

**MODELING THE CHOICE OF TELECOMMUTING 2:
A CASE OF THE PREFERRED IMPOSSIBLE ALTERNATIVE**

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ABSTRACT

A conceptual model of the choice to telecommute was advanced in an earlier paper (Mokhtarian and Salomon, 1994). In this paper, we present empirical data from a non-representative sample of 628 City of San Diego employees on key variables and relationships in that model. The relationships among possibility, preference, and choice are examined. A key finding is the existence of a large group of people (57% of the sample) for whom telecommuting is a Preferred Impossible Alternative. Dichotomous and continuous constraints are distinguished, and three dichotomous constraints are defined. Lack of awareness is active for 4%, job unsuitability for 44%, and manager disapproval for 51% of the sample. For 68% of the sample, at least one of these constraints is active. Even among those for whom none of the dichotomous constraints is in force, most people do not choose telecommuting due to the presence of active continuous constraints. For only 11% of the entire sample, telecommuting is possible, preferred, and chosen. The potential impacts of self-selection bias are estimated, and sampling bias is qualitatively assessed. This analysis provides a crude but useful estimate of the potential of telecommuting in the population, and more specifically, the relative share of potential telecommuters who are prevented by key dichotomous constraints from choosing that option.

Modeling the Choice of Telecommuting 2: A Case of the Preferred Impossible Alternative

1. INTRODUCTION

Telecommuting has been defined as the use of telecommunications technology to modify or replace the commute to a conventional workplace. In both versions, working from home or from a telecenter, it is now a commonly-discussed (if not yet commonly-implemented) strategy for reducing congestion and vehicular emissions as well as addressing a number of other business and social issues. Transportation planners in particular have a need to forecast the ultimate adoption of telecommuting, to be able to estimate its impacts on travel and consequent energy and emissions impacts. Aggregate forecasts to date (Nilles, 1988; Boghani, *et al.*, 1991; US Department of Transportation, 1993; Handy and Mokhtarian, 1993; US Department of Energy, 1994) have primarily been based on hypothetical scenarios without a formal evaluation of the likelihood of those scenarios materializing. This approach is perhaps necessary during the early stages of an innovation, when adequate empirical data are unavailable. The ideal, however, is to develop a forecast based on a causal model of adoption behavior. A foundation for such an aggregate forecast would be a disaggregate model focusing on the individual's decision to adopt telecommuting.

This paper is the second in a series of articles describing the development of such a disaggregate model. The first paper (Mokhtarian and Salomon, 1994) presented a conceptual model of the individual choice process. In this model, basic types of factors in the choice process are identified: constraints (factors which prevent or hinder change if they are present), facilitators (factors which allow change, or make the change easier or more effective, if they are present), and drives (factors which motivate a person to consider a change). The same factor may be either a constraint or a facilitator, depending on whether it is present in a positive or negative sense. Constraints/facilitators include external variables related to awareness, the organization, and the job, and internal psychosocial variables. Drives may be related to work, family, leisure, ideology, and travel. The absence of active constraints is a necessary but not sufficient condition for telecommuting to be adopted by an individual. **One or more drives must also be present for telecommuting to be chosen.**

The choice set contains those alternative solutions perceived to be feasible by the individual. It may or may not contain telecommuting (depending on whether all constraints are non-binding or not), and probably contains other alternatives having nothing to do with

telecommuting. Each alternative is evaluated in terms of how effectively it satisfies the drive, and the individual's attitudes toward it. The alternative (or bundle of alternatives) which maximizes individual utility becomes the preferred behavioral pattern. However, constraints may prevent the preferred behavior from being chosen. The process is a dynamic one, in which previous choices affect attitudes and constraints and alter drives.

Telecommuting seems to be mentioned as a desired arrangement much more often than it is actually practiced. This is partially a result of the effects of constraints which mean that, even for individuals who prefer to telecommute, it is not a viable choice alternative. Because of this peculiarity, we are separately modelling the preference for and the choice of telecommuting.

