommuting workers' morale would be positive, only 18% believe telecommuters would increase their productivity. This result clearly reflects executives' concerns about the telecommuter's work performance. Executives also expect a negative influence on workers who do not telecommute: 44% of the executives believe the influence would be negative on both the productivity and morale of non-telecommuters, while only about 10% think it would be positive in both cases.

Management issues have long been considered to be the major barrier to the executives' adoption of telecommuting. The responses to related concerns (questions 9 to 12) indicate that more than half of the executives think telecommuting would have a negative effect on both their workload (56%) and their communications with the staff (59%), and 70% of the executives believe their supervision would be negatively affected. Additionally, more executives (40%) believe telecommuting would have a negative effect on data security than executives (10%) who think it would be positive. These findings confirm widely expressed thoughts in the literature that some managers are reluctant to adopt telecommuting because of serious concerns about their ability to retain proper management control.

The responses to each attitudinal question were also cross-tabulated with the attributes of the executives and organizations listed in Table 4.6. Due to the relatively small size of the executive sample, Fisher's exact tests (Schlotzhauer and Littell, 1987), instead of the commonly used chi-squared tests, were performed to examine the independence between responses to each attitudinal question and each of the above variables. Table 4.9 summarizes the test results for seven of the above variables that have significant effects on the responses to at least one question. In marked contrast to the employee data presented in the previous section, none of the executives' socio-economic attributes appear to affect their attitudes toward telecommuting; instead their attitudes are primarily influenced by management-related characteristics and the availability of telecommunications facilities in the organization.

The executive's expectation about the effect of telecommuting on his/her workload is influenced by the job title: fewer presidents or vice presidents (5%) believe the effect is positive than other executives (26%). As expected, executives with fewer subordinates are more likely to

Table 4.8Executive Responses to Attitudinal Questions

Questions	**Responses (relative frequency, in percent)**				
	1	**2**	**3**	**4**	**5**
	very negative		*neutral*		*very positive*
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:					
1. the firm's ability to retain and recruit employees ?	4.9	11.1	29.6	39.5	14.8
2. telecommuting employee productivity ?	18.3	31.7	31.7	13.4	4.9
3. non-telecommuting employee productivity ?	16.0	28.4	48.1	7.4	0.0
4. overall staff productivity ?	17.1	30.5	30.5	20.7	1.2
5. telecommuting employee morale ?	8.6	4.9	19.8	50.6	16.0
6. non-telecommuting employee morale ?	11.1	32.1	45.7	11.1	0.0
7. overall employee absenteeism ?	11.0	13.4	52.4	18.3	4.9
8. the firm's public image ?	12.2	17.1	45.1	20.7	4.9
9. your ability to manage your workload ?	19.5	36.6	23.2	13.4	7.3
10. your ability to communicate with your staff ?	20.7	37.8	30.5	8.5	2.4
11. your ability to supervise your staff ?	29.3	40.2	24.4	4.9	1.2
12. security of data and information ?	14.6	25.6	50.0	4.9	4.9

Table 4.9 Results of Fisher's Exact Tests of Executive Responses to Attitudinal Questions

	Attitudinal questions											
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
job title									*			
number of subordinates directly supervised	#	+			*				*			
method of supervision		+							#	*		
familiarity with telecommuting		*			+					*	*	
awareness of someone who telecommutes		#	#	*			*			*		*
penetration of telecommunications and computing technologies				+							*	
presence of telecommuters in the organization			*						*	*	*	#

+ 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

Null hypothesis: The responses to attitudinal questions are independent of the variables listed in the first column.

have positive attitudes than others: 29% of executives with less than six subordinates, traditionally the recommended span, (group 1) feel telecommuters would increase their productivity, a feeling shared by only 13% of other executives (group 2). Similarly, while less than half (46%) of the executives in group 1 expect the effect on their workload to be negative, more than half (60%) of the executives in group 2 have the same expectation. The supervision methods also affect executives' attitudes: 58% of the executives who rely on "reviewing completed tasks" indicate telecommuting would negatively affect their communications with the staff; a larger portion (69%) of executives not using this method have the same response. In addition, while only 22% of executives who use "written reports" but not "on-site supervision" believe telecommuters would decrease their productivity, 55% of other executives believe so. Clearly, executives who supervise employees by reviewing the final product, but not by looking over their shoulders during work hours, are more inclined to have positive attitudes.

Since telecommuting is not widely adopted, executives' awareness of it is expected to affect their attitudes. In general, fewer executives who are familiar with it (group 1) than others (group 2) expect a negative effect: 53% of the members in group 1 expect a negative effect on their communications with staff, compared with 84% in group 2. Extremely, most executives (95%) in group 2 believe their ability to supervise will be negatively affected . This percentage, however, drops to 62% for executives in group 1. The penetration of relevant technology has positive impacts on executives' attitudes. About 38% of the executives in organizations with more than 5 personal computers and 2 mainframe terminals feel telecommuting would increase the productivity of the staff overall, while only 19% of other executives have the same expectation. Executives in organizations with a telecommuting program (group 1) are more likely to exhibit positive attitudes as well: in this group more executives (43%) believe the effect on their workload would be positive than those (36%) who believe it would be negative. Different attitudes are also manifested with regard to the influence on data security: among executives from organizations without such a program (group 2), 48% think the influence would be negative and only 2% think it would be positive. On the other hand, only 36% of the executives in group 1 expect a negative effect, and an equal percentage expect the effect to be positive.

STATED PREFERENCES FOR TELECOMMUTING ALTERNATIVES

This section discusses the responses to questions regarding the employee's willingness to telecommute and the executive's preference for supporting a telecommuting program in the organization, under different telecommuting scenarios.

Employee Stated Preferences for Telecommuting

Table 4.10 lists the employees' responses to seven telecommuting program scenarios, defined in terms of who assumes the costs to work from home and the corresponding salary changes to telecommuting employees. For each scenario, the employee was asked to state his/her willingness of working from home from one of the following alternatives: (1) every day, (2) several days per week, (3) possibly, and (4) no. The third option "possibly" was not available for scenario 4.

Scenario 4 (salary increases, no cost to employee) was designed to dominate all others. As confirmed by the results, 86.1% of the respondents are interested in telecommuting at least several days per week. Under scenario 1 (same salary and no cost to employee), the "status quo," about 66% of the employees will opt to work from home at least several days per week. The desire to telecommute is quickly dampened as employees are asked to incur some of the additional costs: the percentage of willing telecommuters drops to 38% if employees have to pay for an additional phone line (scenario 2), and to 29% if a computer must be purchased (scenario 3). Similarly, salary decreases do not encourage telecommuting, and appear to be even less tolerated than having to assume some costs for telecommuting. Under scenario 6 (5% salary decrease, no cost to employee), the percent of willing telecommuters decreases to 21%, and further drops to 10% if one has to give up 10% of his/her salary (scenario 7). Overall, the results indicate that employee participation in telecommuting highly depends on the specifics of the program, particularly its cost implications. While some may be willing to incur the costs to acquire necessary equipment, employees do not appear to value telecommuting sufficiently to take a pay cut for the privilege. It can also be noted that under all program scenarios, more employees would rather telecommute only a few days per week than every day.

The responses to each telecommuting scenario were also cross-tabulated with the same variables considered in the attitudinal analysis. Table 4.11 indicates that the same 14 variables found to significantly influence employee attitudes affect their preferences as well. Consistent with the attitudinal results, female employees express a stronger preference for working from home than male: under the status quo, 73% of the female respondents would like to work from home, while only 58% of the male expressed such preference. Similarly, both employees with at least a medium proficiency of computer skills and employees with at least one personal computer at home are more likely to participate in telecommuting. Household characteristics affect the employee's preference for telecommuting as well: under scenario 1, 90% of employees with more than 2 children under 16 at home would like to work from home, compared with 63% of other

Table 4.10 Employee Responses to Stated Preference for Telecommuting Program Scenarios

Telecommuting Program Scenario	Responses (relative frequency, in percent)* 1	2	3	4
1. Salary stays the same; employer pays all costs	21.6	44.5	22.0	11.8
2. Salary stays the same; employee incurs the cost of a new phone line	11.9	25.8	33.4	28.9
3. Salary stays the same; employee buys a personal computer	9.2	16.0	31.8	43.0
4. Salary increases 5%; employer pays all costs	34.0	52.1	**	13.8
5. Salary increases 5%; employee pays part of the costs	16.2	28.2	27.8	27.8
6. Salary decreases 5%; employer pays all costs	7.9	12.8	21.2	58.1
7. Salary decreases 10%; employer pays all costs	5.2	5.0	12.4	77.4

* 1: Would like to work from home everyday.
2: Would like to work from home several days per week.
3: Possibly would like to work from home.
4: Do not want to work from home.
** This scenario only allowed three responses in the questionnaire.

Table 4.11 Results of Chi-Square Tests of Employee Responses to Stated Preference Questions

Variables	Stated preference questions 1	2	3	4	5	6	7
gender	*			*		+	
age	+	*		+	+	+	
education level				*	+		
computer skill	*	*	+	+	*		
# of children under 16 at home	+		*	*	*		
# people with a driver's license	*	*		+			*
# of personal computers at home			*		*		
trip distance	+	*	+	*			
AM travel time	*	+		*		+	
PM travel time	*	*		*		+	
AM stops for pick up/drop off per week	*	+		+	+		
PM stops for pick up/drop off per week	*	*		+	+	+	
currently work from home			*		*	+	+
job category	*	+	+	*			

+ significant at the 0.05 level, but not at the 0.01 level

* significant at the 0.01 level

Null hypothesis: The responses to attitudinal questions are independent of the variables listed in the first column.

employees. Also consistent with the attitudinal results, the employee's job title and prior telecommuting experience affect his/her preferences: a greater fraction of current full-time or part-time telecommuters indicate a preference for telecommuting than those without such experience. In addition, a smaller percentage of respondents within the management group (categories 1 and 2) would like to work from home than others.

In general, commuting attributes do not affect the employee's assessment of his/her job's suitability for telecommuting. However, these attributes significantly affect the employee's willingness to work from home. A higher percentage of respondents with longer trip distances or travel time prefer to work from home than others. For example, under scenario 1, 70% of employees with AM travel greater than 19 minutes (the sample mean plus half of the standard deviation) would like to work from home, compared to 59% of respondents with AM travel less than 9 minutes (the sample mean minus half of the standard deviation).

Employer Stated Preferences for Telecommuting

Table 4.12 summarizes the executives' responses to nine telecommuting program scenarios, defined on the basis of who assumes the additional costs of telecommuting and the corresponding salary changes to telecommuters. Five of these scenarios are identical to those included in the employee survey. For each scenario, executives were asked to state their willingness to support such a program in the organization from one of the following responses: (1) yes, (2) possibly, and (3) no. Under scenario 1 (employee salary (ES) remains the same and employer incurs no additional costs), the cost-neutral "status quo" from the employer's standpoint, about 67% of the executives would support a telecommuting program. Keeping the ES fixed, this percentage decreases to 51% under scenario 2 (some costs assumed by the employer) and further to 41% under scenario 3 (all costs paid by the employer) as the costs incurred by the employer increase.

A priori, scenario 4 (ES decreases 5% and employer incurs no additional cost) was thought to dominate all others from the employer's viewpoint. The results, however, do not support this assumption. Compared to scenario 1, the percentage of telecommuting supporters drops to 40% under scenario 4, to 34% under scenario 5 (ES decreases 5% and employer assumes some costs), and to 23% under scenario 6 (ES decreases 5% and employer pays all costs). Apparently, a 5% decrease in the employee's salary does not stimulate executives' willingness to support telecommuting but appears to decrease the percentage of supporters by about 20%. This somewhat unexpected finding suggests that executives probably recognize

Table 4.12 Executive Responses to Stated Preferences for Telecommuting Program Scenarios

Telecommuting Program Scenario	Responses (relative frequency, in percent) 1 *Yes*	2 *Possibly*	3 *No*
1. Employee salary stays the same; employer incurs no costs	33.3 (35.5)	33.3 (29.0)	33.3 (35.5)
2. Employee salary stays the same; employer assumes some costs	25.9 (25.8)	24.7 (19.4)	49.4 (54.8)
3. Employee salary stays the same; employer pays all costs	25.9 (32.3)	14.8 (12.9)	59.3 (54.8)
4. Employee salary decreases 5%; employer incurs no costs	8.8 (0.0)	31.3 (38.7)	60.0 (61.3)
5. Employee salary decreases 5%; employer assumes some costs	5.0 (0.0)	28.8 (22.6)	66.3 (77.4)
6. Employee salary decreases 5%; employer pays all costs	7.5 (0.0)	15.0 (16.1)	77.5 (83.9)
7. Employee salary increases 5%; employer incurs no costs	7.5 (9.7)	15.0 (16.1)	77.5 (74.2)
8. Employee salary increases 5%; employer assumes some costs	7.5 (9.7)	8.8 (9.7)	83.8 (80.6)
9. Employee salary increases 5%; employer pays all costs	8.8 (9.7)	7.5 (6.5)	83.8 (83.9)

Note: 1. Numbers in parentheses are relative frequency in terms of responding organizations.

2. Responses were received from executives in 31 organizations.

that it would be unfair to penalize an employee who wishes to telecommute if he/she continues to perform the same job duties.

While executives in general are not inclined to reduce telecommuters' salaries, they certainly do not believe telecommuters should receive a salary increase. The latter appears to be even less tolerable than the former. Under scenario 7 (ES increases 5%, and employer pays no cost), the percent of telecommuting supporters drops to 23%, and further drops to 16% if the employer is required to assume some or all costs (scenarios 8 and 9, respectively). Results from scenarios 7 to 9 also exhibit the tendency noted earlier of decreasing support for telecommuting by executives as the additional costs incurred by the employer increase.

The responses to telecommuting program scenarios were also summarized on the basis of organizations and listed in Table 4.12. Responses from organizations with more than one respondent are represented by the majority of their sampled executives. Overall, these relative frequency distributions are comparable to those based on individual executives' responses.

Responses to alternative telecommuting scenarios were also cross-tabulated with respect to the same variables considered in the analysis of executives' attitudes. Table 4.13 lists the four variables that significantly affect the executive's preference, using Fisher's exact tests. Variables not affecting executives' attitudes have no bearing on their preferences, either. Similar to the attitudinal results, executives with less power in the decision making process exhibited a stronger preference for supporting telecommuting: while fewer presidents or vice presidents indicated their support under the first three scenarios (30%, 25%, and 15%, respectively), more than 50% of other executives indicated such support (78%, 58%, and 50%, respectively). Management span affects executive preferences as well: a larger fraction of executives with less than 6 subordinates would support telecommuting (89%, 67%, and 55% for the first three scenarios, compared with 54%, 40% and 31%, respectively, of other executives). As expected, the executive's awareness of someone who telecommutes increases his/her support for telecommuting as well.

The penetration of related technology is the only organizational attribute that significantly influences executive preferences. The percentage of telecommuting supporters drops from 69%, 69%, and 62% (for scenarios 1 to 3, respectively) of executives whose organizations have more than 5 personal computers and 2 mainframe terminals (group 1) to 65%, 45%, and 35%, respectively, of other executives (group 2). Another interesting result appears from this analysis: while the percentage of telecommuting supporters in group 1 remains approximately the same from scenarios 1 to 3, the corresponding percentage drops substantively in group 2 as the additional costs incurred by the organization increase.

Comparison of Employee and Executive Stated Preferences for Telecommuting Alternatives

Data obtained from both employees and executives in the same organizations provide an opportunity to compare their respective preferences for telecommuting. The responses from five organizations with at least three sampled executives, listed in Table 4.14, are selected for such a comparison. Again, Fisher's exact test is used for independence tests due to the small executive sample. Test results (Table 4.15) of the responses to six scenarios asked of both employees and executives clearly reveal that employees have stronger preferences than executives. Among all respondents, for example, most employees (88%) would like to telecommute under scenario 3 (the employee's salary remains the same and the employer pays all costs), while only 41% of the executives would support such a program. The divergence between the responses from the two groups is maximal under scenario 6, theoretically the best scenario for employees and the worst for executives (employee salary increases 5% and employer pays all costs). While about 87% of employees would like to telecommute under this scenario, only 16% of executives would support it.

Similar results are found within individual organizations. For example, a dominant majority of employees (95%) from the publishing firm would like to telecommute under scenario 3, but only 40% of executives would support it. The difference within the architectural firm is also dramatic: about 83% of its employees desire to telecommute under scenario 6, supported by only 29% of its executives. These results are confirmed by Kendall's tau-b measures (Schlotzhauer and Littell, 1987) as listed in Table 4.16, most of which are positive and significantly different from zero at the 5% level. For the given measure design (for respondents: 1 if an employee and 2 if an executive; for responses: 1 if yes, 2 if possibly, and 3 if no), positive measures indicate executives are more likely to answer "no" than employees.

The present results indicate that executives are more reluctant to adopt telecommuting than employees. However, because voluntary telecommuters require the approval of their supervisors, executive attitudes and preferences play a decisive role in the initiation of a telecommuting program (SCAG, 1986). The results thus imply that an effort to remove management barriers would be essential to encourage telecommuting adoption.

Table 4.13 Results of Fisher's Exact Tests of Executive Responses to Stated Preference Questions

Variables	Stated preference questions 1	2	3	4	5	6	7	8	9
job title	#	*	*						
number of subordinates directly supervised	#	*	+						
method of supervision									
familiarity with telecommuting									
awareness of someone who telecommutes	+			+			*	#	#
telecommunications technology adoption	*	+	+		*				
existence of telecommuters in the organization									

+ 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

Null hypothesis: The responses to attitudinal questions are independent of the variables listed in the first column.

Table 4.14 Executive and Employee Responses to Stated Preferences for Telecommuting Program Scenarios from Selected Organizations

Telecommuting Program Scenario	Responses (relative frequency, in percent) 1 *Yes*	2 *Possibly*	3 *No*
1. Employee salary stays the same; employer assumes some costs (employee adds a new telephone number)			
a. an accounting firm [7;3]			
employee	28.6	28.6	42.9
executive	0.0	33.3	66.7
b. an advertising firm [17;4]			
employee	41.2	35.3	23.5
executive	0.0	25.0	75.0
c. an architects firm [12;7]			
employee	16.7	41.7	41.7
executive	28.6	0.0	71.4
d. a computer software firm [28;3]			
employee	46.4	39.3	14.3
executive	66.7	0.0	33.3
e. a publishing firm [109;5]			
employee	38.5	30.3	31.2
executive	20.0	20.0	60.0
f. all firms [695;83]			
employee	37.7	33.4	28.9
executive	25.9	24.7	49.4
2. Employee salary stays the same; employer assumes some costs (employee buys a personal computer)			
a. an accounting firm			
employee	28.6	14.3	57.1
executive	0.0	33.3	66.7
b. an advertising firm			
employee	31.3	31.3	37.5
executive	0.0	25.0	75.0
c. an architects firm			
employee	0.0	33.3	66.7
executive	28.6	0.0	71.4
d. a computer software firm			
employee	32.1	32.1	35.7
executive	66.7	0.0	33.3
e. a publishing firm			
employee	22.9	30.3	46.8
executive	20.0	20.0	60.0
f. all firms			
employee	25.1	31.9	43.0
executive	25.9	24.7	49.4

Note : Numbers in brackets are [# of employee responses received; # of executive responses received]

Table 4.14 Executive and Employee Responses to Stated Preferences for Telecommuting Program Scenarios from Selected Organizations (Continued)

Telecommuting Program Scenario	**Responses (relative frequency, in percent)**		
	1	**2**	**3**
	Yes	*Possibly*	*No*
3. Employee salary stays the same; employer pays all costs			
a. an accounting firm			
employee	42.9	28.6	28.6
executive	0.0	0.0	100.0
b. an advertising firm			
employee	52.9	29.4	17.7
executive	0.0	0.0	100.0
c. an architects firm			
employee	50.0	25.0	25.0
executive	28.6	0.0	71.4
d. a computer software firm			
employee	78.6	14.3	7.1
executive	66.7	0.0	33.3
e. a publishing firm			
employee	74.3	21.1	4.6
executive	20.0	20.0	60.0
f. all firms			
employee	66.2	22.0	11.8
executive	25.9	14.8	59.3
4. Employee salary decreases 5%; employer pays all costs			
a. an accounting firm			
employee	14.3	14.3	71.4
executive	0.0	0.0	100.0
b. an advertising firm			
employee	29.4	5.9	64.7
executive	0.0	25.0	75.0
c. an architects firm			
employee	8.3	33.3	58.3
executive	28.6	0.0	71.4
d. a computer software firm			
employee	22.2	18.5	59.3
executive	0.0	0.0	100.0
e. a publishing firm			
employee	17.6	18.5	63.9
executive	0.0	25.0	75.0
f. all firms			
employee	21.0	21.2	57.9
executive	7.5	15.0	77.5

Table 4.14 Executive and Employee Responses to Stated Preferences for Telecommuting Program Scenarios from Selected Organizations (Continued)

Telecommuting Program Scenario	**Responses (relative frequency, in percent)** 1 *Yes*	2 *Possibly*	3 *No*
5. Employee salary increases 5%; employer assumes some costs			
a. an accounting firm			
employee	42.9	28.6	28.6
executive	0.0	0.0	100.0
b. an advertising firm			
employee	35.3	29.4	35.3
executive	0.0	0.0	100.0
c. an architects firm			
employee	33.3	33.3	33.3
executive	28.6	0.0	71.4
d. a computer software firm			
employee	51.9	25.9	22.2
executive	0.0	0.0	100.0
e. a publishing firm			
employee	42.2	30.3	27.5
executive	0.0	25.0	75.0
f. all firms			
employee	44.7	28.2	27.1
executive	7.5	8.8	83.8
6. Employee salary increases 5%; employer pays all costs			
a. an accounting firm			
employee	0.0	71.4	28.6
executive	0.0	0.0	100.0
b. an advertising firm			
employee	11.8	58.8	29.4
executive	0.0	0.0	100.0
c. an architects firm			
employee	27.3	45.5	27.3
executive	28.6	0.0	71.4
d. a computer software firm			
employee	18.5	70.4	11.1
executive	0.0	0.0	100.0
e. a publishing firm			
employee	37.7	51.9	10.4
executive	0.0	25.0	75.0
f. all firms			
employee	33.9	52.1	13.8
executive	8.8	7.5	83.8

Table 4.15 Results of Fisher's Exact Tests of Responses from Employees and Executives to Different Telecommuting Program Scenarios

	Scenario					
Organizations	**1**	**2**	**3**	**4**	**5**	**6**
1 (an accounting firm [07;3])						
2 (an advertising firm [17;4])			#			*
3 (an architects firm [12;7])		*				+
4 (a computer software firm [28;3])					*	#
5 (a publishing firm [109;5])			#		+	#
6 (all firms [695;83])	#		#	#	#	

Note 1: Numbers in brackets are as [# of employee responses received; # of executive responses received].

Note 2 (scenarios)

1: employee salary: the same	employer: some costs (employee: a new phone line)
2: employee salary: the same	employer: some costs (employee: a personal computer)
3: employee salary: the same	employer: all costs
4: employee salary: - 5%	employer: all costs
5: employee salary: + 5%	employer: some costs
6: employee salary: + 5%	employer: all costs

Note 3

+ : 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

Null hypothesis: The responses from employees and executives are independent.

Table 4.16 Results of Kendall's Tau-B Measures of Responses from Employees and Executives to Different Telecommuting Program Scenarios

	Scenarios					
Organizations	**1**	**2**	**3**	**4**	**5**	**6**
1 (an accounting firm [07;3])	.27 (.24)		.59 (.16)	.32 (.13)	.59 (.16)	.66 (.18)
2 (an advertising firm [17;4])	.42 (.14)	.32 (.15)	.57 (.12)		.45 (.11)	.51 (.12)
3 (an architects firm [12;7])			.34 (.21)		.24 (.22)	.27 (.24)
4 (a computer software firm [28;3])				.24 (.07)	.41 (.11)	.52 (.13)
5 (a publishing firm [109;5])	.11 (.09)		.29 (.11)		.19 (.06)	.26 (.08)
6 (all firms [695;83])	.11 (.04)		.30 (.04)	.12 (.03)	.31 (.03)	.37 (.03)

Note 1: Numbers in brackets are as [# of employee responses received; # of executive responses received].

