On Modeling the Choices of Work Hour Arrangement, Location and Frequency of Telecommuting

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ABSTRACT
A comprehensive model of three distinct dimensions of work related choices is proposed in this study. The different choice dimensions considered are work hour arrangement, location, and frequency of telecommuting. Such a model underscores the role of employee work hour arrangement in telecommuting choices by bringing out the differences in preferences for telecommuting frequency (both home and center-based) between employees with different work hour arrangements. The model is applied using data from a survey of San Diego city employees conducted in 1992. The results indicate the importance of modeling work-related decisions as a joint choice rather than examining individual dimensions of work decisions in isolation.

Keywords: Telecommuting, work-hour arrangement, location and frequency of telecommuting, nested logit model, multinomial logit model

1. INTRODUCTION

Traffic congestion is one of the foremost problems faced by the urban and suburban dwellers of today. A recent study conducted by TTI (Schrank and Lomax, 2005) indicates that the cost of congestion in the U.S. has increased from $12.5 billion in 1982 to $63.1 billion in 2003 and that, in the same period of time, the number of urban areas with more than 20 hours of delay per peak traveler has grown from 5 to 51. Urban planners and policy makers have hence been constantly exploring options to mitigate traffic congestion and to improve air quality. Telecommuting is one such option that has received substantial attention and has been studied with considerable interest in the recent past. Telecommuting can be defined as working at home or at a location close to home instead of commuting to a conventional work location (Mannering and Mokhtarian, 1995). Mokhtarian *et al.* (2005) highlight the lack of consensus over the definition of telecommuting and hence the total number of telecommuters in the US. They review a variety of definitions, and estimates of the amounts of telecommuting presented in a number of different studies. For example, they mention the American Housing Survey count of 5.6 million people telecommuting in 1999, where people working at home for at least one day of the preceding week instead of traveling to work were counted (Mokhtarian *et al.*, 2005).

The potential impacts of telecommuting on travel are quite complex. This is because, though telecommuting generally substitutes for the commute trip (in this study, we neglect partial-day telecommuting, in which the commute is only displaced in time rather than replaced altogether), it can lead to additional trips due to the added time accruing to the telecommuting employee and the availability of the employee's vehicle for use by other household members (Kitamura *et al.*, 1991). Notwithstanding this possibility, telecommuting is an important option to consider for reducing peak period congestion, since most additional trips generated by telecommuting are likely to be outside the peak periods. Thus, several earlier studies have investigated the propensity to telecommute as a function of a wide variety of explanatory factors, including demographic, job, and attitudinal characteristics of employees, and transportation level of service variables (see Table 1 for an overview of these studies, including the data used in the study, the methodology, the dependent variable, and the independent variables). Further, some studies (for example, see Bagley & Mokhtarian, 1997) have also considered the location of telecommuting, that is, the choice of home-based vs. center-based telecommuting.

The objective of this study is to contribute to this telecommuting literature by underscoring the joint nature of employee work-hour arrangement choices with telecommuting location choices (based on the home-based versus center-based distinction) and telecommuting frequency choices (including the choice not to telecommute). We discuss the empirical treatment of telecommuting location and frequency in Section 2.3, but define our operationalization of work-hour arrangement here because the focus on this dimension is an important contribution of the study. Specifically, we consider work-hour arrangement by defining two broad categories of temporal scheduling: conventional and unconventional. An employee with a conventional work-hour arrangement works for about 7½ to 8 hours a day with a start time between 8 AM and 9 AM (*i.e.*, commutes to work in the AM peak and returns home in the PM peak). On the other hand, an employee with an unconventional work-hour arrangement could be a part-time employee, or have a flex-time or compressed work week arrangement (see Yeraguntla and Bhat, 2005 for an extensive discussion of unconventional work arrangements). While a part-time employee generally works for less than 8 hours a day and/or fewer than five days a week, a flex-time employee works for about 8 hours a day with the start time of work outside the 8 AM - 9 AM peak, and an employee with a compressed work week arrangement works for 9 to 10 hours a

day with a day off every one or two weeks. In other words, an employee with a conventional work-hour arrangement commutes to work in the AM peak and returns home in the PM peak, while an employee with an unconventional work hour arrangement typically avoids commuting in either the AM peak or the PM peak, or both (even if only some days a week, as in the case of part-time workers who work full days on the days they do work, but work fewer than five days a week).

The motivation for our proposed joint (or "package") model of work-hour arrangement, location, and frequency of telecommuting stems from three broad observations in the literature. First, several studies (Bailey and Kurland, 2002; Popuri and Bhat, 2003; Yeraguntla and Bhat, 2005) indicate that part-time employees and contract workers are more inclined toward telecommuting than are full-fledged employees. The probable reason for this could be that the same familial orientations or other personal responsibilities that make an individual seek one form of flexible work (part-time or contract) could make another form (telecommuting) also attractive (Mannering and Mokhtarian, 1995; Yen and Mahmassani, 1997). Conversely, the nature of work in certain types of conventional work arrangements (for example, personal assistants) may require the employee to be physically present at the work location during conventional work hours.