Through the design and administration of a questionnaire, data have been collected to quantify the variables and the relationships in the model. This second paper in the series examines several key relationships, namely those among constraints on, preference for, and choice of telecommuting. We explore the extent to which lack of awareness, job unsuitability, and lack of manager support are active constraints in our sample, and we empirically confirm the existence of a large gap between the number of people wanting to telecommute and those who are actually able to do so.

The organization of this paper is as follows: Section 2 describes the survey design and data collection process, and the resulting data set. In Section 3, several possible dependent variables are identified, and the variables used in the analysis reported here are selected. Section 4 discusses the role of constraints, operationally defines three dichotomous constraints, and examines the degree to which each of those constraints occurs in our sample. In Section 5 we explore the relationships among possibility, preference, and choice of telecommuting, including the prominence of the Preferred Impossible Alternative. We estimate the impact of self-selection bias on the observed results. Section 6 summarizes the key findings and describes the next stage in the modeling process.

2. DATA COLLECTION

A fourteen-page self-administered questionnaire was developed to obtain data on the variables of interest in the model. The survey contained questions regarding respondents' previous awareness of and experience with telecommuting; their job characteristics; their ability to telecommute; perceived advantages and disadvantages of telecommuting; information on other choices they may have made to satisfy the hypothesized lifestyle

drives; attitudes toward telecommuting and issues related to lifestyle drives; and sociodemographic characteristics.

The survey was first pre-tested on a sample of 35 employees of the University of California, Davis, and in a larger field test administered to 320 employees of the State of California with an overall response rate of 56%. This field test evaluated the impact of two different cover letters on response rate and content (Mokhtarian, *et al.*, 1994).

The final version of the survey was administered to employees of the City of San Diego in December 1992. The City has had a growing and relatively visible telecommuting program for its employees since early 1990. The sample was intended to obtain data from a diversity of respondents, including those for whom constraints such as job suitability prevented them from telecommuting. Further, given that many "non-information-worker" jobs deal with information to some extent, it was felt that attempts to exclude employees from the sampling frame based on job title alone was likely to eliminate many people who could telecommute at least part-time and/or on occasional partial days (Mokhtarian, 1991). At the same time, however, it would not be efficient in this small-scale exploratory research for the sampling frame to contain a high proportion of people who had virtually no ability to telecommute. First, the response rates would likely be much lower for this group of people, and second, the data from those who did respond would add little meaningful insight into the choice process. Also, it was considered desirable **B**again, at this exploratory stage **B**to maximize the number of known telecommuters in the sampling frame so as to have a large enough group of "choosers" on which to build choice models.

Accordingly, the sampling frame was developed by selecting six of the larger departments out of a total of 27 within the City, and sampling every regular employee within those departments. The departments selected were those with a relatively high number of then-current telecommuters and/or with a high proportion of workers whose jobs would be well-suited for telecommuting. Most departments with a high proportion of location-dependent workers (such as Fire, General Services, Parks and Recreation, Police, and Water Utilities) were excluded from the sampling frame, even though several of those departments had existing telecommuters. On the other hand, the Building Inspection department *was* included because a relatively large number of its employees (33 out of approximately 200) were already telecommuting.

It is important to realize that the final sample cannot be considered representative of the workforce as a whole in terms of the population *distribution* of key variables including the

choice of telecommuting. It may be argued, however, that the sample adequately represents the population *relationships* of explanatory variables to the choice and preference of telecommuting (i.e. the importance of those variables as determined by their magnitude and significance in a quantitative model).

As an incentive to respond, those who returned the survey were entered into a drawing for \$100. A total of 1428 surveys were sent out, of which six were undeliverable and six were duplicated names. The remaining 1416 surveys were distributed among the six selected departments as follows: Attorney (289), Auditor (113), Building Inspection (215), Engineering and Development (418), Financial Management and Purchasing (152), and Planning (229). A total of 629 surveys were returned, one of which was largely blank and therefore discarded from further analysis. The remaining 628 yielded an effective response rate of 44%, which was considered excellent for a survey of such length and general distribution. Response rates varied among departments, with a high of 48.8% in Financial Management and Purchasing and a low of 40.5% in Building Inspection.