Note 2 (scenarios)

1: employee salary: the same	employer: some costs (employee: a new phone line)
2: employee salary: the same	employer: some costs (employee: a personal computer)
3: employee salary: the same	employer: all costs
4: employee salary: - 5%	employer: all costs
5: employee salary: + 5%	employer: some costs
6: employee salary: + 5%	employer: all costs

Note 3 : Standard error estimates for 95% confidence intervals are listed in parentheses.

CONFIRMATORY FACTOR ANALYSIS OF THE ATTITUDINAL INFORMATION

As presented in chapter 2, people's attitudes influence their behavior (Fishbein and Ajen, 1975). Additionally, in the absence of a large base of established telecommuters, prevailing attitudes toward telecommuting can provide useful insights into factors that affect a person's likelihood to adopt telecommuting. Furthermore, factor analysis provides a vehicle to identify the basic dimensions, which can be labeled as "factors" or "general attitudes" underlying the individual's attitudes toward telecommuting. While retaining approximately the same exploratory power, the dimensions identified through such analysis are generally fewer than the directly measured attitudes, and therefore are parsimonious in terms of model specification when attitudinal measurements are included in the choice models. This section performs a confirmatory factor analysis aimed at identifying the basic dimensions of the directly measured attitudes, with the employee results presented first and then the executive's.

Employee Attitudes toward Telecommuting

The 18 attitudinal questions in the employee survey, listed in Table 4.6, are intended to measure the following seven general attitudes thought to affect employee adoption of telecommuting:

1. transportation systems performance (questions 1 to 3),
2. importance of working in the office (questions 7 to 9),
3 importance of social interactions with co-workers (questions 10 and 11),
4. job suitability for telecommuting (questions 12 to 15),
5. telecommuting effect on job performance (questions 16 and 18),
6. telecommuting effect on family (questions 4 and 17), and
7. working independently (questions 5 and 6).

The confirmatory factor analysis (CFA) was performed using the SAS CALIS procedure (SAS, 1990) with maximum likelihood as its estimation method. The measured variables in the CFA model correspond to the employee responses to those attitudinal questions except that the number "6" was subtracted from all responses to question 1 in order to keep variables 1, 2, and 3 consistent. The factor pattern is specified as above, with assumed correlations between factors. The estimates of the factor loadings, reported in Table 4.17 along with the corresponding t-values, indicate that all are significantly different from zero at the 0.01 level. In addition, 10 variables load on the specified factors with values greater than 0.60, usually considered a high loading, while only one variable has a loading less than 0.30, a low loading. Statistics such as the goodness-of-fit index (GFI=0.90) and the adjusted GFI (0.8) indicate that the model fits the observed data very well. Inspection of the residual correlation matrix shows that the estimated factor loadings predict the correlation matrix fairly well and, therefore, support the specified factor pattern that those 18 measured variables load on the seven factors (general attitudes).

Table 4.18 shows the estimated correlation coefficients between factors. While all terms are significant (at the 0.01 level), most of the coefficients are less than 0.5 and greater than -0.5, indicating that in general the correlations between factors are not high. The highest two correlations exist between factors 6 and 7 (0.90), factors 6 and 5 (0.83). In other words, there appears to be strong positive correlations between an employee's expectation of the effects of telecommuting on the family and his/her preference for working independently as well as his/her expectation of the effect of telecommuting on job performance.

Employer Attitudes toward Telecommuting

Twelve attitudinal questions were included in the executive survey as listed in Table 4.8. Those questions were assumed to measure four general attitudes believed to affect the employer's likelihood to support telecommuting. These attitudes pertain to the effects of a telecommuting program on:

1. telecommuting workers and image of the organization (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).

A confirmatory factor analysis was also performed to verify whether or not the variation of executive responses to those 12 questions could be explained by the above four general attitudes. The specified factor pattern and estimated results are reported in Table 4.19, along with the corresponding t-values. Correlations between factors are also specified in the model. The results in Table 4.19 indicate that all loadings are significantly different from zero at the 0.01 level. In addition, 10 variables have high loadings (greater than 0.6) on the specified factors, while no variable has a loading less than 0.30, a low loading. Statistics such as the goodness-of-fit index (GFI=0.86) and the adjusted GFI (0.77) also indicate that the model fits the observed data well. Further inspection of the residual correlation matrix reveals that the estimated factor loadings predict the correlation matrix fairly well and thus support the specified factor pattern.

Table 4.20 shows that all of the estimated correlation coefficients between factors are statistically significant. The highest correlation (0.90) exists between factors 2 and 3, indicating

Table 4.17 Estimated Factor Pattern from the Confirmatory Factor Analysis (Employee Results)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
1	0.69(17.7)						
2	0.87(23.1)						
3	0.79(20.8)						
4						0.34(7.1)	
5							0.74(11.2)
6							0.29(6.0)
7		0.68(14.6)					
8		0.59(12.8)					
9		0.54(11.8)					
10			1.00(8.7)				
11			0.41(6.8)				
12				0.87(25.5)			
13				0.89(26.5)			
14				0.58(14.8)			
15				0.63(16.4)			
16					0.92(13.7)		
17						0.53(9.7)	
18					0.36(7.7)		

* The t values are listed in parentheses.

Table 4.18 Estimated Factor Correlations from the Confirmatory Factor Analysis (Employee Results)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Factor 1	1.00						
Factor 2		1.00					
Factor 3		0.42	1.00				
Factor 4	-0.15	-0.51	-0.22	1.00			
Factor 5	-0.19	-0.30	-0.25	0.58	1.00		
Factor 6	-0.36	-0.32	-0.21	0.69	0.83	1.00	
Factor 7	-0.25	-0.42	-0.21	0.50	0.59	0.90	1.00

Table 4.19 Estimated Factor Pattern from the Confirmatory Factor Analysis (Executive Results)

Variables	Factor 1	Factor 2	Factor 3	Factor 4
1	0.62(5.8)			
2	0.85(8.9)			
3		0.98(8.2)		
4			0.88(8.7)	
5	0.62(5.9)			
6		0.65(5.6)		
7			0.58(5.4)	
8	0.62(5.8)			
9				0.68(6.6)
10				0.85(8.9)
11				0.90(9.8)
12				0.40(3.5)

* The t values are listed in parentheses.

Table 4.20 Estimated Factor Correlations from the Confirmatory Factor Analysis (Executive Results)

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00			
Factor 2	0.79	1.00		
Factor 3	0.66	0.90	1.00	
Factor 4	0.20	0.30	0.63	1.00

that the executive's attitudes toward the effects of a telecommuting program on non-telecommuting workers and workers overall are highly correlated.

SUMMARY

This chapter has presented an explanatory analysis of stated preference data obtained from a telecommuting survey in three Texas cities (Austin, Dallas, and Houston), including both decision makers (employees and employer) involved in the adoption process. The results indicate that employee attitudes and preferences toward telecommuting are significantly influenced by their personal and household characteristics such as gender, job characteristic, computer proficiency, number of children under 16 and personal computers at home, as well as commuting attributes. Factors that affect executive attitudes and preferences primarily reflect management concerns such as productivity, morale, absenteeism, and data security. Comparison of employee and executive responses from the same organizations indicate that executives are more reluctant to adopt telecommuting than employees. Additionally, factor analysis identifies the underlying dimensions of employee and employer attitudes toward telecommuting.

Overall, the present results broaden the body of telecommuting literature that has heretofore lacked systematic inquiry, and provide useful guideposts for the specification of telecommuting adoption models for both employees and employers. The empirical adoption model estimation is discussed in chapters 5 and 6 for those two respective decision makers.

CHAPTER 5
THE EMPLOYEE TELECOMMUTING ADOPTION MODEL

INTRODUCTION

The conceptual framework of chapter 2, which articulates the interactions involved in the adoption process, guides the entire study, including the survey design, the exploratory analysis of the sample data, and the contextual and substantive aspects of model development. The generalized ordinal probit model introduced in chapter 3 and described in Appendix A provides the mathematical formulation for the telecommuting choice models investigated in the following two chapters. An essential feature of the derived model is the ability to capture serial correlation or autocorrelation existing in the observations. In addition, combined with the causal relationships articulated in the adoption framework, the exploratory analysis results performed in the previous chapter play a major role in the empirical specification of the choice models. The latter are estimated using the maximum likelihood procedure described in Appendix B for the generalized ordinal probit model. At the core of this estimation procedure lies a Monte Carlo simulation to evaluate the individual choice probabilities of the ordered alternatives, for a given set of parameter values.

As previously mentioned, the telecommuting adoption process involves two principal decision makers, namely the employee and the employer. This chapter specifies and estimates the employee telecommuting choice model. The specification and estimation of the employer model are presented in chapter 6.

MODEL SPECIFICATION

As presented in chapter 4, employees were asked to indicate their willingness to telecommute under each of the seven telecommuting program scenarios from one of the following four alternatives: (1) working from home every day, (2) working from home several days per week, (3) possibly working from home, and (4) not to work from home. It is assumed in this study that these four possible responses reflect the employee's preference for telecommuting, with "working from home every day" representing the highest preference and "not to work from home" the lowest. Without loss of generality, the employee's responses to each scenario question were transformed by subtracting 5 such that the preference measures are from the lowest attractiveness (1) "no" to the highest (4) "every day."

It is also assumed that there is one latent variable and five utility thresholds (labeled from 0 to 4) associated with each employee in each program scenario. The latent variable is a measure of the employee's perceived utility of a given telecommuting program scenario, and the utility thresholds are in a monotonically increasing order such that the employee chooses alternative i if and only if the perceived utility is located in the interval between utility thresholds i-1 and i, where i=1, 2, 3, or 4. Alternatively, the latent variable can be interpreted as a measure of the employee's propensity to telecommute. With the assumption that the disturbances of the latent variable and the thresholds are multivariate normally distributed, the generalized ordinal probit (GOP) model derived in chapter 3 can be used to estimate the employee's telecommuting choice model based on the observed data. Since there are seven program scenarios for each employee, the dynamic version of the model (DGOP) is applied to capture the autocorrelation among the disturbances of the latent variable or the thresholds in the responses to different scenarios.

Empirically, three major components need to be specified in order to estimate the employee telecommuting choice model using the DGOP framework: the systematic components of the latent variable and the utility thresholds, as well as the variance-covariance structure of the disturbances, which are discussed hereafter.

Specification of the Latent Variable

The latent variable associated with each employee represents his/her utility of a particular telecommuting program, or propensity to telecommute under that option. This variable therefore varies across different program scenarios, as well as across decision-makers. The systematic component of the latent variable is assumed to be a linear function of some known attributes, though the DGOP model does not preclude the analyst from specifying a nonlinear function. Following these assumptions, the latent variable presented in equation 3.6 can be specified as follows:

$$\begin{aligned} Y_n^t &= V_n^t + u_n^t \\ &= \beta\, Z_n^t + u_n^t \quad (t=1, 2, \ldots, 7) \end{aligned} \tag{5.1}$$

where Y_n^t, V_n^t, and u_n^t represent the latent variable, its systematic and random components associated with individual n under scenario t, Z_n^t is a vector of measured attributes known to the analyst, and β is the parameter vector to be estimated.

Based on the telecommuting adoption process framework presented in chapter 2, four groups of attributes are assumed to affect the employee's perceived utility of each telecommuting program scenario and thus included in the Z vector. As identified *a priori* in chapter 2 and confirmed by the exploratory analysis in chapter 4, the first group is comprised of the economic implications of the telecommuting program design. They are defined in terms of how much additional cost the employee incurs in order to work from home (ranging from no cost to adding a new telephone line at home or buying a personal computer) and the corresponding salary change to the employee if he/she works from home (from increasing 5% to decreasing 10%). The second group includes the employee's personal and household characteristics such as gender, age, educational level, computer proficiency, as well as the number of children under age 16 and personal computers at home. The third group consists of the employee's job characteristics, including job title, amount of time the employee spends in communication with customers, supervisor(s), subordinate(s), or co-workers, and number of hours he/she uses a computer or typewriter on work every day. Finally, the employee's commuting attributes such as travel time, distance from home to the workplace, and number of stops on the way to work and on the way back home are included in the fourth group. Descriptive summary statistics for attributes specified in the employee model are listed in Table 4.3.

Variables in the first group, that capture the economic implications of different programs, are different across the seven telecommuting program scenarios for each employee. The estimated coefficients of these variables have important policy implications on the design of telecommuting programs. Other variables specified in the model represent the effects of the employee's individual, household, and commuting attributes as well as job characteristics on his/her willingness for telecommuting. Consequently, for a specific employee they do not vary across different scenarios. These variables, however, vary across employees. The combined specification of these four groups of variables allows the latent variable to vary among telecommuting scenarios and the population, and capture the effects of attributes of both the employee and the program design itself.

Specification of the Utility Thresholds

Fishbein and Ajen's (1975) general attitude-behavior model proposes that people's attitudes toward an object affect their intentions with respect to the object, which in turn influence their actual behavior. Based on this framework, it is assumed in this study that the measured stated preferences from employees can be interpreted as their intentions regarding telecommuting. Therefore, the employee's attitudes toward telecommuting are believed to affect his/her preferences for participating in such a program. The influence of these attitudes is reflected in the utility thresholds in the telecommuting choice model. These thresholds, presented in equation A.7, can be specified as functions of the measured attitudes. Similar to the specification of the latent variable, these functions are assumed to be linear in this study, recognizing that the DGOP model formulation does not exclude a nonlinear specification. The linear assumption leads to the following specification of the utility thresholds.

$$\begin{aligned} \mu_{in}^{t} &= S_{in}^{t} + \varepsilon_{in}^{t} \\ &= \alpha_{i}^{t} F_{in}^{t} + \varepsilon_{in}^{t} \quad (t=1, 2,..., 7 \text{ and } i=0, 1,..., 4) \end{aligned} \tag{5.2}$$

In equation 5.2, μ_{in}^{t}, S_{in}^{t}, and ε_{in}^{t} are threshold i, its observable and unobservable components for individual n and scenario t. In addition, for utility threshold i in program scenario t, F_{in}^{t} is a vector which represents the measured attitudes of the employee, and α_{i}^{t} is the parameter vector to be estimated. The specification of the F vector is discussed in the next section.

Though the specification in equation 5.2 is theoretically sound, empirically the sample size may not be large enough to estimate each parameter in vector α_{i}^{t}, t=1, 2,..., 7 and i=0, 1,..., 4. Further assumptions are made in this study to simplify the computation and improve the accuracy of the estimates. First, since only the relative magnitudes of the utility thresholds matter in the ordered-response model, the lowest threshold (i=0) is set at negative infinity while the highest one (i=4) is taken as positive infinity. In addition, the mean value of the second threshold (i=1) is set to zero (McKelvey and Zavoina, 1975). These assumptions lead to the specification of only two systematic components of the utility thresholds (i=2, 3) for each decision scenario in the employee telecommuting choice model. Finally, since F represents the employee's attitudes toward telecommuting, it is reasonable to assume that F is the same across the seven decision scenarios for a given utility threshold . That is, $F_{in}^{t} = F_{in}^{\tau}$ (t, t=1, 2,..., 7 and i=0, 1,..., 4). These three assumptions simplify the specification of the utility thresholds in equation 5.2 as follows:

$$\begin{aligned} \mu_{0n} &= -\infty \\ \mu_{1n} &= 0 + \varepsilon_{1n} \\ \mu_{2n} &= \alpha_{2} F_{2n} + \varepsilon_{2n} \\ \mu_{3n} &= \alpha_{3} F_{3n} + \varepsilon_{3n} \end{aligned} \tag{5.3}$$

$\mu_{4n} = +\infty$

As presented in chapter 4, the eighteen attitudinal questions asked in the employee survey measure seven general employee attitudes (factors) toward telecommuting. The regression weights of these seven general attitudes on the eighteen directly measured attitudes for each employee were also obtained from the confirmatory factory analysis reported in chapter 4. Unlike the factor pattern, which represents the loadings of the measured variables on each factor, as discussed in chapter 4, the regression weights provide a transformation from the measured responses to the factor scores (McDonald, 1985). Therefore, for each employee, there are seven transformed factor scores as measures of the seven general attitudes. Table 5.1 lists the regression weights for each factor, as derived from the confirmatory factor analysis performed in the previous chapter. In this study the seven general attitudes, instead of the eighteen direct measures, are specified in the F vector in equation 5.3 to decrease the number of explanatory variables. This specification reduces the estimation effort, minimizes possible multicollinearity among the specified variables, and ultimately improves the accuracy of the estimates.

Specification of the Variance-Covariance Structure

The simplifying assumptions made regarding the utility thresholds in the previous section lead to the specification of only two systematic components (F_{2n} and F_{3n}) and three disturbances (ε_{1n}, ε_{2n}, and ε_{3n}) as per equation 5.3. In addition to the three utility threshold disturbances, there is a random component for the latent variable (u) in each scenario. Consequently, the general variance-covariance structure of the employee telecommuting choice model disturbances is a 28 by 28 matrix, with 4 elements for each of the 7 scenarios. This variance-covariance matrix Σ can be expressed in equation 5.4. For simplicity, the individual index n is omitted in the following discussion.

As discussed in Appendix A, each element in equation 5.4 is a 7 by 7 submatrix. The off-diagonal elements of Σ are the covariance matrices of the corresponding disturbances. For example, $\Sigma_{\varepsilon_i\varepsilon_j}=E(\varepsilon_i^{t}, \varepsilon_j^{\tau})$ (t=1, 2,...,7, τ=1, 2,...,7, and i, j=1, 2, 3, i $\neq$ j). Under the assumed disturbance structure of the DGOP model presented in Appendix A, the disturbance of the latent variable or a utility threshold in scenario t is assumed to be correlated with only disturbances of the same random variable in the other scenarios. That is, both the covariances of (u^t, ε_j^{τ}, $t \neq \tau$) and (ε_i^t, ε_j^{τ}, $t \neq \tau$ and $i \neq j$) are assumed to be zero (i, j=1, 2, 3). Furthermore, the latent variable disturbances are assumed independent of the utility thresholds, i.e. the elements of $\Sigma_{u\varepsilon_i}$ are all zero, i=1, 2, 3. Therefore, all remaining off-diagonal submatrices of Σ are diagonal. For example, the covariances between utility thresholds i and j (i, j=1, 2, 3, i $\neq$ j), i.e. $\Sigma_{\varepsilon_i\varepsilon_j}$ in equation 5.4, can be expressed as follows:

Table 5.1 Factor Score Regression Coefficients on the Measured Attitudes (Employee Results)

	General Attitudes (Factors)						
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0.197	-0.007	0.000	-0.001	-0.002	-0.031	-0.013
2	0.517	-0.019	0.000	-0.004	-0.004	-0.080	-0.035
3	0.322	-0.012	0.000	-0.002	-0.003	-0.050	-0.022
4	-0.009	0.008	0.000	0.011	0.023	0.059	0.074
5	-0.019	-0.078	-0.001	0.015	0.043	0.337	0.535
6	-0.003	-0.014	0.000	0.002	0.007	0.062	0.099
7	-0.007	0.369	0.000	-0.027	0.005	0.027	-0.056
8	-0.005	0.267	0.000	-0.019	0.004	0.019	-0.040
9	-0.004	0.228	0.000	-0.016	0.003	0.016	-0.034
10	-0.006	0.152	1.000	-0.001	-0.028	0.001	-0.010
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	-0.004	-0.080	0.000	0.363	0.035	0.106	0.030
13	-0.006	-0.099	-0.001	0.451	0.044	0.132	0.037
14	-0.001	-0.019	0.000	0.087	0.007	0.025	0.006
15	-0.001	-0.022	0.000	0.105	0.009	0.030	0.008
16	-0.010	0.024	-0.001	0.063	0.826	0.415	0.162
17	-0.018	0.016	0.000	0.021	0.046	0.115	0.145
18	0.000	0.002	0.000	0.003	0.050	0.025	0.009

Note: the general attitudes (factors)
1. transportation systems performance
2. importance of working in the office
3. importance of social interactions with co-workers
4. job suitability for telecommuting
5. the effect of telecommuting on job performance
6. the effect of telecommuting on family
7. working independently

$$\Sigma = \begin{array}{c|cccc} & u & \varepsilon_1 & \varepsilon_2 & \varepsilon_3 \\ \hline u & \Sigma_{uu} & \Sigma_{u\varepsilon_1} & \Sigma_{u\varepsilon_2} & \Sigma_{u\varepsilon_3} \\ \varepsilon_1 & \Sigma_{u\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_2} & \Sigma_{\varepsilon_1\varepsilon_3} \\ \varepsilon_2 & \Sigma_{u\varepsilon_2} & \Sigma_{\varepsilon_1\varepsilon_2} & \Sigma_{\varepsilon_2\varepsilon_2} & \Sigma_{\varepsilon_2\varepsilon_3} \\ \varepsilon_3 & \Sigma_{u\varepsilon_3} & \Sigma_{\varepsilon_1\varepsilon_3} & \Sigma_{\varepsilon_2\varepsilon_3} & \Sigma_{\varepsilon_3\varepsilon_3} \end{array} \quad (5.4)$$

number of scenarios

	1	2	3	4	5	6	7
1	$cov(\varepsilon^1_i, \varepsilon^1_j)$	0	0	0	0	0	0
2	0	$cov(\varepsilon^2_i, \varepsilon^2_j)$	0	0	0	0	0
3	0	0	$cov(\varepsilon^3_i, \varepsilon^3_j)$	0	0	0	0
4	0	0	0	$cov(\varepsilon^4_i, \varepsilon^4_j)$	0	0	0
5	0	0	0	0	$cov(\varepsilon^5_i, \varepsilon^5_j)$	0	0
6	0	0	0	0	0	$cov(\varepsilon^6_i, \varepsilon^6_j)$	0
7	0	0	0	0	0	0	$cov(\varepsilon^7_i, \varepsilon^7_j)$

(5.5)

In the estimation procedure used in this study, the four diagonal submatrices Σ_{uu}, $\Sigma_{\varepsilon_1\varepsilon_1}$, $\Sigma_{\varepsilon_2\varepsilon_2}$, and $\Sigma_{\varepsilon_3\varepsilon_3}$ specified by the analyst are used to generate unconstrained random variates u, ε_1, ε_2, and ε_3 as described in Appendix B. After they are generated, the utility threshold disturbances ε_1, ε_2, and ε_3 may be discarded if they violate the ordered threshold sequence. The likelihood search procedure results in estimates of the specified parameters used in the generation process, prior to the truncation induced by the ordered sequence constraint. While the elements of Σ_{uu} are not affected by the truncation under the independence assumption between u and ε's, and therefore the estimated parameters are those of the final model, the actual variance and covariance elements for the threshold disturbances, i.e. in $\Sigma_{\varepsilon_i\varepsilon_i}$, after truncation, may be different from the estimated parameters that form the basis of variate generation process.

The specification of the diagonal matrix $\Sigma_{\varepsilon_i \varepsilon_i}$ used in the random variate generation process can be specified as follows:

number of scenarios

	1	2	3	4	5	6	7
1	σ^2_{i1}	$\gamma_{i12}\sigma_{i1}\sigma_{i2}$	$\gamma_{i13}\sigma_{i1}\sigma_{i3}$	$\gamma_{i14}\sigma_{i1}\sigma_{i4}$	$\gamma_{i15}\sigma_{i1}\sigma_{i5}$	$\gamma_{i16}\sigma_{i1}\sigma_{i6}$	$\gamma_{i17}\sigma_{i1}\sigma_{i7}$
2		σ^2_{i2}	$\gamma_{i23}\sigma_{i2}\sigma_{i3}$	$\gamma_{i24}\sigma_{i2}\sigma_{i4}$	$\gamma_{i25}\sigma_{i2}\sigma_{i5}$	$\gamma_{i26}\sigma_{i2}\sigma_{i6}$	$\gamma_{i27}\sigma_{i2}\sigma_{i7}$
3			σ^2_{i3}	$\gamma_{i34}\sigma_{i3}\sigma_{i4}$	$\gamma_{i35}\sigma_{i3}\sigma_{i5}$	$\gamma_{i36}\sigma_{i3}\sigma_{i6}$	$\gamma_{i37}\sigma_{i3}\sigma_{i7}$
4				σ^2_{i4}	$\gamma_{i45}\sigma_{i4}\sigma_{i5}$	$\gamma_{i46}\sigma_{i4}\sigma_{i6}$	$\gamma_{i47}\sigma_{i4}\sigma_{i7}$
5					σ^2_{i5}	$\gamma_{i56}\sigma_{i5}\sigma_{i6}$	$\gamma_{i57}\sigma_{i5}\sigma_{i7}$
6						σ^2_{i6}	$\gamma_{i67}\sigma_{i6}\sigma_{i7}$
7							σ^2_{i7}

(5.6)

In matrix $\Sigma_{\varepsilon_i \varepsilon_i}$ (5.6), σ^2_{it} is the variance of ε_i in scenario t, and $\gamma_{it\tau}$ is the correlation coefficient of ε_i^t and ε_i^τ (t, τ=1, 2,..., 7). Of course, the matrix is symmetric. In general, there could be up to 28 parameters to be estimated in each submatrix, adding up to 112 parameters for these four variance-covariance matrices. It is empirically impossible to estimate all these parameters (Bunch, 1991). Therefore, some meaningful restrictions are imposed. In particular, the respective variances of the disturbances of each utility threshold and of the latent variable are assumed to be equal for the seven scenarios, and the correlation coefficient between any two scenarios (for a given variable) is also the same. This assumption leads to the following variance-covariance submatrix $\Sigma_{\varepsilon_i \varepsilon_i}$ in equation 5.7.