Second, employees commuting to work face traffic congestion and commute stress and this may encourage employees to telecommute more frequently (Mokhtarian and Salomon, 1996b, 1997). Further, presumably employees with conventional work-hour arrangements tend to experience more travel related discomforts than do the employees with unconventional work-hour arrangements, since the former group more often commutes during peak periods than does the latter group. Hence, the detrimental effects of traffic congestion and commute stress may be stronger for these employees and may motivate them to telecommute more (partly counteracting the first observation above).

Third, certain subjective perceptions of employees (both personal and job-related) may make them less (or more) oriented toward telecommuting than other employees (Mokhtarian and Salomon, 1996a, 1996b, 1997), and such traits may also be correlated with work-hour arrangement. For example, clerical employees (conventional work arrangement) may think that management would perceive them negatively if they telecommuted (Bailey and Kurland, 2002; Mannering and Mokhtarian 1995; Mokhtarian *et al.*, 1998). Or, it is possible that employees who feel they lack self-discipline prefer to telecommute less (Mannering and Mokhtarian, 1995), and for the same reason may feel less inclined to take up a flex-time (unconventional) work-hour arrangement.

Fourth, there may be some unobserved personality traits that make individuals prefer certain work arrangement types or telecommuting locations or telecommuting frequency. These unobserved factors can generate correlations in the preferences for joint "packages" of work hour arrangement, location, and frequency. For instance, it is possible that employees with conventional work-hour arrangements are "old-fashioned" or "traditional" and have an inertia toward exploring new work arrangements such as telecommuting, while employees with unconventional work-hour arrangements are more "open-minded" to exploring telecommuting.

Finally, while evaluating policies that encourage telecommuting, it is important to consider employees' work-hour arrangements. This is because telecommuting helps in congestion mitigation by substituting for the commute trip during the time window of the employee's usual commute, which in turn is closely related to the work-hour arrangement of the employee. Hence, the employee is affected by a policy that encourages telecommuting, only if it

applies during the usual time window of his/her commute trip. Consider, for example, a policy that intends to reduce commute travel and promote telecommuting by penalizing peak period travel (for example, by tolling). If an employee's work-hour arrangement is such that he/she does not commute to work in either the morning peak or the evening peak or both, then he/she is obviously either only partially affected or totally unaffected by the peak period penalizing policy. Hence, while evaluating the impact of such policies, the work-hour arrangement should be considered along with telecommuting frequency.

In summary, although no previous studies of telecommuting adoption or frequency have included work-hour arrangement as a dependent variable to be modeled simultaneously (see Table 1), there are several good reasons to do so. Accomplishing that is the purpose of the present study. The rest of the paper is structured in the following way. The next section provides a brief description of the source and sample characteristics of the data used in this study, along with details on the way the dependent variable is structured. This is followed by an overview of the methodology used for the model in section 3. Section 4 presents and discusses the empirical results of the models developed, followed by the policy implications of the models in section 5. Finally, section 6 outlines the conclusions of the study and also identifies some directions for future research in this field.

2. DATA SOURCE, SAMPLE CHARACTERISTICS, AND DEPENDENT VARIABLE

2.1 Data Source

The data source used in this analysis is from the 1992 San Diego telecommuter survey conducted by the University of California, Davis. The survey, which was 14 pages long, collected data in six sections from employees of the City of San Diego. While the first section collected information about the employee's awareness of, and experience with, telecommuting, the second section collected data on several job-related characteristics. The third section collected information on the frequency (current and preferred) of telecommuting (both home and center) and the fourth section collected information on some life-style decisions related to telecommuting. The fifth section elicited views on issues that were related to telecommuting, and the final section requested general demographic and travel information. A detailed description of the survey and sample characteristics can be found elsewhere (Mokhtarian and Salomon, 1996a). In particular, the study design deliberately oversampled telecommuters, and only six city departments were surveyed. Thus, the sample is not representative of salaried employees everywhere, but since the purpose of our study is to analyze relationships among multiple variables rather than to estimate descriptive parameters (such as means) for individual variables, a completely representative sample is not essential.

A total of 628 responses were obtained from the survey. After cleaning the data for missing observations, a large number (89 observations) of which were due to unclear work hour arrangement of employees, a total of 305 observations were considered for model development.

2.2 Sample Characteristics

2.2.1 Demographic Characteristics

The gender distribution in the sample was 51.8% male and 48.2% female. Most employees fell into the 31-40-year-old (43%) and 41-50-year-old (24.3%) age groups. The sample was well-educated with 31.8% graduating from a 4-year college and an additional 26.2% completing graduate degrees. Middle-income employees dominated the sample with 32.5% of the sample falling into the $35,000-$54,999 bracket and 25.2% falling into the $55,000-$74,999 bracket.