The above specification reduces the number of parameters in each variance-covariance submatrix to two, σ_i and γ_i (i=1, 2, 3 for thresholds and u for the latent variable). It follows that there are fourteen parameters to be estimated in the variance-covariance matrix Σ , with two in each diagonal submatrix and one in each upper (or lower) triangle submatrix.

number of scenarios

	1	2	3	4	5	6	7
1	σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
2		σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
3			σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
4				σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
5					σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
6						σ_i^2	$\gamma_i\sigma_i\sigma_i$
7							σ_i^2

(5.7)

ESTIMATION RESULTS AND DISCUSSION

The employee survey data described in chapter 4 were used to estimate the employee telecommuting choice model parameters, following the specification presented in the previous section. The estimation procedure of the DGOP model developed in chapter 3 was coded in FORTRAN computer language. Table 5.2 lists the parameter estimates and their corresponding t-values for the employee choice model. As indicated in the exploratory analysis, of the 694 questionnaires received from the employee survey, 554 were usable in model estimation.

The estimation results in Table 5.2 show that the coefficients of all variables aimed at capturing the economic implications of the particular telecommuting program appear to be significantly different from zero. As expected, a 5% salary increase (SI5) has a positive influence on the employee's perceived utility or propensity for telecommuting (the latent variable in the model formulation). Therefore, a salary increase will increase the probability that the employee chooses a higher frequency of telecommuting, all else being equal. On the other hand, the effect of salary decrease (SD5 and SD10) is negative, implying that the employee is less likely to choose telecommuting if he/she has to sacrifice part of his/her salary. Similarly, responsibility for additional costs to work from home (ANL, BPC, and PART) negatively affects employee preference, with all estimated coefficients being negative.

The relative magnitudes of the estimated parameters reveal useful information on employee preference from the standpoint of program design and public policy. For instance, the relative values of the estimated coefficients of SD5 (-1.311) and SI5 (0.293) indicate that a salary decrease exerts a stronger effect on employee preference than a comparable increase. Additionally, the coefficients of both indicators (dummy) variables for 10% salary decrease (-1.909) and 5% decrease (-1.311) confirm that the former has a stronger effect. However, the relative coefficient values suggest a non-proportional relationship between the amount of salary decrease and its influence on the latent variable, with a decreasing marginal effect of further salary decrease. The asymmetry between the effect on employee preference of positive and negative salary changes, and the decreasing marginal effect of salary decreases are illustrated in Figure 5.1.

Similarly, the significant differences among the coefficients of the indicator (dummy) variables ANL, BPC, and PART (-0.643, -0.901, and -0.807, respectively) indicate that requiring the telecommuter to buy a personal computer (BPC) is a stronger deterrent to telecommuting than other additional cost items.

The coefficients of SD5 and SD10 are statistically less than the parameters of ANL, BPC, and PART, indicating salary sacrifice has a stronger negative effect on the employee than having to acquire a new telephone line or a personal computer in order to work from home. This finding has important implications on telecommuting program design for organizations willing to provide such work arrangement.

The employee's personal and household characteristics significantly affect his/her choice of telecommuting programs, evidenced by the estimated coefficients of the number of children under age 16 (CHIL16), number of personal computers at home (HOMEPC), and the employee's computer proficiency level (SKILL). The estimated parameters of CHIL16 and HOMEPC (0.142 and 0.202, respectively) indicate that employees with more children under 16 or personal computers at home are more likely to adopt telecommuting, all else being equal. Similarly, employees with higher computer proficiency levels exhibit stronger preferences for working from home, confirming the speculation in the literature that computer-related workers are a promising target group for telecommuting.

As indicated in chapter 2, the number of children under 16 variable (CHIL16) serves as a proxy of the employee household life cycle, and HOMEPC is an index of the penetration of telecommunications and information technology (one of the key factors in the framework of Figure 2.1) at the household level. While computer proficiency is an employee characteristic, it is also an index of the prevailing technology at the individual level. Wider spread of telecommunications and information technologies has a positive influence on employee adoption of telecommuting.

Among employee job characteristics, the longer the employee needs to communicate face-to-face with co-workers (HRFACE, -0.344), the lower the probability he/she will choose a high frequency of telecommuting. On the other hand, the number of hours in which the employee uses a computer on work each day (HRCOMP, 0.175) has a positive effect on the perceived attractiveness of telecommuting. These findings are consistent with widely accepted thinking in the literature that information-related jobs are more telecommutable than others, while jobs that require frequent face-to-face communication with other workers are less telecommutable.

As pointed out in chapter 2, the distance from home to the work place and daily commuting time represent proxies for two environmental factors that are believed to affect employee telecommuting adoption: the land use pattern and the transportation system performance, respectively. The results in Table 5.2 indicate that only the coefficient of the distance (DSTRIP) (0.028) is statistically significant, partly due to the correlation between these two attributes. The results, however, confirm findings from other studies that employees who incur longer travel are more likely to prefer working from home, other things being equal. Employees who incur longer travel times can achieve greater savings from working from home than closer workers.

The average number of stops (STOPS) associated with commuting trips is used as a proxy of the employee's activity pattern and his/her share of household duties. The empirical result, with -0.124 as the estimated coefficient of the STOPS variable, is consistent with the *a priori* speculation presented in chapter 2 that if work is not the only purpose (final good) of the daily commuting trip (derived demand), the employee is more reluctant to replace the trip by working from home.

With respect to the utility thresholds, three of the employee's general attitudes toward telecommuting are found to significantly affect the thresholds: (1) the job's suitability for telecommuting (FJOBSU), (2) the effect of telecommuting on one's family (FFAMIL), and (3) the importance of social interactions with co-workers (FSOCIO). The negative coefficient estimates of FJOBSU (-0.436 and -0.318 for thresholds 2 and 3) and FFAMIL (-0.577 and -0.126) suggest that high scores on those two attitudes will reduce the thresholds underlying the telecommuting decision mechanism. The ordered-response model implies that for a fixed latent variable a decrease in thresholds increases the probability that the employee will choose an alternative with higher attractiveness. In other words, all else being equal, employees with higher scores on these attitudes are more likely to work from home. As expected, if the employee feels that his/her job is suitable for telecommuting and that working from home will beneficially affect his/her relationship with other household members, then he/she would be more likely to telecommute.

In contrast to the first two general attitudes, the effect of the third one (FSOCIO, with estimated parameters 0.568 and 0.820 for thresholds 2 and 3) on the thresholds is positive, indicating that employees who find social interactions with co-workers important are less likely to adopt a high frequency of working from home.

The results in Table 5.2 also indicate that all estimates of the specified standard deviations and correlation coefficients are statistically significant. In addition, the estimated correlation coefficients show that for the latent variable or a specific utility threshold i (i=1, 2, 3) the disturbances in different decision scenarios are positively correlated. While all t values listed in Table 5.2 are computed to test the null hypothesis that the true parameter of the corresponding variable is zero, all estimates of the correlation coefficients (γ_u, γ_1, γ_2, and γ_3) are also tested against the hypothesis that the true parameter is equal to one. The results indicate that all four parameters are significantly different from one. These two tests imply that all correlation coefficients are greater than zero but less than one.

SUMMARY

This chapter has discussed the specification issues of the employee telecommuting adoption model, and presented successful estimation results using the procedure developed in chapter 3. The results confirm most of the exploratory findings presented in chapter 4, namely that employee participation in telecommuting is primarily influenced by five groups of attributes: (1) economic implications of program design, (2) personal and household characteristics, (3) job characteristics, (4) commuting attributes, and (5) attitudes toward telecommuting.

Estimated coefficients of variables regarding program specifics also reveal important information. First, both changes in employee salary and the costs incurred by telecommuters significantly influence employee telecommuting adoption, with the former having a stronger effect. Secondly, the relative coefficient values indicate that the effect of salary decrease is stronger than salary increase, and the marginal effect of salary decrease is decreasing.

Another important feature that emerges from the estimation results is that the dynamic structure of the generalized ordinal probit model successfully captures the autocorrelation among responses from the same employee, which ultimately improves the precision of the parameter estimates.

Table 5.2 Estimation Results of Employee Telecommuting Choice Model

Variables		Parameter estimates*	
Specified in the latent variable			
Constant		-0.190	
(Economic implications)			
SI5:	Change in telecommuter salary (1 if increase 5 %; 0 otherwise)	0.293	(30.0)
SD5:	Change in telecommuter salary (1 if decrease 5 %; 0 otherwise)	-1.311	(-4.9)
SD10:	Change in telecommuter salary (1 if decrease 10 %; 0 otherwise)	-1.909	(-9.8)
ANL:	Additional phone costs assumed by employee (1 if need to add a new phone line at home; 0 otherwise)	-0.643	(-31.0)
BPC:	Additional computer costs assumed by employee (1 if need to buy a personal computer; 0 otherwise)	-0.901	(-7.3)
PART:	Additional partial costs assumed by employee (1 if need to pay part of the costs; 0 otherwise)	-0.807	(-8.9)
(Employee personal and household characteristics)			
CHIL16:	Number of children under age 16 at home	0.142	(3.2)
HOMEPC:	Number of personal computers at home	0.202	(9.6)
SKILL:	Index of computer proficiency (1 if at least one skill at medium or high level; 0 otherwise)	0.272	(16.0)
(Employee job characteristics)			
HRFACE:	Number of hours communicating with co-workers face-to-face per day	-0.344	(-18.0)
HRCOMP:	Number of hours using a computer on work per day	0.175	(17.0)
(Employee commuting attributes)			
DSTRIP:	Distances from home to the workplace, miles	0.028	(15.0)
STOPS:	Average number of stops on the way to work and back home per week	-0.124	(-14.0)

* Numbers in parentheses are t-values

Table 5.2 Estimation Results of Employee Telecommuting Choice Model (Continued)

Variables		Parameter estimates*	
Specified in the utility thresholds			
Utility threshold 2			
Constant		2.270	
FJOBSU:	Regression score of the employee's attitudes toward job suitability for telecommuting	-0.436	(-33.0)
FFAMIL:	Regression score of the employee's attitudes toward telecommuting effect on family	-0.577	(-31.0)
FSOCIO:	Regression score of the employee's attitudes toward the importance of social interactions with co-workers	0.568	(14.0)
Utility threshold 3			
Constant		2.864	
FJOBSU:		-0.318	(-3.4)
FFAMIL:		-0.126	(-2.0)
FSOCIO:		0.820	(8.4)
Variance-covariance			
σ_u	Standard deviation of the latent variable	0.734	(48.0)
γ_u	Correlation coefficient of latent variable under different scenarios	0.138	(7.9)
σ_1	Standard deviation of threshold 1	0.982	(49.0)
γ_1	Correlation coefficient of threshold 1 under different scenarios	0.573	(89.0)
σ_2	Standard deviation of threshold 2	0.986	(34.0)
γ_2	Correlation coefficient of threshold 2 under different scenarios	0.096	(17.0)
σ_3	Standard deviation of threshold 3	0.914	(13.0)
γ_3	Correlation coefficient of threshold 3 under different scenarios	0.615	(7.1)
Cov(u, 1)	Covariance of disturbances of the latent variable and threshold 1	0.206	(27.0)
Cov(u, 2)	Covariance of disturbances of the latent variable and threshold 2	0.033	(12.0)
Cov(u, 3)	Covariance of disturbances of the latent variable and threshold 3	0.134	(19.0)
Cov(1, 2)	Covariance of disturbances of thresholds 1 and 2	0.450	(80.0)
Cov(1, 3)	Covariance of disturbances of thresholds 1 and 3	0.174	(13.0)
Cov(2, 3)	Covariance of disturbances of thresholds 2 and 3	0.426	(27.0)

Overall statistics

Number of observations	545
Log likelihood value at zero	-5228.7
Log likelihood value at convergence	-3909.0

* Numbers in parentheses are t-values

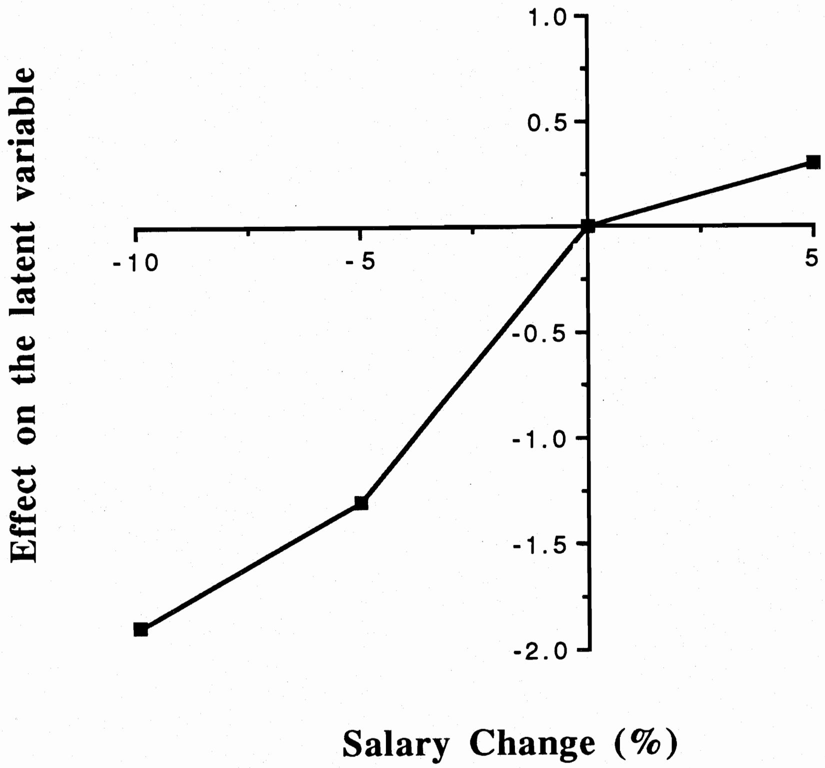

Figure 5.1 Effect of Salary Changes on Latent Variable (Employee Model)

CHAPTER 6
THE EMPLOYER TELECOMMUTING ADOPTION MODEL

INTRODUCTION

As discussed in chapter 2, the number of decision makers involved in organizational strategic decision-making varies across organizations. Recognizing that executives may play an important role in this process regardless of the size of the formal decision group and the underlying decision mechanism, the executives' stated preferences obtained from the survey described in chapter 4 are used in this chapter to empirically estimate a model of employer support for telecommuting. While the employee responses to each telecommuting program scenario represent preferences for his/her own telecommuting, the executive responses provide his/her willingness to support a telecommuting program of given characteristics in the organization.

As in the employee model of the previous chapter, the alternative responses for each program scenario in the executive survey (1: yes, 2: possibly, and 3: no) reflect the perceived attractiveness or utility of the defined telecommuting programs to the executive. Like the employee data, the number "4" was subtracted from the executive initial response codes so as to re-order the three response alternatives from the lowest attractiveness (1) "no" to the highest (3) "yes." Therefore, an ordered-response model is also appropriate to formulate the executive's choice of supporting a telecommuting program in the organization. Recognizing that there are nine scenarios for each respondent, the DGOP model is employed to capture the possible autocorrelation existing in responses from the same respondent. As mentioned in chapter 4, eighty-three executive questionnaires were received, yielding a total of eighty observations for model estimation.

The employee telecommuting choice model was discussed in the previous chapter. This chapter presents the employer model, with the model specification described in the next section, which is followed by the interpretation of estimation results.

MODEL SPECIFICATION

Specification of Latent Variable and Utility Thresholds

Similarly to the employee telecommuting choice model, three parts need to be specified in the employer model: the systematic components of the latent variable and the utility thresholds, and their variance-covariance structure. A latent variable is associated with each executive for each decision scenario; it measures the executive's perceived utility or attractiveness of the corresponding telecommuting program design. Alternatively, it can be viewed as a measure of the executive's propensity to support such a program. The systematic component of the latent variable is specified as a linear function of some known attributes.

While the employee model had four alternative responses for each scenario, only three alternatives are possible in the executive survey. Therefore, four utility thresholds (labeled from 0 to 3) need to be specified for each scenario in the employer model. As discussed in the previous chapter, because only the relative magnitudes of the utility thresholds matter, the lowest utility threshold (threshold 0) is set to negative infinity, the highest (threshold 3) to positive infinity, and the mean value of the second (threshold 1) to zero (McKelvey and Zavoina, 1975). This simplifying assumption leaves only the systematic component of the third utility threshold (threshold 2) to be specified. This component is also taken as a linear function of some known attributes, and restricted to be the same across the nine scenarios for each executive (as argued in the employee model). The employer model is thus specified as follows:

$$
\begin{aligned}
&Y^t_n = \beta\, Z^t_n + u^t_n \quad (t=1, 2,\ldots, 9) \\
&\mu_{0n} = -\infty \\
&\mu_{1n} = 0 + \varepsilon_{1n} \\
&\mu_{2n} = \alpha_2\, F_{2n} + \varepsilon_{2n} \\
&\mu_{3n} = +\infty
\end{aligned}
\qquad (6.1)
$$

In equation 6.1, Y^t_n and u^t_n denote the latent variable and its disturbance for individual n in scenario t (t=1, 2,..., 9). Similarly, μ_{in} and ε_{in} denote utility threshold i and its random component. Z^t_n and F_{2n} are vectors of observed attributes to be specified in the model, and β and α_2 are parameter vectors to be estimated.

Three attribute groups are specified in the Z vector: (1) economic implications of the telecommuting program design, (2) executive personal and management-related information, and (3) current availability of telecommunications facilities in the organization. The first group consists of the additional cost incurred by the employer to initiate a telecommuting program (ranging from no cost, some cost to all cost), and the corresponding salary change to telecommuting employees (from increasing 5% to decreasing 5%). The second group includes the executive's age, gender, educational level, job title, supervision methods, and number of directly supervised subordinates (management span). The final group is comprised of organizational characteristics such as the numbers of personal computers or mainframe terminals available to employees. Descriptive summary statistics of these attributes are listed in Table 4.5.

Variables in the first group differ across the nine telecommuting program scenarios for each executive. The estimated coefficients of these variables have implications for telecommuting program design. Variables in the second and third groups vary across executives but not across program scenarios. The resulting specification allows the latent variable to vary not only across telecommuting scenarios but also across the population of executives, and thus capture the effect of attributes of both the executive and organization, as well as the program design itself.

Additionally, as discussed in the specification of the employee utility thresholds, the regression scores that measure four general attitudes of executives toward telecommuting are specified in the employer model. The four attitudes pertain to the effect of telecommuting on (1) telecommuting workers and the organization's public image, (2) non-telecommuting workers, (3) overall workers, and (4) management concerns. These regression scores are obtained from a confirmatory factor analysis (CFA) using the executives' responses to the twelve attitudinal questions included in the executive survey (McDonald, 1985). These questions and the CFA results were discussed in chapter 4. Table 6.1 lists the regression weights for each factor (general attitudes), from which the directly measured twelve attitude scores of each executive can be transformed to four factor scores.

The four attitude scores are specified in the F vector in equation 6.1. Compared with the specification of the twelve directly measured attitudes, the use of general attitude scores reduces the number of parameters to be estimated and the possible correlations in the explanatory variables, and thus increases the accuracy of the parameter estimates.

Table 6.1 Factor Score Regression Coefficients on the Measured Attitudes (Employer Results)

Variable	General Attitudes (Factors) 1	2	3	4
1	0.108	-0.003	0.073	0.026
2	0.334	-0.009	0.225	0.079
3	-0.065	0.926	0.247	-0.016
4	0.292	0.043	0.395	0.039
5	0.111	-0.003	0.075	0.026
6	-0.003	-0.047	0.012	-0.001
7	0.065	0.010	0.087	0.009
8	0.109	-0.003	0.073	0.026
9	0.033	-0.001	0.012	0.130
10	0.077	-0.002	0.029	0.300
11	0.120	-0.003	0.045	0.471
12	0.012	0.000	0.005	0.048

Note: The general attitudes (factors) pertain to the effects of a telecommuting program on:
1. telecommuting workers and image of the organization,
2. non-telecommuting workers,
3. workers overall, and
4. managerial effectiveness and related concerns.

Specification of the Variance-Covariance Structure

In addition to the two disturbances of the utility thresholds ε_{1n} and, ε_{2n} in equation 6.1, there is a random component of the latent variable for each scenario. Consequently, the general variance-covariance structure of the employer telecommuting support model is a 27 by 27 matrix, with three elements for each of the nine program scenarios. As discussed in chapter 3, this variance-covariance matrix Σ can be represented as follows. For simplicity, the individual index n is eliminated in the following discussion.

$$\Sigma = \begin{array}{c|ccc} & u & \varepsilon_1 & \varepsilon_2 \\ u & \Sigma_{uu} & \Sigma_{u\varepsilon_1} & \Sigma_{u\varepsilon_2} \\ \varepsilon_1 & \Sigma_{u\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_2} \\ \varepsilon_2 & \Sigma_{u\varepsilon_2} & \Sigma_{\varepsilon_1\varepsilon_2} & \Sigma_{\varepsilon_2\varepsilon_2} \end{array} \qquad (6.2)$$

As discussed in the employee model specification, each element in equation 6.2 is a 9 by 9 submatrix. Following the DGOP model assumptions in Appendix A and the discussion in chapter 5, the covariances of both (u^t, ε_j^τ, $t \neq \tau$) and (ε_i^t, ε_j^τ, $t \neq \tau$ and $i \neq j$) are assumed to be 0, and all off-diagonal submatrices of matrix Σ are diagonal. For example, the covariances between utility thresholds i and j ($i \neq j$), i.e. $\Sigma_{\varepsilon_i\varepsilon_j}$, can be expressed as follows:

number of scenarios

	1	2	3	4	5	6	7	8	9
1	$cov(\varepsilon^1_i, \varepsilon^1_j)$	0	0	0	0	0	0	0	0
2	0	$cov(\varepsilon^2_i, \varepsilon^2_j)$	0	0	0	0	0	0	0
3	0	0	$cov(\varepsilon^3_i, \varepsilon^3_j)$	0	0	0	0	0	0
4	0	0	0	$cov(\varepsilon^4_i, \varepsilon^4_j)$	0	0	0	0	0
5	0	0	0	0	$cov(\varepsilon^5_i, \varepsilon^5_j)$	0	0	0	0
6	0	0	0	0	0	$cov(\varepsilon^6_i, \varepsilon^6_j)$	0	0	0
7	0	0	0	0	0	0	$cov(\varepsilon^7_i, \varepsilon^7_j)$	0	0
8	0	0	0	0	0	0	0	$cov(\varepsilon^8_i, \varepsilon^8_j)$	0
9	0	0	0	0	0	0	0	0	$cov(\varepsilon^9_i, \varepsilon^9_j)$

(6.3)

As explained in chapter 5 in connection with the employee model, three diagonal submatrices (Σ_{uu}, $\Sigma_{\varepsilon_1\varepsilon_1}$, and $\Sigma_{\varepsilon_2\varepsilon_2}$) are specified parametrically in order to generate unconstrained random variates in the computation of choice probabilities in the parameter estimation procedure. In general, the variance-covariance matrix $\Sigma_{\varepsilon_i\varepsilon_i}$ can be specified as presented in equation 6.4.