The average household size was 2.62 with 1.91 vehicles per household. The sample slightly overrepresented women, with 46% women in the workforce nationwide (AFL-CIO, 2004). However, the income and average household size were roughly consistent with those of the population of San Diego as reflected in the Census data (U.S. Census Bureau, 2005).

2.2.2 Job-Related Characteristics

The sample comprised an experienced workforce, having an average 8.03 years of employment with the current employer. With respect to profession, nearly two-thirds (64.9%) were in the professional or technical fields, while 13.1% were managers and 18.7% worked in a clerical occupation.

2.2.3 Transportation- (Commute-) Related Characteristics

Most employees (70.2%) did not consider the car to be a status symbol, but rather a convenient way to get around. The average one-way commute distance was 13.02 miles, while the average commute time to work was 26.31 minutes and the average commute time from work was 28.72 minutes. This is somewhat higher than the median travel time of 22.90 minutes for the city of San Diego (U.S. Census Bureau, 2005). More than four-fifths of the sample (84.9%) considered the option of telecommuting to reduce the stress of congestion, while 45.9% changed their work trip departure time within the past year to avoid congestion.

2.2.4 Attitudinal Characteristics

Employees showed good awareness of telecommuting, as 74.4% of the employees knew someone who telecommuted. Nearly a third (29.5%) agreed that they lacked self-discipline, while 91.5% were generally satisfied with their life. A large majority (95.3%) of the sample reported being willing to reduce their driving in order to improve air quality, although this result is subject to a social desirability bias. Familial orientations were clear (albeit subject to the same bias), with 88.9% reportedly agreeing upon the importance of family and friends over work.

2.3 Dependent Variable

The dependent variable, as noted previously, is a combination of alternatives along three different dimensions: work-hour arrangement, location, and frequency of telecommuting. The set of all possible combinations of all the alternatives for the three dimensions creates the final pool of alternatives from which the employee chooses one alternative. Hence, the model predicts the probability with which an employee chooses a particular work-hour arrangement, location of telecommuting, and frequency of telecommuting from that location. As indicated earlier, the alternatives along the work-hour arrangement dimension were twofold- conventional and unconventional.

To obtain an empirically workable operationalization of the alternatives along the telecommuting location and frequency dimension, telecommuting frequency as elicited from respondents (not at all, less than once a month, about 1-3 days a month, 1-2 days a week, 3-4 days a week, 5 days a week, and occasional partial days) was cross-tabulated with telecommuting location as obtained in the survey (home, center, or both). Though the survey asked employees to report their actual frequencies and their preferred frequencies from each telecommuting location, preference data rather than adoption data is used in our model. This is because there were not enough cases of center based telecommuting in the adoption data. Table 2 shows the cross-tabulation results. The first cell of the first column in the table, which

corresponds to ‘not at all’ from home and ‘not at all’ from center, was identified as the alternative ‘neither’ along the location dimension (*i.e.*, preference for neither home nor center). The rest of the cells in column 1 (*i.e.*, ‘not at all’ for center and all options other than ‘not at all’ for home) were grouped into the ‘home’ location category, as these employees showed exclusive preference for teleworking from home (shaded light in the table). All the other cells in the table were grouped into the ‘home-center’ location category, as these employees (with one exception, who preferred center only) showed preferences for telecommuting from both home and center (shaded dark in the table). Given the way the preference questions were asked, cases in this last category could be expressing an “either” preference, not necessarily a “both” preference. That is, their response for one location could be based on an assumption of “if the other location were not available”, and in general should be interpreted as the maximum amount the respondent would like to telecommute from that location, not necessarily the ideal preferred amount. In any case, the dimension of location was narrowed down to three mutually exclusive alternatives in the empirical analysis: neither, home, and home-center.

Some of the telecommuting frequency categories in Table 2 have very few observations, and so we pooled the raw frequency categories into three more aggregate categories. Specifically, ‘less than once a month’, ‘about 1-3 days a month’, and ‘occasional partial days’ were pooled into a ‘low frequency’ category. The alternative ‘1-2 days a week’ was relabeled as ‘medium frequency’, and the remaining two categories (‘3-4 days a week’ and ‘5 days a week’) were combined into a ‘high frequency’ category. The higher of the home- and center-based aggregate telecommuting frequency categories was designated as the telecommuting frequency for the employees falling in the ‘home-center’ telecommuting location category.

Overall, the dependent variable is characterized by 14 alternatives (each individual chooses one of these 14 alternatives), each alternative representing a particular combination of work hour arrangement (conventional versus unconventional), telecommuting location (neither, home, or home-center), and telecommuting frequency (low, moderate, high). The 14 alternatives and the number (percentage) of individuals in the sample choosing each alternative is provided in Table 3. The reader will note from the table that there are very few individuals who prefer not to telecommute at all (only 24 of the 305 individuals; 24 corresponds to the sum of the numbers for alternatives 1 and 8 in Table 3)). This is, of course, because the survey over-sampled telecommuters and also because of the use of telecommuting preference data.

3. METHODOLOGY

Three discrete choice modeling approaches were considered in this study: multinomial logit (MNL), nested logit (NL), and mixed multinomial logit (MMNL).

3.1 Multinomial Logit Model (MNL)

The dependent variable of the MNL model is as described in the previous section. If alternative specific parameters are estimated for each alternative for a given explanatory variable in the MNL model, then each alternative must have a sufficient number of observations to estimate the corresponding parameters. However, this was not the case as some alternatives had very few observations. Hence, parameters are defined specific to the alternatives of the three dimensions (work-hour arrangement, location and frequency of telecommuting) rather than specific to 13 of the 14 available alternatives. Hence, the number of observations for each alternative of a

dimension gets pooled and thereby enables the efficient estimation of parameters. Further, this reduces the number of parameters required to be estimated for each explanatory variable.[1]

3.2 Nested Logit Model (NL)

One limitation of an MNL model is the independence of irrelevant alternatives (IIA) property, due to the assumption that the error terms are independent across alternative utilities. However, this may not hold true in many cases. For instance, there may be some unobserved factors (such as say a need or desire to have a temporal discipline for work activity) that may predispose an individual to work conventional times rather than unconventional times (compared to her/his observationally equivalent peers). By the same token, there may also be unobserved factors (such as say a need or desire for temporal flexibility in work activity) that may draw an individual toward unconventional work hours. If this is the case, the unobserved personality trait of "need/desire for temporal discipline" and "need/desire for temporal flexibility" will get manifested in the form of correlation in the error terms across the joint alternatives that share a conventional work arrangement and the joint alternatives that share an unconventional work arrangement, respectively. That is, individuals are "sticky" in their preferences along the work hour arrangement dimension. Alternatively, one can also conceive of common unobserved factors that make individuals "sticky" in their preference for telecommuting location and/or telecommuting frequency. Such error correlations can be accommodated through the use of nested logit structures.

In the current study, we tested alternative nesting structures, but the simple structure with unobserved error correlations along the work-hour arrangement dimension provided the best statistical results as well as a dissimilarity parameter (or logsum parameter) that was statistically significantly different from 1 at the 90% confidence level.

3.3 Mixed Multinomial Logit (MMNL) Model

A mixed multinomial logit (MMNL) model (see Bhat, 2000) enables the accommodation of richer correlation structures across alternatives than does the NL model. We tested several different MMNL specifications in the current study, but none of them yielded a better data fit than the NL model.

4. EMPIRICAL RESULTS

In this section, we present the results of the NL model that included unobserved correlations along the work hour arrangement dimension. This model included a common error component for all alternatives that include a conventional work arrangement, and another error component for all alternatives that include an unconventional work arrangement. The levels of correlation across the conventional work arrangement alternatives and the unconventional work arrangement

[1] Of course, this also places restrictions because it does not allow variables to have interaction effects on utility among the three dimensions of work hours, location, and frequency (over and beyond unidimensional variable effects). However, the joint model here is not the same as estimating separate MNL models for each dimension and obtaining an effective probability for each "joint" choice by multiplying the appropriate uni-dimensional probabilities. This is because we include alternative specific constants for 13 of the 14 joint choice alternatives, which considers the general predispositions in the population toward specific combinations of work hours, telecommuting location, and frequency. Of course, we also consider correlations in unobserved factors that make an individual inclined toward certain combinations more so than others, as we discuss in the next section (Section 3.2).Thus, the model estimated here is a joint "package" model of work hours, telecommuting location, and telecommuting frequency, even if restricted by the sample in its accommodation of explanatory variable effects.

alternatives were not statistically different, and hence a single dissimilarity (or logsum) parameter for both "nests" is estimated. This dissimilarity parameter is estimated to be 0.79 with a t-statistic of 1.71 for the null hypothesis that the parameter is not statistically different from 1 (the NL model collapses to the MNL model if the dissimilarity parameter is not statistically different from 1). Thus, at the 90% level, we can reject the hypothesis that there is no unobserved correlation along the work-hour arrangement dimension. That is, the results indicate the presence of unobserved factors that predispose individuals toward a certain type of work hour arrangement. An alternative way of looking at this result is that individuals are '"sticky" along their work hour arrangement choice due to unobserved factors. This makes individuals tend to retain their work hour arrangement more so than sticking to their telecommuting location and frequency in response to changes in demographic and transportation-related variables.