In equation 6.4, σ_i^2 is the variance of the latent variable or utility thresholds, and γ_i is the correlation coefficient, where i is an index with values 1 and 2 representing utility thresholds 1 and 2, respectively, and u representing the latent variable. Additionally, the matrix is symmetric. The specification presented in equation 6.4 reduces the number of parameters in each variance-covariance submatrix to two (σ_i and γ_i). It follows that there are nine parameters to be estimated in the variance-covariance matrix Σ , with two in each diagonal submatrix and one in each upper (or lower) triangle submatrix.

number of scenarios

	1	2	3	4	5	6	7	8	9
1	σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
2		σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
3			σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
4				σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
5					σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
6						σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
7							σ_i^2	$\gamma_i\sigma_i\sigma_i$	$\gamma_i\sigma_i\sigma_i$
8								σ_i^2	$\gamma_i\sigma_i\sigma_i$
9									σ_i^2

(6.4)

ESTIMATION RESULTS AND DISCUSSION

The DGOP estimation procedure developed in chapter 3 was also applied to the executive model using the survey data. Table 6.2 shows the parameter estimates and their corresponding t values for the executive choice model. All variables intended to capture the economic aspects of the program designs are statistically significant. As expected, employer responsibility for some (ES) or all (ET) additional telecommuting costs has a negative effect on the executive's preference, with estimated coefficients -0.414 and -0.572 for the respective indicator (dummy) variables. Similarly, the negative coefficient of (dummy) variable SI5 indicates that an increase in the telecommuter salary reduces the probability that the executive will support such a program, all else being equal.

Interestingly, a decrease in the telecommuter salary (SD5) exerts a negative influence on the executive's willingness to support telecommuting, indicating that a program that reduces the employee's salary will not necessarily increase the likelihood of executive support. This result might be contrary to the *a priori* speculation that the executive would support any program that could cut the organization's cost. Executives undoubtedly believe that it would be unfair to penalize a telecommuter if he/she could have the same job performance, and that reducing the telecommuter's salary would not be viewed favorably by the employees, and would therefore lead to a poor public image of the organization.

The relative values of the coefficient estimates of SI5 (-1.031) and SD5 (-0.676) indicate that an employee salary increase exerts a stronger effect on employer support than a decrease. Though executives may not wish to decrease the telecommuter salary, they find it less tolerable to increase telecommuting employee salaries. This asymmetry between the effect on employer support of positive and negative changes in employee salary is illustrated in Figure 6.1. As expected, the significant difference between the coefficients of ES (-0.414) and ET (-0.572) indicates that the employer is less inclined to support a program when the organization incurs all additional costs than when the employer incur only part of the additional costs.

The estimated coefficients of variables SI5, ES, and ET also provide an opportunity to compare the relative effects of an employee salary increase versus employer responsibility for additional telecommuting. The results imply an increase in telecommuter salaries is less tolerated by the executive than having to assume some or all telecommuting costs.

Two variables describing the executives' management-related characteristics significantly affect their preferences for supporting a telecommuting program: job title (JT) and management span. For example, the negative coefficient of JT (-0.772) implies that all else being equal, presidents or vice presidents are more reluctant to support a telecommuting program than others. On the other hand, executives with a management span of less than six employees are more willing to initiate a telecommuting program than others, as indicated by the corresponding coefficient (0.451). The results indicate that executives with more power in the decision making process or a greater number of directly supervised subordinates are less likely to support telecommuting. The former result has a strong policy implication in that executives who generally make the decision appear to have a lower probability of supporting telecommuting than others.

In terms of personal characteristics, the estimated coefficient of the executive's educational achievement level indicator (EA, 0.439) indicates that executives with at least a master's degree have a higher probability of supporting telecommuting. On the other hand, executives who know someone who telecommutes are more likely to support it. Furthermore, as indicated in Table 6.2, none of the organizational characteristics has a significant effect on the propensity to support telecommuting.

Two of the executive's four general attitudes toward telecommuting are found to significantly affect the utility thresholds. These attitudes pertain to the effect of a telecommuting program on (1) telecommuting workers and the public image of the organization (FTELE) and (2) management concerns such as employee productivity, executive ability to supervise telecommuters, and data security (FMANG). The estimated coefficients (-0.488 and -0.118 for FTELE and FMANG, respectively) indicate that the effect of both attitudes are negative, implying that a positive attitude toward telecommuting will reduce the executive's utility thresholds, thereby increasing the probability that the executive support a telecommuting program. Recall that positive attitudes imply that the executive feels telecommuting will increase the telecommuter's productivity and improve the executive's ability to supervise subordinates.

The results in Table 6.2 also indicate that all estimates of the specified standard deviations and correlation coefficients are statistically significant. In addition, the estimated correlation coefficients show that for the latent variable or a specific utility threshold i (i=1, 2) there exist positive correlations among the disturbances in different decision scenarios. While all t values listed in Table 6.2 are for the null hypothesis that the true coefficient of the corresponding variable is zero, all estimates of the standard deviations (γ_u, γ_1, and γ_2,) are also tested against the hypothesis that the true parameter is equal to one. The results indicate that all three parameters are significantly different from one. These two tests imply that all correlation coefficients are greater than zero but less than one.

Table 6.2 Estimation Results of Employer Telecommuting Support Model

Variables		Parameter estimates*	
Specified in the latent variable			
Constant		0.229	
(Economic implications)			
SI5:	Telecommuter salary change (1 if increase 5 %; 0 otherwise)	-1.031	(-3.5)
SD5:	Telecommuter salary change (1 if decrease 5 %; 0 otherwise)	-0.676	(-37.0)
ES:	Employer responsibility for additional partial telecommuting costs (1 if some costs; 0 otherwise)	-0.414	(-32.0)
ET:	Employer responsibility for all additional telecommuting costs (1 if total costs; 0 otherwise)	-0.572	(-22.0)
(Executive personal characteristics)			
EA:	Executive's educational achievement (1 if a master or Ph.D. degree; 0 otherwise)	0.493	(12.0)
AW:	Awareness of telecommuting (1 if the executive knows someone who telecommutes; 0 otherwise)	0.537	(19.0)
(Executive job 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 the executive (1 if <= 5; 0 otherwise)	0.451	(23.0)

* Numbers in parentheses are t-values

Table 6.2 Estimation Results of Employer Telecommuting Support Model (Continued)

Variables		Parameter estimates*	
Specified in the utility threshold			
Utility threshold 2			
Constant		3.923	
FTELE:	Regression score of executive attitudes toward telecommuting effect on telecommuters and public image of organization	-0.488	(-60.0)
FMANG:	Regression score of executive attitudes toward the management impacts of telecommuting	-0.118	(-22.0)
Variance-covariance			
σ_u	Standard deviation of the disturbance of the latent variable	1.180	(72.0)
γ_u	Correlation coefficient of disturbances of latent variables under different scenarios	0.700	(19.0)
σ_1	Standard deviation of the disturbance of threshold 1	0.773	(81.0)
γ_1	Correlation coefficient of disturbances of threshold 1 under different scenarios	0.755	(54.0)
σ_2	Standard deviation of the disturbance of threshold 2	0.994	(100.0)
γ_2	Correlation coefficient of disturbances of threshold 2 under different scenarios	0.236	(27.0)
Cov(u, 1)	Covariance of disturbances of the latent variable and threshold 1	0.192	(27.0)
Cov(u, 2)	Covariance of disturbances of the latent variable and threshold 2	0.180	(21.0)
Cov(1, 2)	Covariance of disturbances of thresholds 1 and 2	0.281	(27.0)

Overall statistics

Number of observations	80
Log likelihood value at zero	-791.0
Log likelihood value at convergence	-407.1

* Numbers in parentheses are t-values

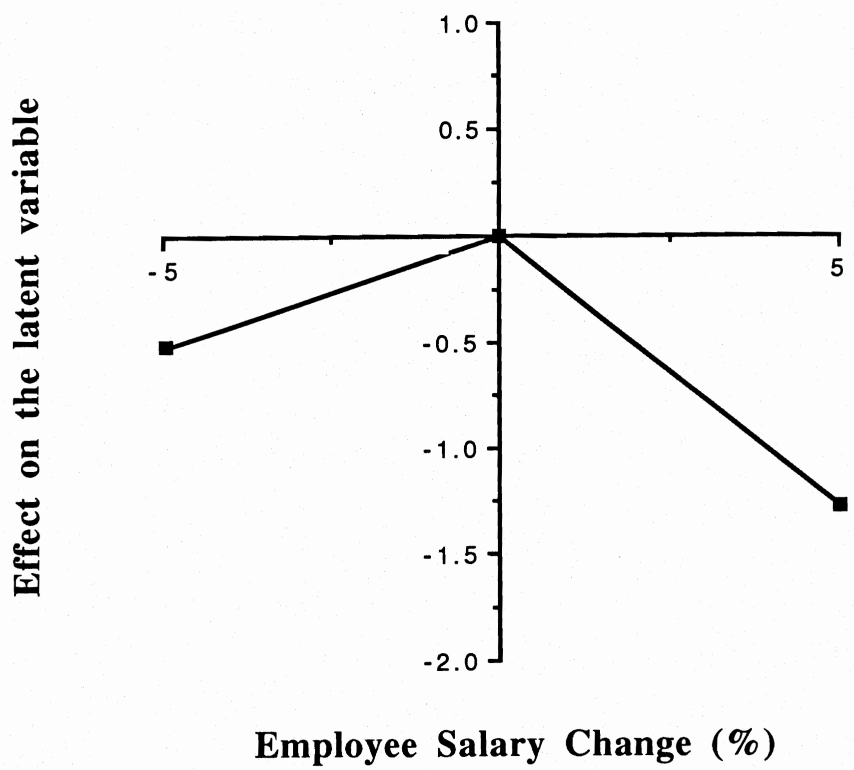

Figure 6.1 Effect of Employee Salary Changes on Latent Variable (Employer Model)

SUMMARY

This chapter has discussed the specification of the employer telecommuting adoption model, and presented successful estimation results using the procedure developed in chapter 3. Estimation results confirm most of the exploratory findings presented in chapter 4, namely that executive support of telecommuting is influenced by four groups of attributes: (1) economic implications of program design, (2) personal characteristics, (3) job title and management-related characteristics, and (4) attitudes toward telecommuting.

As expected, estimation results regarding program specifics indicate that employers are not likely to support a telecommuting program that increases telecommuter salary. On the other hand, they do not think that telecommuters should incur a decrease in salary, which is one of the major concerns of employee adoption. Other estimates confirm that management issues are the major obstacle to employer support, as seen in the exploratory results of chapter 4 and widely speculated in the literature.

Similarly to the employee model, estimation results also indicate significant autocorrelation among responses from the same executive, which are captured by the dynamic structure of the generalized ordinal probit model.

CHAPTER 7
APPLICATION OF THE TELECOMMUTING ADOPTION MODELS

INTRODUCTION

The previous chapters have presented the estimated telecommuting adoption models for both employees and employers, based on the generalized ordinal probit formulation derived in this work and estimated using a procedure that relies on a Monte Carlo simulation approach to calculate the choice probabilities. The models themselves provide a systematic and quantitative analysis of telecommuting participation by employees and program adoption by employers, yielding important substantive insights into the underlying behavioral processes. By identifying the relative importance of the factors that influence these decisions, the results also have policy implications in terms of telecommuting program design, the role that telecommuting might play as a demand management tool, and policy actions that might encourage more widespread adoption.

While the estimated choice models in chapters 5 and 6 constitute a contribution to telecommuting and travel behavior research in their own right, an important motivating objective of the quantitative analysis is to predict the extent to which telecommuting might be adopted under certain scenarios. Since telecommuting has been advocated as one of the most promising substitutes of work trips, the major causes of traffic congestion and air pollution during peak hours, the amount to which telecommuting is adopted determines the potential impacts of telecommuting on transportation systems. Furthermore, this matter is important to organizations concerned with the management aspects of telecommuting employees.

The present chapter is intended to illustrate the application of the telecommuting adoption models developed in chapters 5 and 6 to the prediction issue. The following section develops predictions of the probabilities of employee participation in various types of telecommuting programs, employer support of such programs in the organization, and the joint adoption by both decision makers. The third section provides estimates of the price elasticity of some policy variables of program specifics, as well as elasticities with respect to other explanatory variables. Finally, the impacts of telecommuting on fuel savings is estimated.

PREDICTION OF TELECOMMUTING ADOPTION

Though the theoretical background of the ordered response formulation of the telecommuting adoption models is different from the conventional random utility maximization probit model, it is nevertheless a member of the discrete choice model family. Therefore, the aggregate prediction methods with discrete choice models are applicable here as well (Koppelman, 1975; Ben-Akiva and Lerman, 1985). In this illustration, aggregate population probability predictions are obtained using the widely used classification approach.

First, the population is partitioned into mutually exclusive and collectively exhaustive groups. Each group is usually assumed to be homogeneous in the explanatory variables. Secondly, for each group, the probabilities that each alternative will be chosen are calculated, based on the estimated choice model and the representative values of explanatory variables for the group. The aggregation of the results from each group, weighted by the respective group sizes, provides the desired population-level prediction. The following section discusses the prediction of employee participation in telecommuting, followed by the prediction of employer support.

Prediction of Employee Telecommuting Adoption

Due to limited population information available to the present research and to simplify the calculation, the employee population is divided into two groups only in the following prediction procedure. However, the procedure can be applied to a more detailed partition when information from the target population is available. The employee population is separated into two groups on the basis of their computer skills, found in the previous chapters to significantly influence telecommuting choice. The members of group 1 are proficient at the medium or high level in at least one of the following skills: word processing, spreadsheet, data processing, computer programming, and computer graphics. Other employees belong to group 2. Among those 545 employees used in the model estimation, 84% (458) are in group 1 and 16% (87) are in group 2.

It is assumed that each group is (roughly) homogeneous in the explanatory variables, taken at their mean values for each group, as reported in Table 7.1. The predicted probabilities, listed in Tables 7.2 and 7.3, that each alternative is chosen in each group are calculated based on the estimated model evaluated at the representative values of the specified attributes. As indicated in chapter 5, four ordered alternatives are included in the employee's response set: (1) not to work from home, (2) possibly working from home, (3) working from home several days per week, and (4) working from home every day. All predictions for the employee population in this section are conditional upon the availability of the particular telecommuting program scenario at the place of employment.

Since each group is assumed to be homogeneous, the predicted probabilities reported in Tables 7.2 and 7.3 can also be interpreted as the fraction of respondents in each group who will choose each alternative under different telecommuting program scenarios. Table 7.2 indicates that within the group of employees with higher computer proficiency, about 74% will choose telecommuting at least on a part-time basis under scenario 1 (the status quo). This percentage increases to 83% for a 5% salary increase (scenario 4), but decreases dramatically if telecommuters must sacrifice salary, to 28% in scenario 6 (5% salary decrease) and to only 12% in scenario 7 (10% salary decrease). Within this employee group, 13% will still telecommute under the theoretically worst program scenario.

Compared to the first group, employees with relatively lower computer skills have lower likelihood of choosing telecommuting. Table 7.3 indicates that about 42% of employees in group 2 will choose telecommuting in scenario 1 and 53% in scenario 4. Again, this percentage drops to 7% in scenario 6 and 2% in scenario 7 if employees need to sacrifice salary for telecommuting.

To aggregate the predictions to the whole employee population, three prediction scenarios are considered. First, the fractions of the sample in the two computer proficiency groups are assumed to represent the population composition. This is of course a very strong assumption, because the sample was not selected at random, but from businesses judged *a priori* to offer suitable telecommuting opportunities. In this scenario, 84% of the employee population are in the high computer proficiency group, which constitutes an optimistic prediction scenario. The second scenario assumes a 50-50 split of the population into the two groups. This may be viewed as a neutral scenario. The third assumes 20% of employees in group 1, with 80% in group 2, yielding a conservative prediction scenario.

The aggregate results for the three prediction scenarios are listed in Tables 7.4, 7.5, and 7.6, respectively. Under the optimistic prediction, Table 7.4 illustrates that 78% of employees will consider telecommuting favorably if they receive a 5% salary increase and incur no additional costs (the best scenario for employees), with 0% working from home every day, 23% several days per week, and 55% possibly working from home. The percentage of telecommuting choicemakers reduces to 69% (0%, 16%, and 53% for the corresponding alternatives respectively) under the status-quo telecommuting program scenario (number 1) and dramatically drops to 10% if telecommuters have to sacrifice 10% of salary (the worst scenario for employees).

Compared to the optimistic prediction, the percentage of employees likely to choose telecommuting decreases for all telecommuting program scenarios under both the neutral prediction and the conservative prediction. These numbers are 68%, 58%, and 7% in the neutral prediction for the corresponding three program scenarios (best, neutral, and worst, respectively) and 59%, 48%, and 4% in the conservative prediction. The results reveal that in each prediction case, more than 48% of employees are likely to participate in telecommuting at least on a part-time basis under either the status-quo or best telecommuting program scenario. On the other hand, in the worst telecommuting program scenario, at most about 10% of the employees may choose telecommuting. It appears from the three prediction cases that an increase in salary may not increase by much the percentage of telecommuters. On the other hand, any decrease in salary appears to dramatically reduce the willingness of employees to telecommute.

Table 7.1 Mean Values of Explanatory Variables in Each Group

Variables		group 1	group 2
Specified in the latent variable			
(Employee personal and household characteristics)			
CHIL16:	Number of children under age 16 at home	0.61	0.70
HOMEPC:	Number of personal computers at home	0.60	0.22
(Employee job characteristics)			
HRFACE:	Number of hours communicating with co-workers face-to-face per day	1.69	1.50
HRCOMP:	Number of hours using a computer on work per day	4.65	1.68
(Employee commuting attributes)			
DSTRIP:	Distances from home to the workplace, miles	14.41	13.04
STOPS:	Average number of stops on the way to work and back home per week	2.38	2.84
Specified in the utility threshold			
FJOBSU:	Regression score of the employee's attitudes toward the job suitability for telecommuting	3.36	3.51
FFAMIL:	Regression score of the employee's attitudes toward the effect of telecommuting on family	2.62	2.25
FSOCIO:	Regression score of the employee's attitudes toward the importance of social interactions with co-workers	4.07	3.63

Note: group 1, if the employee has at least one computer proficiency in the medium or high level.
group 2, otherwise

Table 7.2 Predicted Choice Probabilities of Different Telecommuting Program Scenarios for Employees in Group 1 (proficiency at the medium or high level in at least one computer skill)

Telecommuting Program Scenario	Predicted Choice Probabilities 1	2	3	4*
1. Salary stays the same; employer pays all costs	.259	.557	.184	.000
2. Salary stays the same; employee incurs the cost of a new phone line	.485	.443	.073	.000
3. Salary stays the same; employee buys a personal computer	.592	.365	.044	.000
4. Salary increases 5%; employer pays all costs	.173	.568	.259	.000
5. Salary increases 5%; employee pays part of the costs	.439	.471	.090	.000
6. Salary decreases 5%; employer pays all costs	.740	.242	.019	.000
7. Salary decreases 10%; employer pays all costs	.882	.115	.004	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Table 7.3 Predicted Choice Probabilities of Different Telecommuting Program Scenarios for Employees in Group 2 (no proficiency at the medium or high level in any computer skill)

Telecommuting Program Scenario	**Predicted Choice Probabilities** 1	2	3	4*
1. Salary stays the same; employer pays all costs	.579	.368	.053	.000
2. Salary stays the same; employee incurs the cost of a new phone line	.794	.192	.014	.000
3. Salary stays the same; employee buys a personal computer	.861	.132	.007	.000
4. Salary increases 5%; employer pays all costs	.467	.445	.088	.000
5. Salary increases 5%; employee pays part of the costs	.750	.229	.021	.000
6. Salary decreases 5%; employer pays all costs	.930	.068	.002	.000
7. Salary decreases 10%; employer pays all costs	.980	.019	.000	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Table 7.4 Predicted Choice Probabilities of Different Telecommuting Program Scenarios for the Employee Population (Optimistic Prediction, 84% Employees with High Computer Skills and 16% without)

Telecommuting Program Scenario	Predicted Choice Probabilities 1	2	3	4*
1. Salary stays the same; employer pays all costs	.310	.527	.163	.000
2. Salary stays the same; employee incurs the cost of a new phone line	.534	.403	.064	.000
3. Salary stays the same; employee buys a personal computer	.635	.328	.038	.000
4. Salary increases 5%; employer pays all costs	.220	.548	.232	.000
5. Salary increases 5%; employee pays part of the costs	.489	.432	.079	.000
6. Salary decreases 5%; employer pays all costs	.770	.214	.016	.000
7. Salary decreases 10%; employer pays all costs	.898	.100	.003	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Table 7.5 Predicted Choice Probabilities of Different Telecommuting Program Scenarios for the Employee Population (Neutral Prediction, 50% Employees with High Computer Skills, 50% without)

Telecommuting Program Scenario	Predicted Choice Probabilities 1	2	3	4
1. Salary stays the same; employer pays all costs	.419	.463	.119	.000
2. Salary stays the same; employee incurs the cost of a new phone line	.640	.318	.044	.000
3. Salary stays the same; employee buys a personal computer	.727	.249	.026	.000
4. Salary increases 5%; employer pays all costs	.320	.507	.174	.000
5. Salary increases 5%; employee pays part of the costs	.595	.350	.056	.000
6. Salary decreases 5%; employer pays all costs	.835	.155	.011	.000
7. Salary decreases 10%; employer pays all costs	.931	.067	.002	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Table 7.6 Predicted Choice Probabilities of Different Telecommuting Program Scenarios for the Employee Population (Conservative Prediction, 20% Employees with High Computer Skills, 80% without)

Telecommuting Program Scenario	Predicted Choice Probabilities 1	2	3	4
1. Salary stays the same; employer pays all costs	.515	.406	.079	.000
2. Salary stays the same; employee incurs the cost of a new phone line	.732	.242	.026	.000
3. Salary stays the same; employee buys a personal computer	.807	.179	.014	.000
4. Salary increases 5%; employer pays all costs	.408	.470	.122	.000
5. Salary increases 5%; employee pays part of the costs	.688	.277	.035	.000
6. Salary decreases 5%; employer pays all costs	.892	.103	.005	.000
7. Salary decreases 10%; employer pays all costs	.960	.038	.001	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Prediction of Employer Telecommuting Adoption

A classification approach is used again to illustrate the application of the model developed in chapter 6 to predict employer support for initiating a telecommuting program in the organization under different program specifics. Unlike the employee model, all explanatory variables specified in the latent variable of the employer model are binary indicators (dummy variables), including four variables reflecting program specifics and four describing executives' characteristics, as shown in Table 6.2. For prediction purposes, the executive population can be segmented into sixteen groups according to the specified executive attributes, provided that information is available on the population distribution of those groups. To simplify the calculation for demonstration purposes, four representative groups are considered.

The first represents executives likely to exhibit the highest likelihood to support telecommuting; it consists of executives who are not presidents or vice presidents, have a management span of less than six employees, are aware of telecommuting, and have attained a master's or Ph. D. degree. The second group of executives is less likely to support telecommuting; it includes presidents or vice presidents with a management span of at least six employees, who are not aware of telecommuting and do not hold a master's or Ph. D. degree. The other groups are between the above two extreme cases. The third includes presidents or vice presidents with a management span of less than six employees, not aware of telecommuting, and with a master's or Ph. D. degree. The last group provides a reference to the third group, and consists of executives who are not presidents or vice presidents but share all other characteristics with the third group. In addition to the opportunity for comparison that they provide, groups 3 and 4 are considered because they represent a substantial portion of executives in the sample.

Each group is assumed to be homogeneous in terms of the variables specified in the utility thresholds of the employer adoption model. Table 7.7 lists the means of these variables within each group; these are used as the representative values of the specified attributes in the model in the prediction process. Based on these values, the probabilities that each (support level or response) alternative is chosen by the representative executive in each group for the different telecommuting program scenarios are listed in Tables 7.8 to 7.11 (for the four executive groups, respectively).

The predicted results indicate that for group 1 (the most likely telecommuting supporters), at least 65% of the executives are likely to support such a program in the organization under the first six scenarios where the employee's salary (ES) stays the same or decreases 5%. Even in programs where the ES increases 5%, 71% of executives in group 1 would still support telecommuting if the employer incurs no additional costs. In the theoretically worst scenario from the employer's viewpoint (ES increases 5%, employer pays all costs), this percentage remains at 54%. On the other hand, the fraction of potential telecommuting supporters in group 2 drops dramatically. According to Table 7.9, at most about 34% of executives in this group would support telecommuting, and this in the first program scenario (ES the same, no costs to employer). This percentage is less than the support level exhibited by group 1 executives for the worst telecommuting program scenario.