The final specifications of the NL model are presented in Table 4. We do not present the estimation results for the MNL and MMNL models because the NL model provided better results than the MNL model, and the MMNL model did not provide statistically superior results relative to the NL model. The explanatory variables in Table 4 are grouped into demographic variables, job-related characteristics, transportation-related variables, and attitudinal factors. The coefficients on the explanatory variables are defined to be specific to the three dimensions of work-hour arrangement, location and frequency of telecommuting (see Section 3.1). For the work hour arrangement dimension, the variables are introduced with the "unconventional work hour arrangement" as the base category. For the telecommuting location dimension, the variables are introduced with "home-center" being the base. For the frequency dimension, "low frequency" is considered as the base category.[2]

4.1 Demographic Effects

The effect of household size on telecommuting is complex. The signs of the coefficients indicate that as the household size increases, employees are less likely to opt for alternatives with exclusive home telecommuting as compared to other alternatives. On the other hand, as the household size increases, employees are more likely to prefer high-frequency telecommuting alternatives than the other alternatives. This is probably due to the following opposing effects of household size on telecommuting. As the household size increases, the distractions due to other household members increase and the employee may not be very effective at working from home. This is reflected by the negative sign on the former coefficient (whereas employees who prefer 'home-center' alternatives are willing to telecommute from a center, in which case household distractions may not be a concern). On the other hand, as the household size increases, the familial responsibilities increase, motivating the employee to want to telecommute more. This is reflected by the positive sign on the latter coefficient.

4.2 Job-Related Characteristics

Employees in managerial, technical/professional, and clerical occupations are more likely than other occupation types (such as services/repair and production/construction/crafts) to take up conventional work-hour arrangements. As a broad generalization that may reflect general tendencies (although there is considerable variability within each occupation type), employees in

[2] As indicated earlier, 13 alternative-specific constants were also estimated, which capture the general population predispositions for combinations of work hour arrangement, telecommuting location, and telecommuting frequency. These are not shown in Table 4 because they do not have any substantive interpretations.

managerial, technical/professional, and clerical occupations often interact with people within and outside the company. This is likely to increase the preference of such employees to work during usual business hours.

Along the same lines, the nature of work of supervisors often requires them to be physically present in the office. Though this is not a strict requirement and supervisors can telecommute, a high frequency of telecommuting may make the employees under the supervisor perceive him/her less authoritatively. Hence, supervisors are likely not to prefer a high frequency of telecommuting, as indicated by the negative sign on the coefficient for high frequency telecommuting for supervisors.

Several work-related activities of the employee in the recent past are related to his/her telecommuting preferences. Employees who worked unpaid overtime in the past 6 months do not prefer to telecommute with a high frequency. This probably indicates the desire of these employees to get "noticed" by management while they work overtime without pay. Employees who took work home (not as a part of telecommuting) in the past 6 months prefer to telecommute from home. This probably indicates that such employees have a high functional suitability for telecommuting, as well as familiarity with working from home in particular. Similarly, those employees who had bought work-related equipment to be used while working from home are more likely to want to telecommute with a medium or high frequency as compared to low frequency. The personal purchase of home-based work-related equipment not only represents an investment which the employee may wish to take advantage of, but is also a "leading indicator" of a propensity to work from home.

Employees who changed to a new job (with the same employer) in the past 2 years are more likely to want to telecommute with high frequency as compared to other frequencies of telecommuting. Among many reasons for an employee to change jobs, some include convenience, flexibility, and better lifestyle opportunities. It is probably this openness to change and ambition to improve one's work circumstances that also makes the employee prefer a high frequency of telecommuting.

4.3 Transportation-Related Characteristics

Employees who are of the opinion that their "commute is a big hassle" are least likely to prefer not to telecommute at all, and more likely to prefer both home and center as the locations for telecommuting as compared to a strict preference for home (see Table 4). It is logical that the more burdensome the commute is perceived to be, the more inclined the employee would be to relieve it by home *or* center telecommuting, as opposed to restricting the options he/she is willing to consider to home only. Further, along the frequency dimension, employees who feel that their commute is a big hassle are likely to telecommute with a high frequency, as compared to low and medium frequencies. However, such individuals are no more likely to prefer unconventional work hour arrangements relative to individuals who feel their commute is not much of a hassle.

Those employees who had "changed commute departure time over the past year to avoid congestion" are more likely to prefer to telecommute with medium frequency as compared to other frequencies. This greater inclination toward medium frequency could be because the departure time change may have reduced the motivation to telecommute more often, while not solving the problem so completely that telecommuting is no longer attractive at all.