Tables 7.10 and 7.11 confirm that the likely support for each program scenario is between the corresponding percentages of groups 1 and 2. Additionally, for each scenario, the fraction of telecommuting supporters in group 4 is greater than in group 3, confirming that presidents or vice presidents are less likely to support telecommuting, all else being equal. For scenario 1, for example, about 83% of the executives in group 4 will support telecommuting, compared with 62% in group 3 (presidents or vice presidents).

To simplify the prediction of employer telecommuting adoption, it is assumed that there are only two groups (1 and 2) in the executive population. The procedure, however, can be applied to a more detailed prediction with a finer stratification of the executive population. Following the approach used to predict employee adoption, three prediction scenarios are considered. The first (optimistic prediction) assumes that the executive population consists of 80% in group 1 and 20% in group 2. The second (neutral prediction) assumes that 50% is in group 1 and 50% in group 2. Finally, the population composition under the conservative prediction scenario is 20% and 80%, respectively. The predicted results are reported in Tables 7.12, 7.13, and 7.14, for the three scenarios, respectively.

Under the optimistic prediction, at least 44% (in telecommuting program scenario 9) of executives will support a telecommuting program under any program scenario, with more than 54% for the first six scenarios (ES stays the same or decreases 5%). Specifically, the scenario with the most supporters is scenario 1 (cost neutral to the employer); about 80% of executives are likely to support it under this scenario, with 42% choosing "yes" and 38% choosing "possibly." Compared with the optimistic prediction results, the percentage of telecommuting supporters in each scenario decreases under the neutral prediction. However, about 63% of executives still choose to support telecommuting under scenario 1 (most attractive to employer) and about 30% under scenario 9 (least attractive). The corresponding numbers drop to 45% and 15% in the conservative prediction.

Table 7.7 Mean Values of Explanatory Variables in Each Group

Variables		Means of each group* 1	2	3	4
Specified in the utility threshold					
FTELE:	Regression score of the executive's attitudes toward the effect of telecommuting on telecommuters and public image of the organization	3.99	3.43	3.09	3.56
FMANG:	Regression score of the executive's attitudes toward the management impacts of telecommuting	3.25	2.69	2.19	2.60

* group 1 not president or vice president, management span less than 6, aware of telecommuting, with a master's or Ph. D. degree.

* group 2 presidents or vice president, management span greater than or equal to 6, not aware of telecommuting, without a master's or Ph. D. degree.

* group 3 presidents or vice president, management span less than 6, not aware of telecommuting, with a master's or Ph. D. degree.

* group 4 not presidents or vice president, management span less than 6, not aware of telecommuting, with a master's or Ph. D. degree.

Table 7.8 Predicted Probabilities of Executive Support of Different Telecommuting Program Scenarios in Group 1*

Telecommuting Program Scenario	Predicted Choice Probabilities 1 *No*	2 *Possibly*	3 *Yes*
1. Employee salary stays the same; employer incurs no costs	.082	.402	.515
2. Employee salary stays the same; employer assumes some costs	.145	.459	.396
3. Employee salary stays the same; employer pays all costs	.176	.472	.351
4. Employee salary decreases 5%; employer incurs no costs	.199	.486	.315
5. Employee salary decreases 5%; employer assumes some costs	.300	.474	.227
6. Employee salary decreases 5%; employer pays all costs	.350	.458	.192
7. Employee salary increases 5%; employer incurs no costs	.285	.476	.239
8. Employee salary increases 5%; employer assumes some costs	.406	.441	.153
9. Employee salary increases 5%; employer pays all costs	.458	.414	.128

* group 1 not president or vice president, management span less than 6, aware of telecommuting, with a master's or Ph. D. degree.

Table 7.9 Predicted Probabilities of Executive Support of Different Telecommuting Program Scenarios in Group 2*

Telecommuting Program Scenario	**Predicted Choice Probabilities** **1** *No*	**2** *Possibly*	**3** *Yes*
1. Employee salary stays the same; employer incurs no costs	.662	.304	.034
2. Employee salary stays the same; employer assumes some costs	.771	.214	.015
3. Employee salary stays the same; employer pays all costs	.806	.180	.013
4. Employee salary decreases 5%; employer incurs no costs	.832	.156	.012
5. Employee salary decreases 5%; employer assumes some costs	.899	.097	.004
6. Employee salary decreases 5%; employer pays all costs	.918	.079	.003
7. Employee salary increases 5%; employer incurs no costs	.888	.107	.005
8. Employee salary increases 5%; employer assumes some costs	.938	.060	.002
9. Employee salary increases 5%; employer pays all costs	.951	.047	.001

* group 2 president or vice president, management span greater than or equal to 6, not aware of telecommuting, without a master's or Ph. D. degree.

Table 7.10 Predicted Probabilities of Executive Support of Different Telecommuting Program Scenarios in Group 3*

Telecommuting Program Scenario	**Predicted Choice Probabilities** 1 *No*	2 *Possibly*	3 *Yes*
1. Employee salary stays the same; employer incurs no costs	.375	.519	.106
2. Employee salary stays the same; employer assumes some costs	.501	.443	.055
3. Employee salary stays the same; employer pays all costs	.550	.404	.046
4. Employee salary decreases 5%; employer incurs no costs	.587	.376	.037
5. Employee salary decreases 5%; employer assumes some costs	.706	.274	.020
6. Employee salary decreases 5%; employer pays all costs	.743	.241	.016
7. Employee salary increases 5%; employer incurs no costs	.694	.284	.022
8. Employee salary increases 5%; employer assumes some costs	.793	.197	.010
9. Employee salary increases 5%; employer pays all costs	.825	.167	.008

* group 3 president or vice president, management span less than 6, not aware of telecommuting, with a master's or Ph. D. degree.

Table 7.11 Predicted Probabilities of Executive Support of Different Telecommuting Program Scenarios in Group 4*

Telecommuting Program Scenario	Predicted Choice Probabilities 1 *No*	2 *Possibly*	3 *Yes*
1. Employee salary stays the same; employer incurs no costs	.173	.531	.297
2. Employee salary stays the same; employer assumes some costs	.274	.524	.202
3. Employee salary stays the same; employer pays all costs	.307	.524	.169
4. Employee salary decreases 5%; employer incurs no costs	.340	.513	.147
5. Employee salary decreases 5%; employer assumes some costs	.466	.441	.093
6. Employee salary decreases 5%; employer pays all costs	.515	.407	.078
7. Employee salary increases 5%; employer incurs no costs	.451	.451	.098
8. Employee salary increases 5%; employer assumes some costs	.578	.365	.056
9. Employee salary increases 5%; employer pays all costs	.627	.330	.043

* group 4 not president or vice president, management span less than 6, not aware of telecommuting, with a master's or Ph. D. degree.

Table 7.12 Predicted Aggregate Probabilities of Executive Support for Different Telecommuting Program Scenarios (Optimistic Prediction, 80% in Group 1 and 20% in Group 2)

Telecommuting Program Scenario	**Predicted Choice Probabilities**		
	1 *No*	**2** *Possibly*	**3** *Yes*
1. Employee salary stays the same; employer incurs no costs	.198	.382	.419
2. Employee salary stays the same; employer assumes some costs	.270	.410	.320
3. Employee salary stays the same; employer pays all costs	.302	.414	.283
4. Employee salary decreases 5%; employer incurs no costs	.326	.420	.254
5. Employee salary decreases 5%; employer assumes some costs	.420	.399	.182
6. Employee salary decreases 5%; employer pays all costs	.464	.382	.154
7. Employee salary increases 5%; employer incurs no costs	.406	.402	.192
8. Employee salary increases 5%; employer assumes some costs	.512	.365	.123
9. Employee salary increases 5%; employer pays all costs	.557	.341	.103

Table 7.13 Predicted Aggregate Probabilities of Executive Support for Different Telecommuting Program Scenarios (Neutral Prediction, 50% in Group 1 and 50% in Group 2)

Telecommuting Program Scenario	**Predicted Choice Probabilities** 1 *No*	2 *Possibly*	3 *Yes*
1. Employee salary stays the same; employer incurs no costs	.372	.353	.275
2. Employee salary stays the same; employer assumes some costs	.458	.337	.206
3. Employee salary stays the same; employer pays all costs	.491	.326	.182
4. Employee salary decreases 5%; employer incurs no costs	.516	.321	.164
5. Employee salary decreases 5%; employer assumes some costs	.600	.286	.116
6. Employee salary decreases 5%; employer pays all costs	.634	.269	.098
7. Employee salary increases 5%; employer incurs no costs	.587	.292	.122
8. Employee salary increases 5%; employer assumes some costs	.672	.251	.078
9. Employee salary increases 5%; employer pays all costs	.705	.231	.065

Table 7.14 Predicted Aggregate Probabilities of Executive Support for Different Telecommuting Program Scenarios (Conservative Prediction, 20% in Group 1 and 80% in Group 2)

Telecommuting Program Scenario	**Predicted Choice Probabilities**		
	1 *No*	**2** *Possibly*	**3** *Yes*
1. Employee salary stays the same; employer incurs no costs	.546	.324	.130
2. Employee salary stays the same; employer assumes some costs	.646	.263	.091
3. Employee salary stays the same; employer pays all costs	.680	.238	.081
4. Employee salary decreases 5%; employer incurs no costs	.705	.222	.073
5. Employee salary decreases 5%; employer assumes some costs	.779	.172	.049
6. Employee salary decreases 5%; employer pays all costs	.804	.155	.041
7. Employee salary increases 5%; employer incurs no costs	.767	.181	.052
8. Employee salary increases 5%; employer assumes some costs	.832	.136	.032
9. Employee salary increases 5%; employer pays all costs	.852	.120	.026

Joint Prediction of Telecommuting Adoption

As described in the conceptual framework of chapter 2 , it is essential to recognize that the adoption and success of a telecommuting program in the organization is the result of both employer support and employee participation. In other words, it is the joint outcome of decisions made by both actors, and both need to be considered in order to predict the implementation of telecommuting. As noted in section 7.2.1, the employee predictions were conditional upon employers agreeing to provide the particular telecommuting program under consideration. In this section, this conditionality is explicitly incorporated in predicting the extent to which telecommuting might be adopted.

The probability of a joint outcome can be expressed as the product of a conditional probability and a marginal probability. That is, $P(\mathbf{A} \cdot \mathbf{B}) = P(\mathbf{A}|\mathbf{B})\ P(\mathbf{B})$, where $P(\mathbf{B})$ is the probability of event **B** and $P(\mathbf{A}|\mathbf{B})$ is the probability of event **A** conditional on event **B**. Let **A** be employee telecommuting participation and **B** be employer support. Since the predicted probability of employee participation is conditional on the employer's willingness to support such a program, the probability of joint adoption is the product of the probabilities of employee and employer predictions obtained in the previous sections. Furthermore, to predict joint adoption, the favorable response categories in the choice set are combined into only two categories (adoption or not adoption) for both employees and employers. That is, employees who choose "telecommute every day," "telecommute several days per week," or "possibly telecommute" are considered as "adopters," while those who "do not want to telecommute" are included in the other category labeled as "non-adopters." Executives who opt for "yes" or "possibly" in support of telecommuting are also defined as "adopters"; others are "non-adopters."

Additionally, the prediction of employee adoption includes seven program scenarios, and nine for employer adoption. Theoretically, only scenarios considered by both employees and employers provide information for the final prediction. As discussed in the stated preference comparison of employees and executives in chapter 4, six scenarios are common. However, because employees apparently do not want to sacrifice salary in order to telecommute, and employers are generally disinclined to increase telecommuters' salary, the reasonable program scenarios for prediction of possible telecommuting adoption eventually consist of the three scenarios under which telecommuters' salary remains the same. Table 7.15 lists the aggregate fractions of "adopters" for employees and employers, taken separately, under the above three program scenarios (with neutral telecommuter salary), for the three prediction scenarios described earlier for each decision maker (optimistic, neutral, and conservative). These prediction scenarios contribute nine possible combinations of joint prediction, i.e. each employee prediction scenario can be combined with three possible employer prediction scenarios and vice versa. The nine combinations and predicted joint adoption probabilities are listed in Table 7.16.

The results in Table 7.16 indicate that the ultimate joint telecommuting adoption ranges from a high of about 48% (optimistic prediction scenarios for both employees and employers under program scenario 1) to 7% (conservative prediction scenario under program scenario 3). In each case, the likelihood of joint adoption decreases substantially if the costs incurred by telecommuters increase. For example, under the first combination (optimistic for both), this percentage drops from 48% (scenario 1, no costs to telecommuters) to 41% (telecommuters add a new phone line and employer assumes some costs), and further to 34% (telecommuters buy a personal computer and employer pays some costs).

Although the aggregate probability of joint adoption varies from about 50% to less than 10%, the results provide useful information to derive a reasonable range of possible telecommuting adoption. Employees appear to have strong preferences for telecommuting under the fixed-salary scenarios, and a noticeable fraction of employees in the sample have higher computer skills. It is widely cited in the literature that about 50% of U.S. workers can be classified as information workers (Porat, 1977), so the neutral prediction scenario of employee adoption (50% employees with higher computer skills) seems reasonable. On the other hand, with management issues remaining a barrier to employer support, and executive awareness of telecommuting still limited, the neutral or conservative prediction of employer adoption may be appropriate.

The above implies that the predicted results under combinations 5 and 6 in Table 7.16 (neutral for both employees and employers; neutral for employees and conservative for employers) give a reasonable range of the possible joint adoption of telecommuting. In other words, the percentage of joint adoption varies from about 30% to 10%. In general, if the employer is willing to pay all additional costs of telecommuting and telecommuters' salary remains the same, the possible adoption of telecommuting is between 20% and 30%. If the employer is not willing to pay all costs, the adoption is between 10% and 20%. These results are close to other predictions in the literature, e. g. 35% by Illinois Bell (Schlossberg, 1991) and 10% to 20% by Boghani *et al.* (1991).

Table 7.15 Prediction of Adopter Probabilities for Employees and Employers (Separately) under Different Telecommuting Programs in Three Prediction Scenarios

Telecommuting Program Scenario	Predicted Choice Probabilities		
	optimistic	*neutral*	*conservative*
Employee salary stays the same; employer pays all costs			
employee	.690	.582	.485
employer	.697	.508	.319
Employee salary stays the same; employer assumes some costs; employee adds a new phone line			
employee	.467	.362	.268
employer	.730	.543	.354
Employee salary stays the same; employer assumes some costs; employee buys a personal computer			
employee	.366	.275	.193
employer	.730	.543	.354

Table 7.16 Joint Prediction of Telecommuting Adoption Probabilities from Different Combinations of Prediction Scenarios

Joint prediction combinations (employee prediction; employer prediction)		Telecommuting program* 1	2	3
1.(optimistic;	optimistic)	.481	.341	.267
2.(optimistic;	neutral)	.351	.254	.199
3.(optimistic;	conservative)	.220	.165	.130
4.(neutral;	optimistic)	.406	.264	.201
5.(neutral;	neutral)	.296	.197	.149
6.(neutral;	conservative)	.186	.128	.097
7.(conservative;	optimistic)	.338	.196	.141
8.(conservative;	neutral)	.246	.146	.105
9.(conservative;	conservative)	.155	.095	.068

* Notes:
1: employee salary stays the same; employer pays all costs
2: employee salary stays the same; employer assumes some costs; employee adds a new phone line
3: employee salary stays the same; employer assumes some costs; employee buys a personal computer

ELASTICITY ANALYSIS

The prediction of telecommuting adoption by both employees and employers provides useful information for researchers and practitioners in the transportation and management areas, as well as decision makers engaged in public policy development at local and national governments. The estimated telecommuting choice models are also capable of capturing the elasticities of the choice probabilities with respect to various explanatory variables, especially to policy variables such as prices. The elasticities are important for decision makers in the organization or the public sector in that they capture the change of employee telecommuting participation as the explanatory variable is increased or decreased.

In order to calculate the elasticity of telecommuting demand, the demand function for telecommuting is defined in the next section, which is followed by the elasticity analysis itself.

Demand Function and Elasticity

From a microeconomics theory perspective, telecommuting can be considered a goods or service and its demand function can be interpreted as a function of prices and generalized income. The price variables include the costs of telecommuting itself and the costs of its substitute or complementary goods such as "commuting to work." The generalized income variables consist of factors that affect the employee preference for telecommuting, such as personal, household, and job characteristics. The elasticity of telecommuting demand can be calculated after the demand function is defined. According to Daganzo (1979), the estimated telecommuting adoption models in chapters 5 and 6 are choice probability functions (or choice functions for simplicity). The choice function P is a function of a vector of specified attributes **a** and a vector of parameters θ to be estimated, and can be stated as

$$P = P(\theta, \mathbf{a}). \tag{7.1}$$

Specifically, the choice function can be defined for each alternative in the choice set and denoted as $P_j(\theta, \mathbf{a})$, j=1, 2,..., J, where J is the number of alternatives. To obtain the demand function of each alternative, both the choice probability function $P(\theta, \mathbf{a})$ and the probability density function of the specified attribute vector, denoted as $f_A(\mathbf{a})$, need to be considered. For a given vector of model parameters θ, the demand function can be expressed as:

$$D = \int_{a_1} \int_{a_2} \ldots \int_{a_K} P(\theta, \mathbf{a})\, f_A(\mathbf{a})\, N\, d\mathbf{a}$$

$$= N \int_{a_1} \int_{a_2} \ldots \int_{a_K} P(\theta, \mathbf{a})\, f_A(\mathbf{a})\, d\mathbf{a}. \tag{7.2}$$

In equation 7.2, N is the population size and K is the number of attributes specified in the choice function. By definition, $P(\theta, \mathbf{a}) f_A(\mathbf{a}) N$ represents the density of decision makers with attribute vector **a** who choose the alternative of interest. Therefore, the integral in equation 7.2 is the mean of $P(\theta, \mathbf{a}) f_A(\mathbf{a}) N$ with respect to **A** and the demand function can be written as

$$D = E_A[N\, P(\theta, \mathbf{A})]$$
$$= N\, E_A[P(\theta, \mathbf{A})], \tag{7.3}$$

where E_A denotes the expectation function with respect to the vector of random variables **A**. As previously mentioned, the demand function for a specific alternative j is given by

$$D_j = N\, E_A[P_j(\theta, \mathbf{A})],\ j=1, 2, \ldots, J \tag{7.4}$$

Theoretically the elasticity of the demand for choice alternative j with respect to attribute a is:

$$\varepsilon_a^{D_j} = \frac{\partial D_j}{\partial a} \frac{a}{D_j}, \tag{7.5}$$

where D_j is given by equation 7.4. The elasticity defined in equation 7.5 is the point elasticity. In practice, to avoid the partial derivative, an arc elasticity is also defined as

$$\varepsilon_a^{D_j} = \frac{\Delta D_j}{\Delta a} \frac{(a_1 + a_2)/2}{(D_{j1} + D_{j2})/2}$$

$$= \frac{\Delta D_j}{\Delta a} \frac{a_1 + a_2}{D_{j1} + D_{j2}}. \tag{7.6}$$

In equation 7.6, D_{j1} is the demand for alternative j defined at $a=a_1$ and D_{j2} is defined at $a=a_2$. These results can be applied to calculate the elasticity of telecommuting demand, as discussed in the next section.

Elasticity of Employee Telecommuting Demand

The following elasticity analysis of employee telecommuting demand consists of three types of elasticities, corresponding three groups of explanatory variables. The first is the price elasticity, which measures the relative change in the choice probability of each alternative in the choice set (1 to 4) when the costs or salary change incurred by the telecommuter varies. The second is the cross-price elasticity with respect to the price change in substitute or complementary goods such as (physical) commuting. Therefore, the change in telecommuting demand due to the change in the attributes of the employee's commuting trips is considered as the cross-price elasticity. The third includes other variables such as personal or household characteristics and can be viewed as the generalized income elasticity.

To calculate the elasticity of telecommuting demand, equations 7.4 and 7.5 can be combined as:

$$\begin{aligned}\varepsilon_a^{D_j} &= \frac{\partial D_j}{\partial a}\frac{a}{D_j} \\ &= \frac{\partial\,\{N\,E_A\,[P_j\,(\theta,\,\mathbf{A})]\}}{\partial a}\,\frac{a}{N\,E_A\,[P_j\,(\theta,\,\mathbf{A})]} \\ &= \frac{\partial E_A\,[P_j\,(\theta,\,\mathbf{A})]}{\partial a}\,\frac{a}{E_A\,[P_j\,(\theta,\,\mathbf{A})]}. \qquad (7.7)\end{aligned}$$

To the extent that the aggregate demand elasticity is of interest, the elasticity calculation below follows the assumptions made in section 7.2 for the prediction of telecommuting adoption. That is, the employee population is divided into two groups according to computer proficiency level, and each group is homogeneous with respect the explanatory variables. It follows that the expected aggregate probability for each group is the probability of an employee whose values of the explanatory variables are the same as the representative value in the group, taken as the group mean in this research. Under these assumptions, equation 7.7 can be simplified as

$$\varepsilon_a^{D_j} = \frac{\partial P_j(\theta, \bar{\mathbf{A}})}{\partial a} \frac{a}{P_j(\theta, \bar{\mathbf{A}})}, \tag{7.8}$$

where $\bar{\mathbf{A}}$ is the vector of the group mean values of the explanatory variables.

According to equation 7.8, the predicted choice probabilities under the various telecommuting program scenarios listed in Tables 7.2 and 7.3 are necessary to calculate the price elasticity of telecommuting demand.

Price Elasticity The price elasticity of telecommuting demand is the percentage change of the choice probability due to one percent change in the price of telecommuting, all else being equal. If the change of the employee's salary (ES) is viewed as the change in the price that the employee has to pay in order to telecommute, the predicted probabilities under scenarios 1 (ES stays the same and he/she incurs no additional costs), 6 (ES decreases 5% and he/she incurs no additional costs), and 7 (ES decreases 10% and he/she incurs no additional costs) can be used to calculate the price elasticity of telecommuting demand.

Since salary change is specified as a binary indicator (dummy variable), the arc elasticity is adopted to avoid the partial derivative. From scenario 1 to scenario 7, the change in employee salary varies from 0% to -10%, respectively. The price change and the corresponding changes in the choice probabilities of each alternative can be obtained from Tables 7.2 and 7.3. Furthermore, to calculate the arc elasticity, the results from scenario 6 are used to represent the middle point of scenarios 1 and 7. It follows that the price elasticity of the telecommuting demand of each alternative can be calculated by the following equation.

$$\varepsilon_p^{D_j} = \frac{P_j(SD10) - P_j(SD0)}{(-10\%) - (0\%)} \frac{-5\%}{P_j(SD5)}, \tag{7.9}$$

In equation 7.9, $\varepsilon_p^{D_j}$ is the price elasticity of alternative j (j=1, 2, 3, 4), and P_j (SD0), P_j (SD5), and P_j (SD10) are predicted choice probabilities of alternative j under scenarios 1, 6, and 7, respectively.

Table 7.17 lists the price elasticity obtained for each alternative for the two employee population groups. The negative values for alternatives 2 and 3 for each group reflect that decreasing the employee's salary (i.e. increasing the price of telecommuting) reduces telecommuting demand. Additionally, the absolute values of the price elasticity of alternative 3 (the demand for telecommuting on a part-time basis) for both employee groups are greater than one, indicating that the demand for telecommuting is elastic with respect to its monetary price. The price elasticity of alternative 4 is equal to zero due to its zero choice probability predicted in the previous section. Further comparison of the elasticities of different employee groups reveals that the telecommuting demand of employee group 2 (with less computer proficiency) is more elastic than the demand of group 1.

Cross-Price Elasticity and Generalized Income Elasticity Unlike the dummy variables that define the specifics of telecommuting programs, other attributes are continuous and specified as generic variables in the employee telecommuting choice model. Therefore, the calculation of the cross-price elasticity and generalized income elasticity of telecommuting demand is based on the definition of point elasticity. Since the choice probability of the generalized ordinal probit model does not have a closed form, the partial derivative in the point elasticity expression is approximated numerically as follows:

$$\varepsilon_{a_k}^{D_j} = \frac{P_j(\theta, \bar{\mathbf{B}}) - P_j(\theta, \bar{\mathbf{A}})}{\Delta a_k} \frac{a_k}{P_j(\theta, \bar{\mathbf{A}})}, \qquad (7.10)$$

where the elements of vector $\bar{\mathbf{B}}$ are the same as in vector $\bar{\mathbf{A}}$ except that attribute a_k in the former is replaced by $a_k + \Delta a_k$.

Since telecommuting has been advocated as a substitute for work trips, commuting to work can be considered a substitute good of telecommuting. The cross-price elasticity of telecommuting demand is analyzed by examining the change in telecommuting demand due to the change in the price of commuting, taken as the distance from home to the workplace. Table 7.18 lists the cross-price elasticity of telecommuting demand of alternatives 2 and 3 for each employee group under different program scenarios. As shown in the table, all elasticities are positive, indicating that the increase in the costs of commuting will increase the demand for telecommuting. Further comparison of the elasticity for each employee group reveals some interesting results. For employees with lower computer skills (group 2), the cross-price elasticity is greater than the one of group 1 under each program scenario.

Table 7.17 Price Elasticity of Telecommuting Demand of Each Alternative by Employee Group

	Price elasticity of each alternative 1	2	3	4*
Group 1: proficient in at least one computer skill at the medium or high level	.421	-.915	-4.829	.000
Group 2: no computer proficiency at the medium or high level	.216	-2.580	-12.268	.000

* 1: Do not want to work from home.
2: Possibly would like to work from home.
3: Would like to work from home several days per week.
4: Would like to work from home every day.

Table 7.19 presents the generalized income elasticity of telecommuting demand with respect to variables such as the number of children under age 16 (CHIL16) and personal computers (HOMEPC) at home, the average number of stops on the way to work and back home, per week (STOPS), the number of hours communicating with co-workers face-to face, per day (HRFACE), and the number of hours using a computer on work, per day (HRCOMP). While the results indicate that the increase of CHIL16, HOMEPC, and HRCOMP will increase telecommuting demand in each program scenario, the demand is inelastic (i.e. the absolute value of the elasticity is less than one) with respect to the former two attributes. The elasticities with respect to STOPS and HRFACE are negative, showing that the increase of each of the two attributes will decrease telecommuting demand. In general, with respect to both variables, the absolute value of the elasticity of alternative 3 is greater than that of alternative 2. The results also indicate that full-time telecommuting demand is more elastic than part-time telecommuting.

Comparison of the three types of elasticities reveals that the price elasticity is the largest and the generalized income elasticity is the smallest. This result may have strong policy implications in that the price of telecommuting (i.e. the program design) is the most controllable from the policy maker's viewpoint and has the largest relative impact on employee telecommuting participation. In addition, the greater elasticity of full-time telecommuting compared to part-time telecommuting suggest that while the former is more likely to be influenced by the explanatory variables, part-time telecommuting demand is relatively more stable.

Table 7.18 Cross-Price Elasticity of Telecommuting Demand by Employee Group

	Cross-price elasticity in each scenario						
	1	2	3	4	5	6	7**
Average daily am and pm commuting time, minutes							
group 1†:							
alternative 2*	.057	.268	.349	.048	.270	.482	.701
alternative 3	.576	.378	.682	.270	.613	.568	.573
group 2:							
alternative 2	.321	.392	.539	.226	.272	.604	.553
alternative 3	.569	1.194	1.159	.513	.825	2.998	9.953

* alternative 2: possibly work from home.
alternative 3: work from home several days per week.

** scenario 1: salary stays the same; employer pays all costs
scenario 2: salary stays the same; employee incurs the cost of a new phone line
scenario 3: salary stays the same; employee buys a personal computer
scenario 4: salary increases 5%; employer pays all costs
scenario 5: salary increases 5%; employee pays part of the costs
scenario 6: salary decreases 5%; employer pays all costs
scenario 7: salary decreases 10%; employer pays all costs

† group 1: employees with proficiency in at least one computer skill at the medium or high level
group 2: employees with no computer proficiency at the medium or high level

Table 7.19 Generalized Income Elasticity of Telecommuting Demand by Employee Group

		Elasticity in each scenario						
		1	2	3	4	5	6	7**
Number of children under age 16 at home								
group 1†	alternative 2*	.008	.048	.105	.007	.054	.114	.055
	alternative 3	.138	.087	.049	.074	.094	.227	.000
group 2	alternative 2	.094	.101	.114	.072	.075	.191	.221
	alternative 3	.081	.299	.289	.098	.310	2.002	.000
Number of personal computers at home								
group 1	alternative 2	.023	.062	.145	.019	.081	.140	.185
	alternative 3	.161	.087	.049	.082	.094	.227	.000
group 2	alternative 2	.041	.045	.049	.043	.028	.095	.110
	alternative 3	.000	.000	.289	.000	.103	.996	.000
Average number of stops on the way to work and back home, per week								
group 1	alternative 2	-.068	-.182	-.326	.007	-.148	-.298	-.554
	alternative 3	-.380	-.495	-.243	-.401	-.636	-.568	-1.145
group 2	alternative 2	-.275	-.514	-.245	-.188	-.404	-.573	-.221
	alternative 3	-.488	-.746	-1.739	-.562	-.722	-.996	.000

* alternative 2: possibly work from home.
alternative 3: work from home several days per week.

** scenario 1: salary stays the same; employer pays all costs
scenario 2: salary stays the same; employee incurs the cost of a new phone line
scenario 3: salary stays the same; employee buys a personal computer
scenario 4: salary increases 5%; employer pays all costs
scenario 5: salary increases 5%; employee pays part of the costs
scenario 6: salary decreases 5%; employer pays all costs
scenario 7: salary decreases 10%; employer pays all costs

† group 1: employees with proficiency in at least one computer skill at the medium or high level
group 2: employees with no computer proficiency at the medium or high level

Table 7.19 Generalized Income Elasticity of Telecommuting Demand by Employee Group (Continued)

		Elasticity in each scenario						
		1	2	3	4	5	6	7**
Number of hours communicating with co-workers face-to-face per day								
group 1†	alternative 2*	-.114	-.344	-.593	.004	-.355	-.605	-1.052
	alternative 3	-.703	-.990	-.925	-.638	-1.060	-1.250	-2.285
group 2	alternative 2	-.362	-.716	-.490	-.241	-.667	-.794	-.884
	alternative 3	-1.016	-1.492	-1.739	-.954	-.928	-.996	.000
Number of hours using a computer on work per day								
group 1	alternative 2	.125	.531	.773	-.041	.436	1.026	1.292
	alternative 3	1.106	.931	1.265	.744	1.555	.909	2.857
group 2	alternative 2	.263	.347	.359	.173	.244	.572	.442
	alternative 3	.366	.896	1.159	.293	.825	2.002	.000

* alternative 2: possibly work from home.
alternative 3: work from home several days per week.

** scenario 1: salary stays the same; employer pays all costs
scenario 2: salary stays the same; employee incurs the cost of a new phone line
scenario 3: salary stays the same; employee buys a personal computer
scenario 4: salary increases 5%; employer pays all costs
scenario 5: salary increases 5%; employee pays part of the costs
scenario 6: salary decreases 5%; employer pays all costs
scenario 7: salary decreases 10%; employer pays all costs

† group 1: employees with proficiency in at least one computer skill at the medium or high level
group 2: employees with no computer proficiency at the medium or high level

IMPACTS OF TELECOMMUTING ON ENERGY SAVINGS

Four methods have been used previously to estimate fuel savings from telecommuting. The first calculates fuel savings as the product of the average fuel efficiency and average number of miles saved from each telecommuting occasion. The second takes into account differences among individual vehicles and aggregates individual savings, obtained from self-reported fuel efficiency and reduced travel distance due to telecommuting. The third method goes a step further to consider trip characteristics that influence fuel efficiency, including travel speed and whether it is a cold or hot start (Handy *et al.*, 1993). None of the three methods considers network effects in the estimation of energy savings.

The fourth method, developed by Sullivan *et al.* (1993) and used in this paper, relies on the "two-fluid model" of traffic in an urban network (Herman and Prigogine, 1979), which provides a macroscopic network-level description of traffic interactions in a network. It is used in this analysis to translate the fractions of vehicular trips substituted by telecommuting into total savings in vehicle-miles traveled (VMT) in a network. Fuel savings are then calculated based on a calibrated fuel consumption model. The two-fluid model takes into account network attributes such as average speed, concentration, and directional factors. The procedure also recognizes the possible increase in speed experienced by non-telecommuters that continue to commute.

To assess fuel savings due to telecommuting, it is essential to predict the extent to which telecommuting will be adopted. The prediction procedure developed in previous sections is applied to estimate the joint telecommuting adoption in three Texas cities (Austin, Dallas, and Houston), which is the basis of the analysis of telecommuting impacts on fuel savings. Table 7.20 lists the separate and joint predictions for employees and employers by city under the program scenario with neutral telecommuter salary and employers incurring all additional telecommuting costs.

For employee participation, results in Table 7.20 are intended to represent possible adoption by the target group of potential telecommuters, namely information related workers. To facilitate aggregate prediction, the population of information workers is stratified into two groups of employees: those having computer proficiency at the medium or high level as group 1, and others as group 2. The composition of groups 1 and 2 are obtained from the telecommuting survey sample (83% vs. 17%, 87% vs. 13%, and 83% vs. 17% for Austin, Dallas, and Houston, respectively). The values of exogenous variables specified in the estimated adoption models used in the prediction are obtained through the following rationale. First, it is assumed that the distributions of variables such as commuting attributes and the number of children under 16 among members of the target group is the same as the whole population. Therefore, the former are based on surveys with random observations in Texas (Jou *et al.*, 1992), and the latter is based on the U. S. census data (1990). Finally, other job attributes for the target group are based on information from the telecommuting survey conducted to calibrate the adoption models.

Predicting employer adoption is fraught with even greater uncertainty, especially with regard to the characteristics of the population of pertinent decision-makers in information-related organizations. Recognizing this uncertainty, employer adoption is predicted under three alternative scenarios: optimistic, middle, and conservative, as illustrated in Table 7.20, reflecting different composition of the underlying executive population. For aggregate prediction, the population of "representative" decision makers is conveniently stratified into two groups. Members in group 1 do not hold titles of president or vice president, have a management span of less than 6, and possess awareness of telecommuting. Members in the second group hold president or vice president titles, with management spans of at least 6 subordinates, and are not aware of telecommuting. The optimistic scenario assumes that the population of representative decision makers for employer adoption consists of 80% in group 1, and 20% in group 2. The population compositions for the middle and conservative prediction scenarios are 50% vs. 50% and 20% vs. 80%, respectively. Employee adoption (conditional on employer sponsorship) is assumed to be the same across the three prediction scenarios for each city. For each scenario, while employee adoption is predicted by city to reflect differences in transportation system performance and demographic data in the three cities (Table 7.21), employer adoption levels are assumed to be the same in the three cities. Under the optimistic scenario, about 42% of information workers in Austin will choose to work from home about twice per week, with 42% and 36% for Dallas and Houston, respectively. These probabilities decrease to 29%, 29%, and 25% for the middle scenario, and 16%, 17%, and 14% for the conservative scenario, respectively.

To predict fuel savings due to telecommuting, the middle scenario prediction is used as the base case. According to Woods and Poole (1990), 50% of total workers are information related in these cities. Assuming that telecommuting occasions are uniformly distributed across five work days per week, the predicted percentage of total workers who work from home every day is equivalent to 5.8% in Austin, 5.9% in Dallas and 5.0% in Houston, respectively, as listed in Table 7.22. These equivalent percentages of telecommuters are then applied to predict network-wide fuel savings due to telecommuting using the method proposed by Sullivan *et al.* (1993). Table 7.22 shows that predicted adoption of telecommuting will save about 18.4 thousand gallons of gas in Austin per day, 126.7 thousand gallons in Dallas, and 94.4 thousand gallons in

Houston. These savings are equivalent to 2.53%, 2.62%, and 2.08% of the total fuel consumed by vehicles every day in each city, respectively. Table 7.22 also indicates that vehicle fuel savings during peak hours (7-9 A.M. and 4-6 P.M.) on arterial are 3.6 thousand gallons in Austin per day, 23.3 thousand gallons in Dallas, and 22.0 gallons in Houston, which are equivalent to 5.73%, 6.17%, and 5.05% of total fuel consumed by vehicles everyday in the peak on arterial in each city, respectively. As expected, results reveal that fuel savings in terms of percentage in peak are higher than on the daily basis.

To reflect the variation of fuel savings according to different levels of employer adoption, which is believed to play a relatively more important role than employee adoption to date, fuel savings are also predicted under the conservative and optimistic prediction scenarios. In Austin, the conservative prediction indicates an equivalent 3.3% telecommuting penetration every day, resulting in 1.44% savings of daily fuel, or 3.26% fuel savings in peak hours. These numbers increase to 8.3%, 3.62%, and 8.19% under the optimistic scenario, respectively. Overall, the equivalent telecommuting penetration under the conservative scenario is about 3.0% in the three cities, 5.5% under the middle scenario, and 8.0% in the optimistic case. In terms of fuel consumed, daily savings range from about 1.5%, 2.5%, to 3.5% under three different prediction scenarios. Peak savings are about 3.0%, 5.5%, to 8.0%. The results show that fuel savings highly depend on the level of employer telecommuting adoption, and suggest that executives may need to be targeted by public policy makers to promote telecommuting acceptance and penetration.

Table 7.20 Predicted Probabilities of Telecommuting Adoption for Information-Related Workers

Cities	**Predicted Choice Probabilities**		
	Employee	Employer	Joint
Optimistic Scenario			
Austin	.650	.641	.417
Dallas	.657	.641	.421
Houston	.556	.641	.356
Middle Scenario			
Austin	.650	.446	.290
Dallas	.657	.446	.293
Houston	.556	.446	.248
Conservative Scenario			
Austin	.650	.251	.163
Dallas	.657	.251	.165
Houston	.556	.251	.140

Table 7.21 Mean Values of Explanatory Variables Used for Telecommuting Prediction

Variables		Austin	Dallas	Houston
Specified in the latent variable				
(Employee personal and household characteristics)				
CHIL16:	Number of children under age 16 at home	0.64	0.71	0.82
HOMEPC:	Number of personal computers at home	0.56	0.53	0.48
(Employee job characteristics)				
HRFACE:	Number of hours communicating with co-workers face-to-face per day	1.56	1.44	2.17
HRCOMP:	Number of hours using a computer on work per day	4.48	3.90	3.91
(Employee commuting attributes)				
DSTRIP:	Distance from home to the workplace, miles	10.80	13.00	13.90
STOPS:	Average number of stops on the way to work and back home per week	4.25	4.10	4.92
Specified in the utility threshold				
FJOBSU:	Regression score of the employee's attitudes toward the job suitability for telecommuting	3.98	3.90	4.29
FFAMIL:	Regression score of the employee's attitudes toward the effect of telecommuting on family	2.65	2.38	2.67
FSOCIO:	Regression score of the employee's attitudes toward the importance of social interactions with co-workers	3.42	3.33	3.38

Table 7.22 Fuel Consumption Savings from Telecommuting Under Realistic Network Data

	Austin			Dallas			Houston		
	C	M	O	C	M	O	C	M	O
portion of total workers working from home twice per week (%)	8.2	14.5	20.9	8.3	14.7	21.1	7.0	12.4	17.8
equivalent portion of total workers working from home everyday (%)	3.3	5.8	8.3	3.3	5.9	8.4	2.8	5.0	7.1
fuel savings, thousand gallons per day	10.5	18.4	26.3	71.1	126.7	180.4	52.7	94.4	132.2
fuel savings, percentage (%)	1.44	2.53	3.62	1.47	2.62	3.73	1.16	2.08	2.91
fuel savings, thousand gallons, peak on arterial	2.1	3.6	5.2	13.0	23.3	33.1	12.3	22.0	31.2
fuel savings, percentage (%), peak on arterial	3.26	5.73	8.19	3.45	6.17	8.78	2.83	5.05	7.17

Prediction scenarios: C, conservative
M, middle
O, optimistic

SUMMARY

This chapter has demonstrated the application of the estimated employee and employer telecommuting adoption models presented in chapters 5 and 6. Specifically, separate predictions of employee adoption and employer support, as well as prediction of joint adoption by both decision makers were presented. The elasticity of employee telecommuting demand with respect to price, cross-price, and generalized income variables was also analyzed.

The prediction results indicate that joint telecommuting adoption ranges from a high of about 50% under the most optimistic prediction scenario to a low of 6% under the most conservative one, for the fixed-salary program scenario. Under the relatively neutral (and most likely) prediction scenario, the results indicate that if the employer is willing to incur all additional telecommuting costs, possible adoption of telecommuting is between 20% and 30%; if the employer does not incur all additional costs, adoption is between 10% and 20%. These results are shared with other predictions in the literature.

The results of elasticity analysis indicate that price elasticity is largest, followed by cross-price elasticity, while generalized income elasticity is the smallest. In addition, the elasticity of full-time telecommuting demand is greater than for part-time telecommuting. These results could have strong policy implications in terms of telecommuting program design.

Specific predictions for three Texas cities, Austin, Dallas and Houston, suggest a likely potential savings of about 2 to 3.7% of total automotive fuel consumed in these areas, which is equivalent to about 5 to 8% of fuel consumed during the peak period on freeways and main arterials.

APPENDIX A
DEVELOPMENT OF THE GENERALIZED ORDINAL PROBIT MODEL

THE GENERALIZED ORDINAL PROBIT MODEL WITHOUT AUTOCORRELATION: THE GOP MODEL

Let Y_n be a latent variable which is a measure of the utility or attractiveness perceived by individual n, faced with J ordered choice alternatives. Assume that Y_n is a random variable with a measurable systematic component V_n and an unobservable disturbance u_n. Also let μ_{0n}, μ_{1n}, ..., μ_{Jn} be a set of utility thresholds for individual n with corresponding systematic components and disturbances S_{in}'s and ε_{in}'s (i=0, 1,..., J). That is,

$$Y_n = V_n + u_n \tag{A.1}$$

$$\mu_{in} = S_{in} + \varepsilon_{in}, \quad i = 0, 1, ..., J \tag{A.2}$$

where V_n and S_{in} are functions of some known attributes, to be specified according to the analyst's assumptions. The specification issues associated with V_n and S_{in} are discussed in chapter 5.

Since Y_n is unobservable and only discrete choices made by individuals are revealed to the analyst, let Z_{in} be an observable variable with values 1 or 0 such that Z_{in}= 1 if individual n chose alternative i and Z_{in}= 0, otherwise (i=1, 2,..., J). The previously mentioned ordered-response assumptions imply that Z_{in}= 1 if and only if $\mu_{i-1,n} < Y_n < \mu_{in}$ and Z_{in}= 0, otherwise. That is, for individual n the probability that Z_{in}= 1 is the probability of the event $\{ \mu_{i-1,n} < Y_n < \mu_{in} \}$. The probability that individual n chooses alternative i can be derived as follows:

$$\begin{aligned} &P_n(Z_{in}=1, \mu_{0n} < \mu_{1n} < ... < \mu_{Jn}) \\ &= P_n(Z_{in}=1 \mid \mu_{0n} < \mu_{1n} < ... < \mu_{Jn}) P_n(\mu_{0n} < \mu_{1n} < ... < \mu_{Jn}) \\ &= P_n(\mu_{i-1,n} < Y_n < \mu_{in} \mid \mu_{0n} < \mu_{1n} <...< \mu_{Jn}) P_n(\mu_{0n} < \mu_{1n} <...< \mu_{Jn}) \end{aligned} \tag{A.3}$$

For modeling purposes, the probability of $\{\mu_{i-1,n} < Y_n < \mu_{in}\}$ can be viewed as the probability that a pseudo alternative 0 is chosen from a choice set with three alternatives, 0, $\mu_{i-1,n} - Y_n$, and $Y_n - \mu_{in}$, i.e. $P_n(\mu_{i-1,n} < Y_n < \mu_{in}) = P_n(0 > \mu_{i-1,n} - Y_n, 0 > Y_n - \mu_{in})$. If the disturbances of the latent variable and utility thresholds are assumed to be normally distributed, the choice probability $P_n(0 > \mu_{i-1,n} - Y_n, 0 > Y_n - \mu_{in})$ can be formulated as a probit model (Daganzo, 1979).

The ordered-response model in equation A.3 differs from the traditional probit model in that the conditional probability $P_n(\mu_{i-1,n} < Y_n < \mu_{in} \mid \mu_{0n} < \mu_{1n} <...< \mu_{Jn})$, instead of the marginal probability $P_n(\mu_{i-1,n} < Y_n < \mu_{in})$, is included in the equation. In addition, the probability that the ordered sequence of utility thresholds, $P_n(\mu_{0n} < \mu_{1n} <...< \mu_{Jn})$, holds needs to be taken into account in the model. These differences give rise to the need for a special estimation procedure, which is addressed in Appendix B. The merit of this reduction, however, is that an ordered-response model with J alternatives and J+1 utility thresholds can be estimated using a random utility maximization framework with much fewer alternatives than in the original ordered choice set; hence the computation effort for the model estimation is expected to be lower.

Different assumptions regarding the joint distribution of the random disturbances of the latent variable and utility thresholds result in other model forms for the ordered-response choice function formulation in equation A.3. In this study, the normality assumption (and the resulting ordinal probit model) is adopted because of the flexible structure of the probit model. The advantage of probit models, compared with other discrete choice model forms, is that there is no restriction on the specification of the disturbance structures of utilities associated with the choice alternatives. In other words, the generalized ordered-response model developed here allows the analyst to specify a set of correlated stochastic utility thresholds with a general variance-covariance structure. In addition, the thresholds may be correlated with the latent variable. Under the normality assumption, the ordered-response model derived here is the most flexible one in the ordinal probit family and is henceforth labeled as the generalized ordinal probit (GOP) model. The relaxation of the two strong assumptions (deterministic utility thresholds and IID disturbances of latent variables) made by previous ordinal probit models enables the GOP model to represent more realistic behavioral phenomena.

It is straightforward to show that both the M-Z model and Terza's model are two special cases of the above GOP model. Since both the M-Z and the Terza's models assume deterministic utility thresholds, the J+1 thresholds in equation A.2 can be denoted by S_{in} (i = 0, 1, ..., J) without the disturbance terms. Therefore, equation A.3 can be restated as follows.

$$P_n\,(Z_{in}=1,\ \mu_0 < \mu_1 < ... < \mu_J)$$

$$= P_n(S_{i-1,n} < Y_n < S_{in} \mid S_{0n} < S_{1n} <...< S_{Jn})\ P_n(S_{0n} < S_{1n} <...< S_{Jn}) \qquad \text{(A.4)}$$

Additionally, both models implicitly assume that the model is well specified so that the ordered sequence of utility thresholds holds, though empirical estimated results may violate this implicit assumption. If the model is well specified and the threshold sequence holds, the probability $P_n(S_{0n} < S_{1n} <...< S_{Jn})$ in equation A.4 is equal to one and the conditional probability $P_n(S_{i-1,n} < Y_n < S_{in} \mid S_{0n} < S_{1n} <...< S_{Jn})$ reduces to a marginal probability $P_n(S_{i-1,n} < Y_n < S_{in})$. Combined with the second assumption that the disturbances of the latent variable are identically and independently normally distributed (IIND) across the population, the probability that individual n chooses alternative i can be further simplified as follows:

$$
\begin{aligned}
& P_n(Z_{in}=1, \mu_0 < \mu_1 < \dots < \mu_J) \\
&= P_n(S_{i-1,n} < Y_n < S_{in} \mid S_{0n} < S_{1n} <...< S_{Jn})\, P_n(S_{0n} < S_{1n} <...< S_{Jn}) \\
&= P_n(S_{i-1,n} < Y_n < S_{in}) \\
&= P_n(S_{i-1,n} < V_n + u_n < S_{in}) \\
&= P_n(S_{i-1,n} - V_n < u_n < S_{in} - V_n) \\
&= \Phi\left(\frac{S_{in} - V_n}{\sigma}\right) - \Phi\left(\frac{S_{i-1,n} - V_n}{\sigma}\right) \qquad \text{(A.5)}
\end{aligned}
$$

In equation A.5, σ is the standard deviation of the disturbance (u_n) of the latent variable (Y_n), and $\Phi(\cdot)$ is the cumulative distribution function of a standard normal variate. Terza's model assumes that the utility threshold (S_{in}) is a function of the characteristics of the decision maker and thus varies in a systematic manner across the population. In the M-Z model, utility thresholds are assumed to be constant and identical across the population. As presented in equation A.5, under deterministic utility thresholds and IIND latent variable disturbances , both the M-Z model and Terza's model reduce to a binary case and hence have a closed form function for the choice probability. Clearly, these two models are special cases of the GOP model.