Those employees who indicate a higher "importance of telecommuting in reducing commute stress" are less likely to choose a conventional work-hour arrangement as compared to

an unconventional one. However, there is no statistically significant difference in preferences among this group of employees and other employees regarding telecommuting location and frequency. This result is interesting when compared to the result regarding the "commute is a big hassle" variable. One can surmise that the "commute is a big hassle" variable is capturing, in people's perceptions, the "opportunity cost" of commuting time in terms of the lost time for participation in preferred leisure activities, because of which individuals who believe that commuting is a hassle prefer telecommuting options. However, the "importance of telecommuting in reducing commute stress" variable is perhaps capturing, in people's perceptions, the stress caused by the uncertainty of commuter travel time. People who respond with a higher importance on this variable possibly like commuting as part of their routine and do not see it as much of an opportunity cost for leisure participation. But what they don't like is the uncertainty in travel time. This may explain the preference for unconventional work hour arrangements, but no particular preference for telecommuting adoption.

4.4 Attitudinal Factors

A number of attitudinal factors were significant in the model. In the class of general lifestyle attitudes, the employee's familial inclinations (as reflected in the variable "like to spend more time with family and friends" in Table 4) increases the likelihood of preferring both medium and high frequencies of telecommuting. This is not surprising, as one of the key advantages touted for telecommuting is the ability to better balance work and family demands. It is interesting, however, that with this variable in the model, neither gender, nor the presence of young children, nor the interaction of those two variables, was significant. The implication is that it is the family orientation that is important, not traditional gender roles. This is another demonstration of the superior explanatory power of attitudes over demographic variables, which are often used as (frequently unsatisfactory) proxies for attitudes when attitudes are not available. The results also reinforce the intuition that those who are "willing to reduce driving for cleaner air" prefer higher frequencies of telecommuting.

Employee perceptions regarding telecommuting also seem to have a significant relationship with his/her preferences on telecommuting location and frequency. Employees who are under the belief that "telecommuting is for those who use computers" are less likely to prefer telecommuting with medium frequency compared to other frequencies, while those who believe that "even if job is suitable, there may be reasons for not allowing telecommuting" are less likely to commute from home rather than not telecommute at all or telecommute from home-center. The latter result suggests that individuals who believe that a certain degree of supervision is needed to ensure good work performance are not likely to approve of work from home unsupervised.

Telecommuting preferences are also dependent on several work-related attitudes. Employees who believe that "telecommuting is important in getting more work done" are more likely to prefer telecommuting only from home as compared to doing it from home or center, or not at all - perhaps because a telecommuting center seems largely like just another workplace to them, with many of the same stresses and distractions. However not all work-related attitudes encourage employees to telecommute. For example, employees who "value the professional interaction of the workplace" are unlikely to prefer a high frequency for telecommuting, though these individuals are no less likely to adopt some form of telecommuting relative to others. Also, those who are more sensitive to "concerns about opportunities for visibility and career

advancement at the conventional workplace" are not very likely to telecommute from home. These individuals obviously prefer a show of "presence" at a main or center-based workplace.

4.5 Likelihood-Based Model Statistics

The log-likelihood at convergence of the NL model is –687.20, while the log-likelihood value at sample shares (that is, with only the 13 alternative-specific constants) and the dissimilarity parameter is –767.22. The nested likelihood ratio test for testing the presence of exogenous variable effects on the joint preference of work hour arrangement, telecommuting location, and telecommuting frequency is 160, which is substantially larger than the critical chi-square value with 27 degrees of freedom at any reasonable level of significance. This clearly indicates the value of the model estimated in this paper to predict the joint preference of work hour arrangement, telecommuting location, and telecommuting frequency based on individual and household demographics, job-related characteristics, transportation-related variables, and personal attitudes.

5. CONCLUSIONS

This study was conducted with the objective of estimating a joint choice model of three distinct dimensions of work related choices - work hour arrangement, location, and frequency of telecommuting. The data for the study was drawn from a 1992 telecommuting survey of the employees of the city of San Diego. A total of 305 responses were used in the model estimation. Three different model structures (MNL, NL, and MMNL) were estimated, but the NL model provided the best data fit results.

Several interesting observations can be made from our empirical analysis. First, employees in managerial, technical/professional, and clerical occupations are more likely to prefer conventional work hour arrangements than unconventional work hour arrangements. Second, employees who consider telecommuting as an important option to reduce commute stress are more likely to prefer unconventional work hour arrangements than conventional work hour arrangements. These observations highlight the differences in telecommuting preferences among employees with conventional and unconventional work hour arrangement. Third, employees who have taken work home in the recent past (not as a part of telecommuting), and believe strongly in telecommuting as a vehicle to higher work productivity, prefer telecommuting exclusively from home to telecommuting from a home-center or not telecommuting at all. Fourth, increasing household size, purchase of work-related equipment at home, a recent job switch, a family-oriented lifestyle, perceptions of commute as a hassle, and an environmentally 'green" attitude make employees prefer telecommuting with a high frequency.