THE GENERALIZED ORDINAL PROBIT MODEL WITH AUTOCORRELATION: THE DYNAMIC GENERALIZED ORDINAL PROBIT (DGOP) MODEL

The GOP model derived in the previous section is applicable to decision situations that do not generate observations with serial correlation or autocorrelation. For transportation problems dynamic analysis is essential to obtain detailed insights into travel behavior (Mahmassani and Herman, 1984; Mahmassani, 1990; Mahmassani and Herman, 1990). This has led to increasing interest over the past decade in panel data collection techniques and modeling approaches that can deal with data from different time periods. According to Heckman (1981), dynamic behavior phenomena lead to two types of temporal dependence: true (or structural) and spurious (or apparent) dependence. True state dependence refers to the situation in which an individual's decision in one period is systematically affected by his/her previous state(s), whereas spurious state dependence occurs when the unobservables in previous time period(s) affect unobservables in the present period and hence influence the individual's current decision. To model the former dependence is a specification issue; different assumptions result in a variety of model structures such as a Markov model, a Polya process, or a more general renewal process (Heckman, 1981). Spurious state dependence generates serial correlation among the disturbances of random variables associated with different time periods and hence complicates the estimation process due to the elaborate structure of the variance-covariance matrix of the disturbances.

Another survey technique that yields more than one observation (decision) from each individual at the same time typically gives rise to a complicated disturbance structure similar to the one in the dynamic analysis, though the survey data are obtained on a cross-section basis. The correlation between observations from the same individual may be labeled as "autocorrelation," which is similar to serial correlation in panel data. For instance, stated preferences elicited from the same individual under different decision scenarios are autocorrelated in general because of shared unobservables associated with the same decision maker. Though the underlying theoretical assumptions of serial correlation and autocorrelation may be different, both data sets can be analyzed under the same model structure.

A generalized multinomial probit model to treat time-series data within a random utility maximization framework has been proposed by Daganzo and Sheffi (1982). The formulation has also been applied to model the dynamic aspects of travel behavior (Tong, 1990). This section further extends the previously derived GOP model to analyze observations with serial correlation or autocorrelation such as panel data (time-series data) or stated-preferences elicited from the same individual.

The model development is presented hereafter for autocorrelated responses, but the resulting formulation is applicable to serially correlated data. Assume that each individual is asked to provide responses to T decision scenarios and that J ordered alternatives (response categories) are included in each scenario question. Extending the results of the previous section, there are, for individual n, T latent variables ($Y_n^1, Y_n^2, \ldots, Y_n^T$), TJ observable discrete variables ($Z_{1n}^t, Z_{2n}^t, \ldots, Z_{Jn}^t$, t=1, 2,..., T), and T sets of thresholds ($\mu_{0n}^t, \mu_{1n}^t, \ldots, \mu_{Jn}^t$, t=1,2,...,T), such that $Z_{in}^t=1$ if and only if $\mu_{i-1,n}^t < Y_n^t < \mu_{in}^t$; $Z_{in}^t=0$, otherwise. Therefore, the latent variables and utility thresholds can be listed as follows:

$$Y_n^1 = V_n^1 + u_n^1$$

$$Y_n^2 = V_n^2 + u_n^2$$

$$\vdots$$

$$Y_n^T = V_n^T + u_n^T \quad \text{.......(A.6)}$$

$$\mu_{in}^1 = S_{in}^1 + \varepsilon_{in}^1, \quad i = 0, 1, ..., J$$

$$\mu_{in}^2 = S_{in}^2 + \varepsilon_{in}^2, \quad i = 0, 1, ..., J$$

$$\vdots$$

$$\mu_{in}^T = S_{in}^T + \varepsilon_{in}^T, \quad i = 0, 1, ..., J \quad \text{.......(A.7)}$$

In equations A.6 and A.7, V_n^t and u_n^t represent the systematic and random components of the latent variable associated with individual n under scenario t. Similarly, S_{in}^t and ε_{in}^t are the corresponding observable and unobservable components of utility threshold i for individual n and scenario t. According to the ordered-response assumptions, for each individual the probability that $Z_{k^t}^t=1$ (t=1, 2,..., T and k^t can be 1, 2,..., or J) is equal to the joint probability of $\mu_{k^t-1}^t < Y^t < \mu_{k^t}^t$ (t=1, 2, ..., T). This probability is derived as equation A.8 below. For simplicity, the subscript n for individuals is omitted in the remainder of this section.

$$P(Z_{k^t}^t=1, \mu_0^t < \mu_1^t < ... < \mu_J^t , t=1, 2, ..., T)$$
$$= P(Z_{k^t}^t=1 \mid \mu_0^t < \mu_1^t <...< \mu_J^t, t=1, 2,..., T) P(\mu_0^t< \mu_1^t<...< \mu_J^t, t=1, 2,..., T)$$
$$= P(\mu_{k^t-1}^t < Y^t < \mu_{k^t}^t \mid \mu_0^t < \mu_1^t < ... < \mu_J^t , t=1, 2,..., T)$$
$$P(\mu_0^t < \mu_1^t < ... < \mu_J^t , t=1, 2,..., T)$$
$$= P(\mu_{k^t-1}^t - Y^t < 0, Y^t - \mu_{k^t}^t < 0 \mid \mu_0^t < \mu_1^t <...< \mu_J^t , t=1, 2,..., T)$$
$$P(\mu_0^t < \mu_1^t <...< \mu_J^t , t=1, 2,..., T)$$

$$= P[\, 0 > (\mu^1_{k1-1} - Y^1),\ 0 > (Y^1 - \mu^1_{k1}),\ 0 > (\mu^2_{k2-1} - Y^2),\ 0 > (Y^2 - \mu^2_{k2}),\ \ldots,\ 0 > (\mu^T_{kT-1} - Y^T),\ 0 > (Y^T - \mu^T_{kT}) \mid \mu^1_0 < \mu^1_1 < \ldots < \mu^1_J,\ \mu^2_0 < \mu^2_1 < \ldots < \mu^2_J, \ldots,\ \mu^T_0 < \mu^T_1 < \ldots < \mu^T_J \,]\ P[\mu^1_0 < \mu^1_1 < \ldots < \mu^1_J,\ \mu^2_0 < \mu^2_1 < \ldots < \mu^2_J, \ldots,\ \mu^T_0 < \mu^T_1 < \ldots < \mu^T_J \,] \tag{A.8}$$

As shown in equation A.8, the probability that $Z^t_{kt}=1$, for t=1, 2,..., T is equivalent to the probability that a pseudo alternative 0 is chosen from a choice set with (2T+1) alternatives (0, $\mu^1_{k1-1} - Y^1$, $Y^1 - \mu^1_{k1}$, $\mu^2_{k2-1} - Y^2$, $Y^2 - \mu^2_{k2}$, ..., $\mu^T_{kT-1} - Y^T$, $Y^T - \mu^T_{kT}$). Consequently, similarly to the previous GOP model without autocorrelation, the ordered-response model for autocorrelated observations can also be formulated as a choice model in a random utility maximization framework. If the disturbances of the latent variables (u^t, t=1, 2,..., T) and utility thresholds (ε^t_i, i=0, 1,..., J and t=1, 2,..., T) are assumed to be multivarivate normally distributed, the resulting autocorrelated ordered-response model is of the probit form, and thus labeled as the dynamic generalized ordinal probit model (DGOP). Again, the specific form of the conditional probability in the DGOP model is discussed in Appendix B.

To address the autocorrelation arising in the observations, the DGOP model allows the analyst to specify a general disturbance structure for the latent variables and utility thresholds. While it is possible to estimate a general variance-covariance matrix subject to the usual estimability constraint (Bunch, 1991), the structure of the disturbances is derived in this study from the property of ordered-responses. As shown in Figure A.1, for data from the same scenario t, the random components of the latent variable (u^t) and utility thresholds (ε^t_j, j=1, 2,..., J) are assumed to be correlated. On the other hand, for data from different scenarios, the disturbance of the latent variable or a utility threshold in scenario t is assumed to be correlated only with the corresponding random variables in all other scenarios. That is, both covariances of (u^t, ε^τ_j, $t \neq \tau$) and (ε^t_i, ε^τ_j, $t \neq \tau$ and $i \neq j$) are assumed to be 0. Based on these assumptions, the variance-covariance matrix for an example with 3 decision scenarios and 2 utility thresholds for each scenario is shown in Figure A.2 ($Y^t = V^t + u^t$, $\mu^t_{in} = S^t_{in} + \varepsilon^t_{in}$, t=1,2,3 and i=0,1).

The variance-covariance structure in Figure A.2 can be viewed as a matrix consisting of nine sub-matrices as shown in equation A.9. For example, Σ_{uu} represents the variances and covariances of the latent variable disturbances in T scenarios, i.e. Σ_{uu}=E(u^t, u^τ) (t=1, 2,...,T and

τ=1, 2,...,T). Similarly, $\Sigma_{u\varepsilon_i}$ includes the covariances of the latent variable and utility threshold i, i.e. $\Sigma_{u\varepsilon_i}$=Cov(u^t, ε_i^τ) (t=1, 2,...,T, τ=1, 2,...,T) for i=0, 1, ..., J. $\Sigma_{\varepsilon_i\varepsilon_j}$ corresponds to utility thresholds i and j, i.e. $\Sigma_{\varepsilon_i\varepsilon_j}$=E($\varepsilon_i^t$, ε_j^τ) (t=1, 2,...,T, τ=1, 2,...,T) for i=0, 1, ..., J and j=0, 1, ..., J. In the present example, T is equal to 2 and J is equal to 1.

$$\Sigma = \begin{array}{c|ccc} & u & \varepsilon_0 & \varepsilon_1 \\ u & \Sigma_{uu} & \Sigma_{u\varepsilon_0} & \Sigma_{u\varepsilon_1} \\ \varepsilon_0 & \Sigma_{u\varepsilon_0} & \Sigma_{\varepsilon_0\varepsilon_0} & \Sigma_{\varepsilon_0\varepsilon_1} \\ \varepsilon_1 & \Sigma_{u\varepsilon_1} & \Sigma_{\varepsilon_0\varepsilon_1} & \Sigma_{\varepsilon_1\varepsilon_1} \end{array} \qquad \text{(A.9)}$$

The present formulation assumes that the number of ordered alternatives is constant across all scenarios, and thus the number of utility thresholds is also constant. The model, however, can be modified to analyze data with different numbers of ordered alternatives and utility thresholds in each decision scenario.

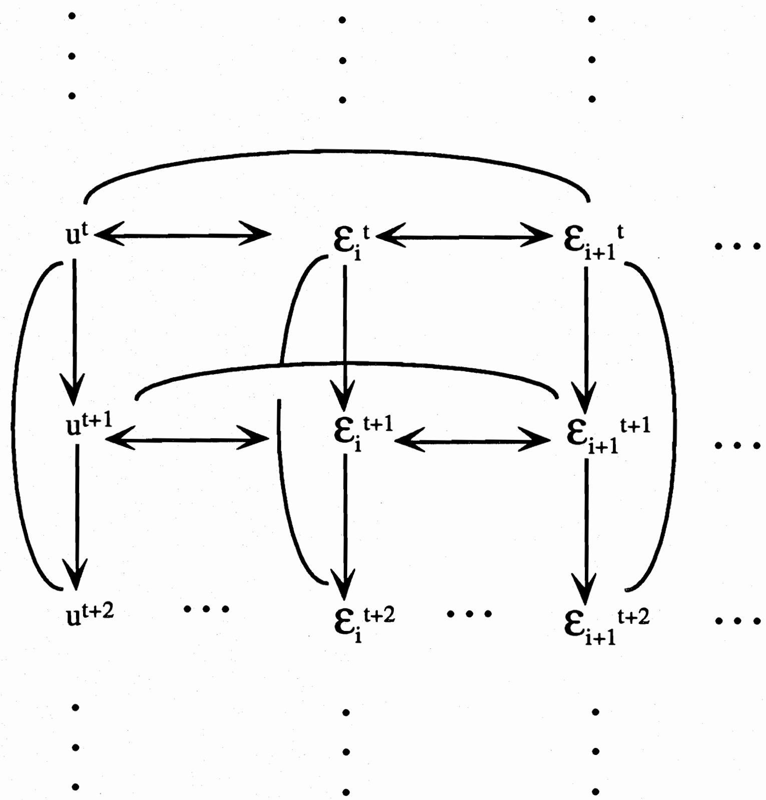

Figure A.1 The Autocorrelation Structure in the Dynamic Generalized Ordinal Probit Model

APPENDIX B
ESTIMATION OF THE DGOP MODEL

The estimation procedure is presented in this section for the DGOP model; the GOP model, with only one choice for each individual, is a special case of the former. The number of ordered alternatives and utility thresholds are assumed to be constant across the scenarios. The maximum likelihood method is used in the estimation. Figure B.1 illustrates a typical maximum likelihood estimation procedure for a choice model. The procedure includes three main modules: initialization, optimization, and convergence check. The initialization module reads the model specification, the starting point, and the observed data. The optimization module consists of a nonlinear search procedure and a mechanism to evaluate the likelihood function, which includes the calculation of the choice probability for each individual. In the present estimation procedure, the BFGS Quasi-Newton method is used in the nonlinear optimization procedure with a backtracking line search method (Dennis and Schnabel, 1983). The final module checks pre-set convergence criteria and calculates various statistics of the estimated results. As mentioned, it is necessary to calculate the choice probability for each individual in each search iteration during the estimation procedure. This probability calculation is the most challenging aspect of the procedure for the multinomial probit (MNP) structure because there is no closed form expression for MNP choice probabilities.

Several methods have been proposed to evaluate MNP probabilities, including (1) numerical integration, (2) approximation methods such as Clark's, separated split, and Mendell-Elston's, and (3) Monte Carlo simulation (Daganzo, 1979; Lam, 1991). Detailed comparisons of these methods can be found in Lam's work (1991). Since the structure of the derived DGOP model differs from the traditional MNP model by the inclusion of a conditional probability and the requirement that the thresholds be properly ordered, a new Monte Carlo simulation procedure to evaluate the DGOP choice probability is developed in this section.

The likelihood that $Z^t_{k^t}=1$ (t=1,2,..., T and k^t=1, 2,..., or J) are observed for individual n is given by equation A.8 as $P(\mu^t_{k^t-1} < Y^t < \mu^t_{k^t} \mid \mu^t_0 < \mu^t_1 <...< \mu^t_J$, t=1, 2,..., T) x $P(\mu^t_0 < \mu^t_1 <...< \mu^t_J$, t=1, 2,..., T). Therefore, for an observed sample the likelihood and log-likelihood functions can be expressed as follows.

$$L^* = \prod_{n=1}^{N} \prod_{k^t n=1}^{J} [P_n(\mu^t_{k^t n-1} < Y^t_n < \mu^t_{k^t n} \mid \mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{Jn}, t=1, 2, \ldots, T)$$

$$P_n(\mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{Jn}, t=1, 2, \ldots, T)]^{\delta_{k^t n}} \qquad (B.1)$$

$$L = \ln L^*$$

$$= \sum_{n=1}^{N} \sum_{k^t n=1}^{J} \delta_{k^t n} \ln [P_n(\mu^t_{k^t n-1} < Y^t_n < \mu^t_{k^t n} \mid \mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{Jn}, t=1, 2, \ldots, T)]$$

$$+ \sum_{n=1}^{N} \ln [P_n(\mu^t_{0n} < \mu^t_{1n} < \ldots < \mu^t_{Jn}, t=1, 2, \ldots, T)] \qquad (B.2)$$

In equations B.1 and B.2, N is the total number of observations in the sample, J is the number of ordered alternatives, ln is the natural logarithm function, and $\delta_{k^t n}$ is an index for individual n with values 1 or 0 such that $\delta_{k^t n} = 1$ if and only if $Z_{k^t n} = 1$ and $\delta_{k^t n} = 0$, otherwise.

The difference between the DGOP model structure and the standard MNP model requires a new estimation procedure. For the DGOP model, in addition to evaluating the probabilities of $(\mu^t_{k^t-1} < Y^t < \mu^t_{k^t})$, it is essential to ensure that the ordered sequence of thresholds holds for each individual in each search iteration. That is, $\mu^t_0 < \mu^t_1 < \ldots < \mu^t_J$ (t=1, 2,..., T) must be imposed at every step of the search procedure. On the other hand, once this order is ensured, $P_n(\mu^t_0 < \mu^t_1 < \ldots < \mu^t_J, t=1, 2, \ldots, T)$ is equal to 1 for each individual, and one can take advantage of this result during the estimation. In particular, this probability becomes a constant in the likelihood function, and can then be left out in the maximization procedure. In addition, the conditional probability $P_n(\mu^t_{k^t-1} < Y^t < \mu^t_{k^t} \mid \mu^t_0 < \mu^t_1 < \ldots < \mu^t_J, t=1, 2, \ldots, T)$ is equivalent to the marginal probability $P_n(\mu^t_{k^t-1} < Y^t < \mu^t_{k^t}\ t=1, 2, \ldots, T)$. Therefore, only $\ln P_n(\mu^t_{k^t-1} < Y^t < \mu^t_{k^t}, t=1, 2, \ldots, T)$ needs to be evaluated in equation B.2. Based on this result and the assumption that the disturbances of latent variables and utility thresholds are multivariate normally distributed across the population with a mean vector **0** and a variance-covariance matrix Σ_n, as shown in Figure A.2 and equation A.9, a procedure to obtain the likelihood value for each individual is proposed as follows. Again, the subscript n for individuals is omitted in the following description.

1. Generate T(J+2) multinomial variates u^t, ε_i^t (t=1, 2,..., T, i=0, 1,..., J) based on the assumed variance-covariance matrix Σ, and calculate the associated latent variable $Y^t = V^t + u^t$ and utility thresholds for this individual $\mu_i^t = S_i^t + \varepsilon_i^t$, t=1, 2,..., T and i=0, 1,..., J.
2. If $\mu_0^t < \mu_1^t < ... < \mu_J^t$ holds for t=1, 2,...,T, μove to step 3; otherwise discard the current normal variates $\varepsilon_i^1, \varepsilon_i^2, ..., \varepsilon_i^T$ (i=0, 1,...,J) and go to step 1.
3. If the number of realizations is sufficient, move to step 4; otherwise go back to step 1.
4. Calculate $P(\mu_{k^t-1}^t < Y^t < \mu_{k^t}^t$, t=1, 2,..., T) and obtain the log likelihood value. $P(\mu_{k^t-1}^t < Y^t < \mu_{k^t}^t$, t=1, 2,..., T) is obtained as the relative frequency with which the pseudo-alternative 0 is the maximum in a choice set with (2T+1) alternatives (0, $\mu_{k^1-1}^1 - Y^1$, $Y^1 - \mu_{k^1}^1$, $\mu_{k^2-1}^2 - Y^2$, $Y^2 - \mu_{k^2}^2$, ..., $\mu_{k^T-1}^T - Y^T$, $Y^T - \mu_{k^T}^T$) among the effective realization of normal variates u^t and ε_i^t, where t=1, 2,..., T and i=0, 1,..., J.

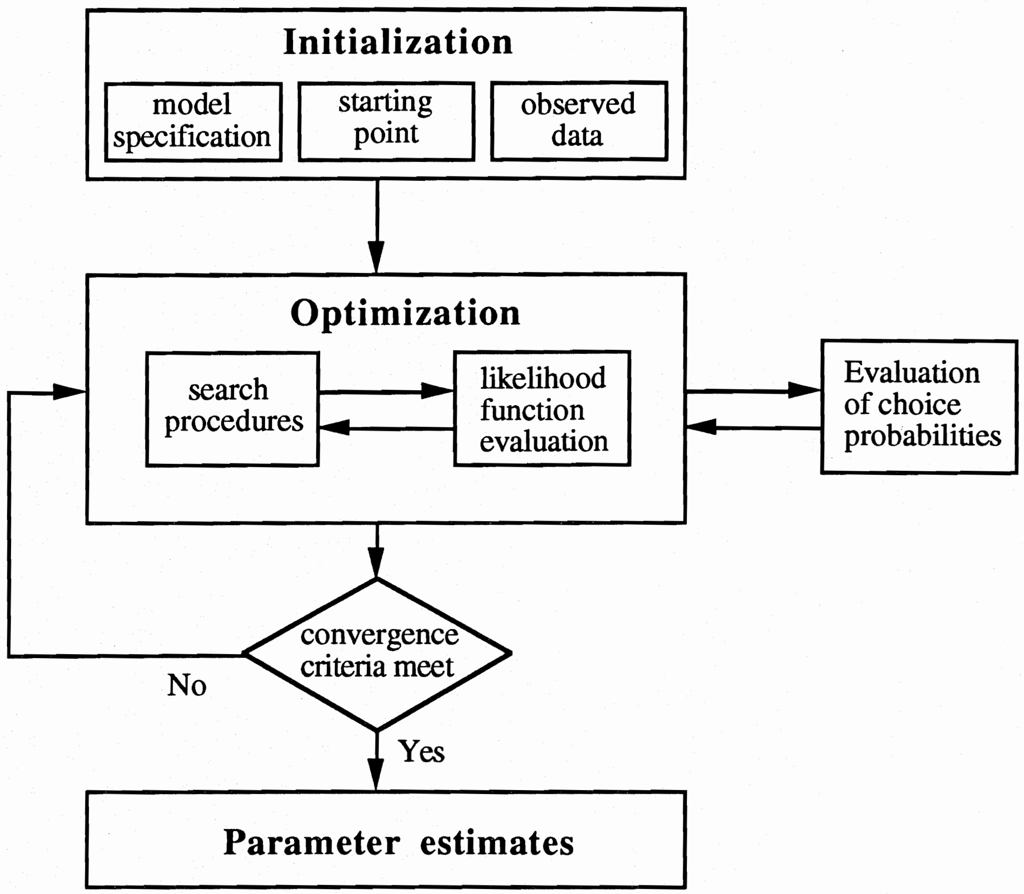

Figure B.1 Maximum Likelihood Estimation Procedures for Choice Model Parameters

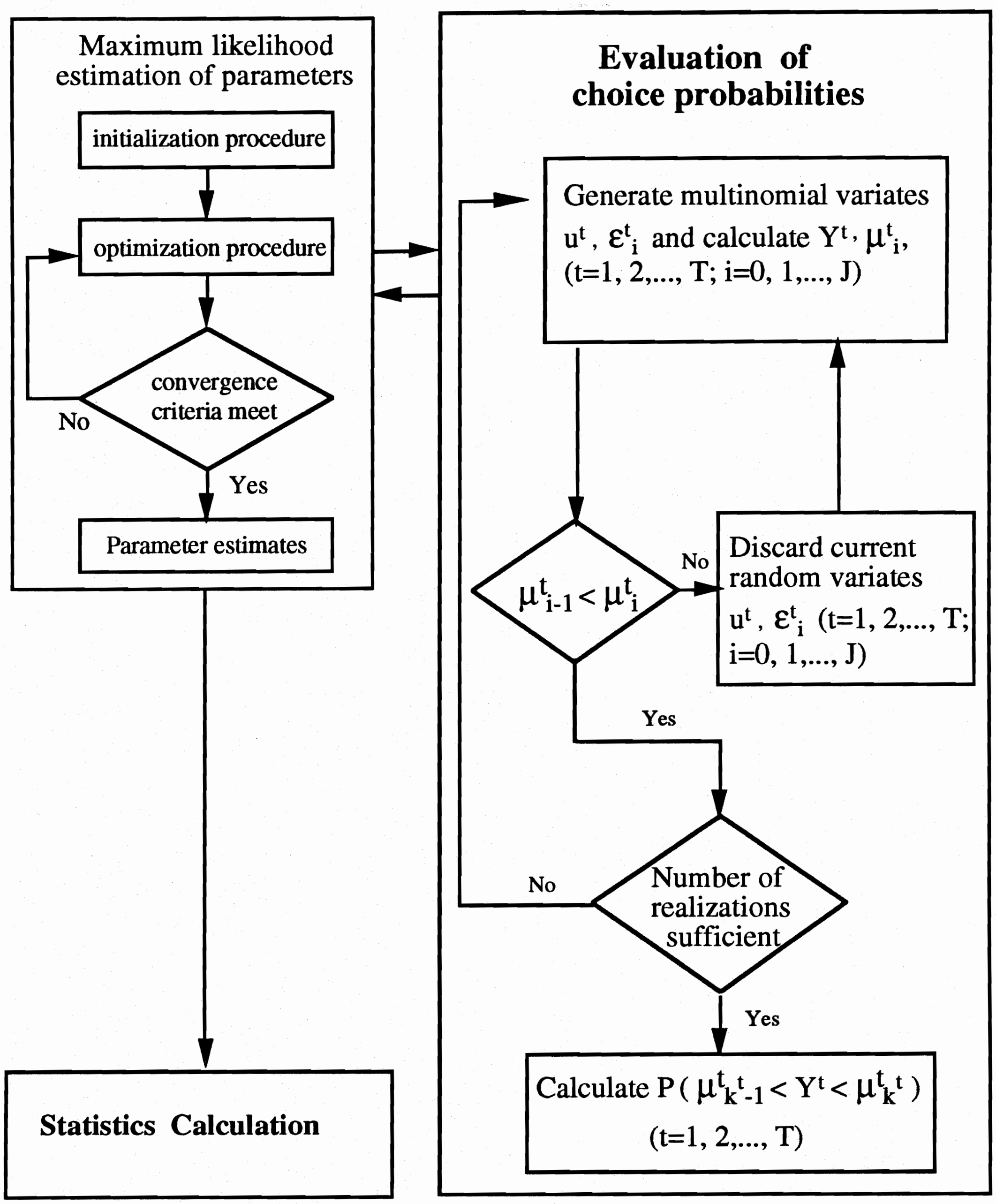

Figure B.2 Simulation Procedure for Probability Evaluation in the Estimation of the Dynamic Generalized Ordinal Probit Model

I_I_I_I_I_I

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: Store Manager, Professor, Mechanic,Clerk) ____________________

2. Are you self-employed ? ___ Yes ___ No

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

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

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, store) ___ 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. If you have more than one workplace outside the home, how many days per week do you spend at the main location ? ___ day(s)

9. Do you currently have the option to work at your home rather than your office either part-time or full-time ? ___ Yes ___ No

10. How far is your residence from your workplace ? ______ miles

11. 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 ______)

12. 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 ______)

13. 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 _________)

(Please continue on the following page)

14. 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
___ personal business
___ work-related errand
___ other (specify ________)
___ shopping
___ food
___ recreation / social

15. 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

16. 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**	___	___	___	___

17. 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**	___	___	___	___

18. 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**	___	___	___	___

19. 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**	___	___	___	___

20. 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 ____________)

(Please continue on the following page)

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	2	3	4	5
1. Do you find commuting to work stressful ?	1 not at all	2	3	4	5 definitely
2. On a typical day, how would you describe the traffic you encounter on your way from home to your workplace ?	1 too congested	2	3	4	5 very smooth
3. On a typical day, how would you describe the traffic you encounter on your way from your workplace to home ?	1 too congested	2	3	4	5 very smooth
4. How important is flexibility of your work schedule for accomplishing your household duties ?	1 not important	2	3	4	5 important
5. Would you like to work independently during more of your work time ?	1 dislike	2	3	4	5 like
6. How do you feel about learning to use new office equipment for your job ?	1 dislike	2	3	4	5 like
7. How essential to your work is frequent input from your supervisor or your co-workers ?	1 not essential	2	3	4	5 essential
8. How important is it for you to attend short-notice meetings during your work hours ?	1 not important	2	3	4	5 important
9. How important is it for you to have immediate access to information or references which are available only at the office ?	1 not important	2	3	4	5 important
10. How important to you are social interactions with your co-workers at work ?	1 not important	2	3	4	5 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. Do you think your job is suitable for working from home every day ?	1 not suitable	2	3	4	5 very suitable
13. Do you think your job is suitable for working from home several days per week ?	1 not suitable	2	3	4	5 very suitable
14. Do you think your supervisor would approve your working from home every day ?	1 not at all	2	3	4	5 definitely
15. Do you think your supervisor would approve your working from home several days per week ?	1 not at all	2	3	4	5 definitely
16. If you could work from home, do you think you could get more work done ?	1 not at all	2	3	4	5 definitely
17. 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
18. 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

(Please continue on the following page)

The following questions ask you to think about various work possibilities for you in the future. For each question, assuming that you have your choice of workplace, please consider the described situation and check one answer.

1. Would you be willing to work from home if,

(a) your **salary stays the same** and **your employer** pays all costs of working from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

(b) your **salary stays the same** but you need to **add a new telephone number (at your expense)** in order to work from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

(c) your **salary stays the same** but you need to **buy a personal computer** in order to work from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

(d) your **salary increases 5%** and **your employer** pays all costs of working from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ No. (If you answer "No," please go to question 2)

(e) your **salary increases 5%** and **you pay part of the costs** of working from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

(f) your **salary decreases 5%** and **your employer** pays all costs of working from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

(g) your **salary decreases 10%** and **your employer** pays all costs of working from home ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ Possibly.
___ No.

2. Would you be willing to work from home if your status were changed from regular employee to contract employee ?

___ Yes, work from home everyday
___ Yes, work from home several days per week and at a workplace outside home the other days
___ No.

3. Do you currently have enough space to work from home ?

___ Yes ___ No ___ Possibly

(Please continue on the following page)

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 18 ___ 18- 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. Do you have a medical condition that impairs your mobility ? ___ Yes ___ No

5. Which best represents your *household's* income per year ? ___ less than 25,000 ___ 25,000- 50,000 ___ 50,000- 75,000 ___ more than 75,000

6. How many children under 16 presently live in your household ? ___
How many of them are pre-schoolers and stay at home all or part of the normal working day ? ___

7. How many adults (excluding yourself) also live in your household ? ___
What are their relationships to you and their occupations ?

	--------- relationship to you --------- (Please check one)				--occupation--
	parent	**spouse/partner**	**son/daughter**	**other**	
1	___	___	___	___	__________
2	___	___	___	___	__________
3	___	___	___	___	__________
4	___	___	___	___	__________
5	___	___	___	___	__________
6	___	___	___	___	__________

8. How many passenger cars (including pick-ups) do you have in your household ? ___

9. How many of these vehicles are equipped with a mobile phone ? ___

10. How many people have a driver's license in your household ? ___

11. How many adults (excluding yourself) in your household have a medical condition that impairs their mobility ? ___

(Please continue on the following page)

12. How many different telephone numbers do you have at home ? ___

13. Do you have a FAX machine at home ? ___ Yes ___ No

14. Do you subscribe to any electronic data-base or home-shopping service for your home personal computer ? ___ Yes ___ No

15. If you have at least one personal computer at home, please indicate how many of each type you own ?

IBM XT / AT :___ IBM PS/2:___
MAC Plus / SE :___ MAC II :___
other:___ (specify ________________)

16. How would you best describe your proficiency level for each specific function on a personal computer ? (check one answer for each function)

	non-existent	low	medium	high
Word Processing packages (e.g. PEII, Word Perfect, Microsoft Word)	___	___	___	___
Spreadsheets (e.g.Lotus 1-2-3, Excel)	___	___	___	___
Data processing packages (e.g. dBASE III)	___	___	___	___
Computer language programming (e.g. BASIC, COBOL, PASCAL,FORTRAN)	___	___	___	___
Computer graphics packages (e.g. Auto Cad, Mac Draw)	___	___	___	___

|_|_|_|_|_|

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 .

1. **What is your job title ?** ______________________

2. **How long have you been employed in your present firm or 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 firm 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. **How often do you employ the following means of supervision ?** (please check all that apply)
   ____ review meetings
   ____ written reports
   ____ activity logs
   ____ on-site supervision
   ____ time-sheets
   ____ review completed task

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

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 organization sponsor a flexible hours work schedule program ?** (i.e. flex-time) ____ **Yes** ____ **No** ____ **Don't know**

(Please continue on the following page)

16. Please list five occupations in your organization you consider telecommutable.

____
____
____
____
____

17. Please list five occupations in your organization you consider NOT telecommutable.

____
____
____
____
____

Please answer the following questions to the extent that they are applicable.

18. 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

19. 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**	___	___	___	___

20. 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**	___	___	___	___

21. 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**	___	___	___	___

22. 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**	___	___	___	___

23. How frequently do you participate in teleconferences?

____ never
____ less than once per month
____ once or twice per month
____ once or twice per week
____ several times per week

(Please continue on the following page)

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

___ Yes
___ Possibly
___ No

5. Do you think a voluntary telecommuting program would be cost-effective ?

___ Yes
___ Possibly
___ No

6. If *you* had the opportunity to telecommute from home at least part-time would you ?

___ Yes
___ Possibly
___ No

(Please continue on the following page)

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 ____)

(Please continue on the following page)

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 workplace ?** ___ miles

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Please use this space for any comments you may have about telecommuting.

BIBLIOGRAPHY

Adler, A.H., (1987) Economic Appraisal of Transport Projects, The World Bank, Johns Hopkins University Press, Baltimore.

Aitchison, J. and Silvey, S., (1957) "The Generalization of Probit Analysis of the Case of Multiple Responses," Biometrica 44, pp. 131-140.

Bailey, D.S. and Foley, J., (1990) "Pacific Bell Works Long Distance," HR Magazine, Vol. 35, Issue 8, pp. 50-52.

Ben-Akiva, M. and Lerman, S.R., (1985) Discrete Choice Analysis, The MIT Press, Cambridge, Massachusetts.

Betts, M., (1991) "Telework Hubs Sprout in Suburban America," Computerworld, Vol.: 25 Issue: 29, Jul. 22, pp. 1,101.

Bhat, C.R., (1991) Toward a Model of Activity Program Generation, Ph.D. Dissertation, Department of Civil Engineering, Northwestern University, Evanston, Illinois.

Boghani, A.B., Kimble E.W., and Spencer, E.E., (1991) Can Telecommunications Help Solve America's Transportation Problems, Reference 65740, Arthur D. Little, Inc., Cambridge, Massachusetts.

Bunch, D.S., (1991) "Estimability in the Multinomial Probit Model," Transportation Research 25B, No. 1, pp. 1-12.

Christensen, K., (1988) Women and Home-Based Work: The Unspoken Contract, Henry Holt and Company, New York.

Cohen, C.A., (1950) "Estimating the Mean and Variance of Normal Populations from Singly and Doubly Truncated Samples," Ann. Math. Statist. 21, pp. 557-569.

Cohen, C.A., (1959) "Simplified Estimators for the Normal Distribution When Samples are Singly Censored or Truncated," Technometrics 1, pp. 217-237.

Cohen, C.A., (1991) Truncated and Censored Samples, Marcel Dekker, Inc., New York.

Coulson-Thomas, C., (1991) "IT and New Forms of Organization for Knowledge Workers: Opportunity and Implementation," Employee Relations, Vol. 13, Issue 4, pp. 22-32.

Daganzo, C., (1979) Multinomial Probit: The Theory and Its Application to Demand Forecasting, Academic Press, New York.

Daganzo, C. and Sheffi, Y. (1982) "Multinomial Probit with Time-series Data: Unifying State Dependence and Serial Correlation Models," Environment and Planning A, Vol. 14, pp. 1377-1388.

Dennis, J.E., Jr. and Schnabel, R.B., (1983) Numerical Methods for Unconstrained Optimization and Nonlinear Equation, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

DeSanctis, G., (1984) "Attitudes Towards Telecommuting: Implications for Work-At-Home Programs," Information & Management, Vol. 7, pp. 133-139.

Di Martino, V. and Wirth, L. (1990) "Telework: A New Way of Working and Living," International Labour Review (Switzerland) Vol. 129, Issue 5, pp. 529-554.

Dresch, P.H., (1991) "The Fax on Telecommuting," Portfolio Vol. 4, No. 1, pp. 34-41.

Farmanfarmaian, R., (1989) "A Manager's Guide to Making Telecommuting Succeed," Working Woman Vol. 14, Issue 2, pp. 46-52.

Fishbein M. & Ajzen I., (1975) Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research, Addison-Wesley.

Frank, J., Shamir, B., and Briggs, W., (1991) "Security-related Behavior of PC Users in Organizations," Information & Management, Vol. 21, pp. 127-135.

Frank, R.H., (1991) Microeconomics, McGraw-Hill Inc., New York.

Fusco, M.A.C., (1990) "Employment Relations Programs," Employment Relations Today, Vol. 17 , Issue 3, pp. 259-263.

Goodrich, J.N., (1990) "Telecommuting in America," Business Horizons, Vol. 33, Issue 4, pp. 31-37.

Gordon, G.E., (1991) "Profiting Through telecommuting in the '90s," Telemarketing Magazine, Vol. 9, Issue 12, pp. 52-55.

Hamilton, C-A, (1987) "Telecommuting," Personnel Journal, April.

Handy, L. S., Mokhtarian, L. P., and Salomon, I. (1993) "A Review of Studies of Telecommuting: Key Issues in the Estimation of Travel, Energy, and Air Quality Impacts," submitted to Transportation Research A.

Hausman, J.A., Lo, A.W., and Mackinlay, C.A., (1991) An Ordered Probit Analysis of Transaction Stock Prices, National Bureau of Economic Research, Working Paper No. 3888.

Heckman, J.J., (1981) "Statistical Models for Discrete Panel Data," In Manski, C. and McFadden D. (Eds), Structural Analysis of Discrete Data with Econometric Applications, MIT Press, pp. 114-178.

Huws, U., (1991) "Telework: Projections," Futures (UK), Vol.: 23, Issue 1, pp. 19-31.

Jackson, S., (1990) "Demographic and Social Trends: Implications for the Information Profession - Part 2: Implications for Educators and Employers," Library Management, Vol. 11, Issue 6, pp. 4-17.

Jones, J.C., (1957-1958) "Automation and Design (1-5)," Design, 103, 104, 106, 108, 110.

Jones, P., Koppelman F., Orfeuil, J.-P., (1990) "Activity Analysis: State-of-the-Art and Future Directions," Developments in Dynamic and Activity-Based Approaches to Travel Analysis, Edited by Jones, P., Avebury, Brookfield, U.S.A.

Jou, R.-C., Mahmassani, H. S., and Joseph, T., (1992) Daily Variability of Commuter Decisions: Dallas Survey Results, Research Report 1216-1, Center for Transportation Research, The University of Texas at Austin.

Katz, A.I., (1987) "The Management, Control, and Evaluation of a Telecommuting Project: A Case Study," Information & Management, Vol. 13, pp. 179-190.

Kiesler, S. and Sproull, L. (1992) "Group Decision Making and Communications Technology," Organizational Behavior and Human Decision Processes, pp. 96-123.

Kitamura, R., (1988) "An Evaluation of Activity-Based Travel Analysis," Transportation 15, pp. 9-34.

Kitamura, R., Goulias, K., and Pendyala, R.M., (1990) "Telecommuting and Travel Demand: An Impact Assessment for State of California Telecommute Pilot Project Participants," Research Report UCD-TRG-RR-90-8, Transportation Research Group, University of California at Davis.

Koppelman, F., (1975) Travel Prediction with Models of Individualistic Choice Behavior, Ph.D. Dissertation, MIT, Cambridge, Massachusetts.

Kutay, A., (1986) "Optimum Office Location and the Comparative statics of Information Economics," Regional Studies 20, pp. 551-564.

Lam, S.-H., (1991) Multinomial Probit Model Estimation: Computational Procedures and Applications, Ph.D. Dissertation, Department of Civil Engineering, The University of Texas at Austin, Austin, Texas.

Lancaster, K., (1966) "A New Approach to Consumer Theory," Journal of Political Economy 174 , pp. 132-157

Lewis, G., (1988) "The Portable Executive," Business Week (Industrial/Technology Edition) Issue 3073, October 10, pp. 102-112

Maddala, G.S., (1983) Limited-dependent and Qualitative Variables in Econometrics, Cambridge University Press, Cambridge.

Mahmassani, H.S., (1990) "Dynamic Models of Commuter Behavior: Experimental Investigation and Application to the Analysis of Planned Traffic Distributions," Transportation Research 24A, No. 6, pp. 465-484.

Mahmassani, H.S., Caplice, C.G., and Walton, M., (1990) "Characteristics of Urban Commuter Behavior: Switching Propensity and Use of Information," Transportation Research Record 1285, pp. 57-69.

Mahmassani, H.S. and Herman, Robert (1984) "Dynamic User Equilibrium Departure Time and Route Choice on Idealized Traffic Arterials," Transportation Science 18, pp. 362-384.

Mahmassani, H.S. and Herman, Robert (1990) "Interactive Experiments for the Study of Tripmaker Behavior Dynamics in Congested Commuting Systems," In Developments in Dynamic and Activity-Based Approaches to Travel Analysis, Avebury, Aldershot, pp. 272-298.

Mahmassani, H.S., Yen, J.-R., Herman, R., and Sullivan M.A., (1994) "Employee Attitudes and Stated Preferences Towards Telecommuting: An Exploratory Analysis," Transportation Research Record, Forthcoming.

Manheim, M.L., (1979) Fundamentals of Transportation Systems Analysis, The MIT Press, Cambridge, Massachusetts.

Manski, C.F. and Salomon, I., (1987) "The Demand for Teleshopping: An Application of Discrete Choice Models," Regional Science and Urban Economics 17, pp. 109-121.

Meyer, M.D. and Miller, E.J., (1984) Urban Transportation Planning: A Decision-Oriented Approach, McGraw-Hill Inc., New York.

McDonald, R.P., (1985) Factor Analysis and Related Methods, Lawrence Erlbaum Associates, New Jersey.

McKelvey, R.D., Zavonia, W., (1975) "A Statistical Model for the Analysis of Ordinal Level Dependent Variables," Journal of Mathematical Sociology, Vol. 4, pp.: 103-120.

Miles, R.E., Snow, C.C., Meyer A., and Coleman, H., Jr., (1978) "Organizational Strategy, Structure and Process," Academy of Management Review, Vol. 3, No. 3, pp. 546-562.

Mokhtarian, P.L., (1988) "An Empirical Evaluation of the Travel Impacts of Teleconferencing," Transportation Research A, Vol. 22A, No. 4, pp. 283-289.

Mokhtarian, P.L., (1990) "A Typology of Relationships Between Telecommunications and Transportation," Transportation Research A, Vol. 24A, No. 3, pp. 231-242.

Mokhtarian, P.L., (1992) "Telecommuting in the United States: Letting our Fingers Do the Commuting," TR News, No 158, pp. 2-7.

Moore, A., (1987) Analyzing the Choices of Telecommunications Media in Business Organizations, Ph.D. dissertation, Department of Civil Engineering, Northwest University, Evanston, Illinois.

Moore, A. and Jovanis, P.P., (1988) "Modeling Media Choices in Business Organizations: Implications for Analyzing Telecommunications-Transportation Interactions," Transportation Research A, Vol. 22A, No. 5, pp. 257-273.

Nilles, J.M., Carlson, F.R., Gray, P. and Hanneman, G.G., (1976) The Telecommunications-Transportation Tradeoff. John Wiley, New York.

Nilles, J.M., (1988) "Traffic Reduction by Telecommuting: a Status Review and Selected Bibliography," Transportation Research A, Vol. 22A, No 4, pp. 301-317.

Nilles, J.M., (1991) "Telecommuting and Urban Sprawl: Mitigator or Inciter," Transportation 18, pp. 411-432.

O'Leary, M., (1991) "Home Sweet Office," CIO, Vol. 4, Issue 10, Jul., pp. 30-40.

Olson, M.H., (1982) "New Information Technology and Organizational Culture," MIS Quarterly Special Issue.

Ord, J.K. and Bagchi, U., (1985) "Truncated Distribution in Inventory Control," Working Paper 82/83-4-8, Department of Management, The University of Texas at Austin.

Paquette, R.J, Ashford, N.J., and Wright P.H., (1982) Transportation Engineering: Planing and Design, John Wiley & Sons, Inc., New York.

Pendyala, R.M., Goulias, K.G., and Kitamura, R., (1991) "Impact of Telecommuting on Spatial and Temporal Patterns of Household Travel," Transportation 18, pp. 383-409.

Porat, M.U., (1977) The Information Economy: Definition and Measurement, OT Special Publication 77-12, U.S. Department of Commerce, Office of Telecommunications, Washington, D.C.

Raths, D., (1990) "Taking an Alternative Route," InfoWorld, Vol. 12, Issue 50, Dec. 10, pp. 51-56.

Rawlins, C., (1989) "The Impacts of Teleconferencing on the Leadership of Small Decision-Making Groups," Journal of Organizational Behavior Management, Vol. 10, Issue 2, pp. 37-52.

Risman, B.J. and Tomaskovic-Devey, D., (1989) "The Social Construction of Technology: Microcomputers and the Organization of work," Business Horizons, Vol. 32, Issue 3, May/June , pp. 71-75.

Roderic, J.C. and Jelley, H.M., (1991) "Managerial Perception of Telecommuting in Two Large Metropolitan Cities," Southwest Journal of Business & Economics, Vol. 8, Issue 1, Spring, pp. 35-41.

Salomon, I., (1985) "Telecommunications and Travel: Substitution or Modified Mobility," Journal of Transport Economics and Policy 19, pp. 219-235.

Salomon, I., (1986) "Telecommuting and Travel Relationships: a Review," Transportation Research A, Vol. 20A, No. 3, pp. 223-238.

Salomon, I., (1988) "Geographical Variations in Telecommunications Systems: the Implications for Location of Activities," Transportation 14, pp. 311-327.

Salomon, I. and Koppelman, F., (1988) "A Framework for Studying Teleshopping Versus Store Shopping," Transportation Research A, Vol. 22A, No. 4, pp. 247-255.

Salomon, I. and Salomon M., (1984) "Telecommuting: The Employees' Perspective," Technological Forecasting and Social Change, Vol. 25, pp. 15-28.

Samuelson C.D. & Biek M., (1991) "Attitudes Towards Energy Conservation: A Confirmatory Factor Analysis," Journal of Applied Social Psychology, 21, pp. 549-568.

SCAG, (1985) The Telecommuting Phenomenon: Overview and Evaluation, Southern California Association of Government, Transportation Planning Department.

Schlossberg, H., (1991) "Illinois Bell Predicts More Americans Will Start Doing Their Homework," Marketing News, Vol. 25, Issue 19, September 16, 1991, pp. 10.

Schlotzhauer, S.D. and Littell, R.C., (1987) SAS System for Elementary Statistical Analysis, SAS Institute Inc., Cary, North Carolina.

Schneider, H., (1986) Truncated and Censored Samples from Normal Populations, Marcel Dekker, Inc., New York.

Solomon, C., (1990) "The Traffic Trap," Personnel, Vol. 69, Issue 11, pp. 64-70.

Sommer, K. and Malins, D.Y., (1991) "Flexible Work Solutions," Small Business Report, Vol. 16, Issue 8, pp. 29-40.

Sullivan, M. A., Mahmassani, H. S., and Herman, Robert, (1993) Telecommunications-Transportation-Energy Interaction: The Potential for Telecommuting to Reduce Urban Network-Wide Fuel Consumption, Research Report SWUTC-93-60018, Center for Transportation Research, The University of Texas at Austin.

Susser, P.A., (1988) "Modern Office Technology and Employee Relations," Employment Relations Today, Vol. 15, pp. 9-18.

SAS, (1990) SAS/STAT User's Guide.

Terza, J.V., (1985) "Ordinal Probit: A Generalization," Commun. Statist.- Theor. Meth. 14(1), pp: 1-11.

Tong, C.-C., (1990) A Study of Dynamic Departure Time and Route Choice Behavior of Urban Commuters, Ph.D. Dissertation, Department of Civil Engineering, The University of Texas at Austin, Austin, Texas.

U. S. Department of Commerce, (1990) 1990 Census of Population Social and Economic Characteristics, Texas, 1990 CP-2-45, Economics and Statistics Administration, Bureau of the Census.

Winship, C., Mare, R.D., (1984) "Regression Models with Ordinal Variables," American Sociological Review, Vol. 49 August, pp: 512-525.

Woelders, H.J., (1990) "Telework: New Opportunities for the Handicapped Unemployed Workers," International Journal of Sociology & Social Policy (UK), Vol. 10, Issue 4, 5, 6, pp 176-180.

Yap, C.S., Tng, H., (1990) "Factors Associated with Attitudes Towards Telecommuting," Information & Management, Vol. 19 Issue 4, pp: 227-235.

Yen, J.-R., (1992) "Effects of Telecommuting on Organizational Strategic Decision Process," unpublished report, University of Texas at Austin.