From a policy standpoint of reducing peak period traffic congestion, it is appealing to examine ways to increase employees with an unconventional work schedule (those who work outside the usual 9-5 schedule) and/or increase the penetration of employees with a conventional, but telecommuting, work schedule. Our results suggest that campaigns to increase the amount of employees with an unconventional work schedule would be best targeted toward industrial sectors/employees associated with services/repair and production/construction/crafts. Such campaigns can perhaps also benefit from focusing on the reduction in the uncertainty of commuting time that accompanies a switch to unconventional work times (rather than focusing on general lifestyle benefits of having more time for leisure activities; see Section 4.3). On the other hand, campaigns to increase the number of employees who work conventional hours and telecommute would be best targeted toward industrial sectors/ employees in the managerial,

technical/professional, and clerical occupations. Such campaigns can benefit from emphasizing the general lifestyle benefits of telecommuting. Also, based on our results, it is possible to identify individuals with certain other characteristics and attitudes that make them more inclined to adopt unconventional work hour arrangements or telecommuting based on our results.

Overall, the inclusion of the work hour arrangement dimension in travel-related analysis can provide important insights and policy information for reducing peak period congestion. To our knowledge, this study is the first to adopt a unifying analysis framework for examining work hour arrangement and telecommuting location/frequency preferences. Future studies should expand on the variable specification adopted here by considering additional interaction effects and including a comprehensive set of commute-related variables (such as commute costs). It would also be helpful to use actual choice data in the analysis rather than using preference data. However, the challenge will be to collect data that can support such efforts.

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LIST OF TABLES

TABLE 1 Empirical Results of Previous Telecommuting Choice Models

Study	Data	Methodology	Dependent variable	Independent variables
Bernardino *et al*. (1993)	USENET newsgroup survey (N=54) SP survey	Ordered probit	Willingness to telecommute (for 8 different telecommuting arrangements with varying attributes including frequency) Alternatives: Willingness ranked in the range 1-5	**Positive effect:** Salary increase, number of children under 18 in the household, one-way travel time saving (if < 40mins), telecommuting option not available **Negative effect:** Equipment and phone bills paid by employee, unpaid overtime work, salary reduction, number of years worked in the organization.
Sullivan *et al*. (1993)	Austin (N=360), Dallas (N=184), Houston (N=150) SP survey	Multinomial logit	Stated preference of telecommuting frequency Alternatives: Full time, part time, possibly, no	**Positive effect:** Round-trip commute time, commute stops per week, average time using computer per day, female with children, males' household income, female, married **Negative effect:** Length of time with firm, face-to-face communication, work end time, age
Olszewski and Mokhtarian (1994)	California (N round 1= 117, N round 2= 114)	Factor analysis	Telecommuting frequency (days/month)	**Positive effect:** Information professional **Negative effect:** policy, engineering, and financial employee groups **No significant effect:** Age, gender, commute distance, female with children
Mannering and Mokhtarian (1995)	San Diego (N=433)	Multinomial logit	Actual telecommuting frequency Alternatives: Never telecommute, infrequently, frequently	**Positive effect:** Household size, female with children, home office space availability, vehicles per capita household, supervisor, remote work indicator, schedule control indicators, familiarity **Negative effect:** Clerical occupation indicator, hours worked in 2wk period, unpaid overtime, lack of self discipline, family orientation indicator. **No significant effect:** Commute length, commute distance, managerial and professional occupation, amount of time spent on face to face contacts
Bernardino and Ben-Akiva (1996)	21 organizations across US (N=176 employees)	Multinomial logit	Choice of telecommuting	**Positive effect:** Change in lifestyle quality (flexibility of schedule, job satisfaction, social life, job opportunity, *etc*.), higher salary to telecommuters **Negative effect:** Change in work-related costs, lower salary to telecommuters

Mokhtarian and Salomon (1996b)	San Diego (N=624)	Binary logit	Binary preference of home-based telecommuting	**Positive effect:** Overtime, commute stress **Negative effect:** Misunderstanding, lack of manager support, job unsuitability, technology availability and office discipline
Yen and Mahmassani (1997)	(Austin, Houston and Dallas)(N=545) SP Survey	Dynamic Generalized Ordinal Probit (DGOP)	Stated preference for telecommuting adoption	**Positive effect:** 5% increase in salary, number of children under 16 at home, number of personal computers at home, number of hours using computer per work day, commute distance, family orientation **Negative effect:** 5% decrease in salary, telecommuting cost faced by employee, number of hours communicating face-to-face with co-workers per day, average number of stops on the way back to work from home per week, job suitability
Mokhtarian and Salomon (1997)	San Diego (N=626)	Binary logit	Binary preference of telecommuting	**Positive effect:** Disability/parental leave, stress, personal benefits, commute stress, commute time, amount of telecommuting job allows **Negative effect:** workplace interaction, concern of household distractions, commuting benefit
Mokhtarian and Meenakshi-sundaram (2002)	California teleworking center users (N=115)	Cluster analysis	Frequency of telecommuting	**Positive effect:** Age, commute length **Negative effect:** Being female **No significant effect:** Education, income
Popuri and Bhat (2003)	New York and New Jersey (N=6532)	Choice (unordered) and frequency (ordered) joint model	Actual choice and frequency of telecommuting	**Positive impact:** Female with children, age, married, licensed driver, number of vehicles, drive to work, work in a private company, length of service, fax availability, multiple phone lines at home **Negative impact:** Female, transit to work

TABLE 2 Cross Tabulation of Preferences for Telecommuting from Home and Center

		Prefer a center							Total
		Not at all	Less than once a month	About 1-3 days a month	1-2 days a week	3-4 days a week	5 days a week	Occasional partial days	
Prefer home	Not at all	24	0	0	1	0	0	0	25
	Less than once a month	0	1	1	0	0	0	0	2
	About 1-3 days a month	20	6	20	3	0	0	1	50
	1-2 days a week	65	0	6	67	7	2	3	150
	3-4 days a week	11	1	1	8	19	0	0	40
	5 days a week	8	0	0	1	2	13	1	25
	Occasional partial days	6	0	0	0	0	0	7	13
Total		134	8	28	80	28	15	12	305

TABLE 3 Sample Distribution of the Dependent Variable

Work-related decisions				Number of respondents	Percent of respondents
Alternative	**Work-hour arrangement**	**Telecommuting location**	**Telecommuting frequency**		
1	Conventional	Neither	-	13	4.3
2	Conventional	Home	Low	17	5.6
3	Conventional	Home	Medium	29	9.5
4	Conventional	Home	High	12	3.9
5	Conventional	Home-center	Low	21	6.9
6	Conventional	Home-center	Medium	36	11.8
7	Conventional	Home-center	High	31	10.2
8	Unconventional	Neither	-	11	3.6
9	Unconventional	Home	Low	9	3.0
10	Unconventional	Home	Medium	36	11.8
11	Unconventional	Home	High	7	2.3
12	Unconventional	Home-center	Low	19	6.2
13	Unconventional	Home-center	Medium	41	13.4
14	Unconventional	Home-center	High	23	7.5

TABLE 4 Estimated Parameters for NL Model

Variable	Work hour arrangement		Location of telecommuting				Frequency of telecommuting			
	Conventional		Home		Neither		Medium		High	
	Est.	t-stat.	Est.	t-stat.	Est.	t-stat.	Est.	t-stat.	Est.	t-stat.
Demographic variables										
Household size	-	-	-0.30	-2.64	-	-	-	-	0.24	2.09
Job-related characteristics										
Occupation: manager	2.48	2.10	-	-	-	-	-	-	-	-
Occupation: technical/professional	2.42	2.19	-	-	-	-	-	-	-	-
Occupation: clerical	2.82	2.43	-	-	-	-	-	-	-	-
Supervisor	-	-	-	-	-	-	-	-	-0.87	-2.52
Work unpaid overtime during past 6 months	-	-	-	-	-	-	-	-	-0.72	-2.15
Take work home during past 6 months	-	-	0.67	2.52	-	-	-	-	-	-
Buy work related equipment for use at home	-	-	-	-	-	-	1.19	3.12	1.28	2.49
Changed to new job (with same employer) in past 2 years	-	-	-	-	-	-	-	-	0.99	2.84
Transportation-related characteristics										
Commute is a big hassle	-	-	-0.43	-3.36	-0.70	-2.42	-	-	0.46	3.34
Changed departure time over past year to avoid congestion	-	-	-	-	-	-	0.46	1.94	-	-
Importance of telecommuting in reducing commute stress	-1.02	-2.64	-	-	-	-	-	-	-	-
Attitudinal factors										
<u>General lifestyle attitudes</u>										
Like to spend more time with family and friends	-	-	-	-	-	-	0.36	2.46	0.53	2.49
Willing to reduce driving for cleaner air	-	-	-	-	-	-	0.31	1.69	0.56	2.30
<u>Employee perceptions regarding telecommuting</u>										
Telecommuting is for those who use computers	-	-	-	-	-	-	-0.23	-1.89	-	-
Even if job is suitable, there may be reasons for not allowing telecommuting	-	-	-0.27	-2.22	-	-	-	-	-	-
<u>Work-related attitudes</u>										
Telecommuting is important in getting more work done	-	-	1.90	2.40	-	-	-	-	-	-
Value the professional interaction of the workplace	-	-	-	-	-	-	-	-	-0.92	-2.25
Concerns about opportunities for visibility and career advancement at the conventional workplace	-	-	-0.63	-1.98	-	-	-	-	-	-