Several summary statistics for the sample are shown in Table 1. In terms of occupation, the sample was clearly dominated by information workers: 58.6% of the sample was professional/technical, 25.0% clerical/administrative support, 11.6% manager/administration, and 4.6% other. A higher proportion of the sample had supervisory responsibilities than suggested by this distribution, however: 10.7% supervised "one or more supervisors", while an additional 24.5% supervised "one or more staff." On average, respondents had been with their present department for 6.0 years, their present employer for 8.7 years, and their present occupation for 8.5 years.

The sample was 52.9% female. The modal age category was 31-40 (38.4%), with the adjacent categories of 41-50 (28.2%) and 21-30 (19.3%) possessing the second and third highest proportion of respondents, respectively. Eleven percent were 51-60 years old, and 2.4% over 60. The average household size was 2.7 persons. Thirty-six percent of the respondents had children 15 or under in the household, including 21% with children 5 or under.

Table 1
Sample Description
(N = 628)

Occupation:			Age:		
Professional/Technical	368	58.6%	21-30	121	19.3%
Cler./ Admin. Support	157	25.0%	31-40	241	38.4%
Manager/ Admin.	73	11.6%	41-50	177	28.2%
Other	29	4.6%	51-60	71	11.3%
Missing	1	0.2%	Over 60	15	2.4%
Job/Occupation Tenure: Average time with...			Missing	3	0.5%
... Department	6.0 yrs.	s.d. 6.3	Vehicle Ownership:		
... Employer	8.7 yrs.	s.d. 7.8	Ave. per HH	1.9	s.d. 1.0
... Occupation	8.5 yrs.	s.d. 7.6	Ave. per lic. driver	0.99	s.d. 0.4
Gender:			Commute Characteristics:		
Female	332	52.9%	Ave. commute length (one-way)	12.9 mi.	s.d. 9.1
Male	293	46.7%	Ave. commute time (round-trip)	54.5 min.	s.d. 26.7
Missing	3	0.5%	Income:		
Household Size:			Less than \$15,000	5	0.8%
Average	2.7	s.d. 1.4	\$15,000 - 34,999	111	17.7%
# HH w/ children <16	227	36.1%	\$35,000 - 54,999	195	31.1%
# HH w/ children < 6	132	21.0%	\$55,000 - 74,999	143	22.8%
			\$75,000 - 94,999	92	14.6%
			\$95,000 or more	71	11.3%
			Missing	11	1.8%

On average, 1.9 vehicles were available to respondent households, 0.99 vehicles per licensed driver. Respondents lived an average of 12.9 miles from work, with an average round-trip commute time of 54.5 minutes. The modal household income category was \$35,000 - 54,999 (31.1%), with an additional 40.5% in the adjacent categories of \$55,000 - 74,999 (22.8%) and \$15,000 - 34,999 (17.7%). Nearly 15% of the sample had household incomes of \$75,000 - 94,999, and 11.3% had incomes of \$95,000 and above.

3. THE DEPENDENT VARIABLE

Telecommuting may be the outcome of very different choice situations. In trying to reproduce it through quantitative models, this implies that different "dependent" variables can be constructed. In this section, we briefly describe the possibilities and the variables chosen for further analysis at this stage of the study.

There are a number of potential drives which encourage individuals to consider the telecommuting alternative to prevailing work arrangements. These include family, work, leisure, ideology and, of course, travel. Thus, a completely specified model of telecommuting adoption should include all possible alternatives for satisfying each of the drives **B**the "universal choice set" illustrated in Table 3 of Mokhtarian and Salomon (1994). Such a model would be extremely complex, both conceptually and in terms of the necessary data required for estimation. One simplification of the completely specified model would be to focus on telecommuting as an alternative in the context of travel decisions, since travel reduction is one of the most often-cited benefits of telecommuting.

For the purposes of the present discussion, we restrict our attention to the simpler and more conventional case of "telecommuting" versus "not telecommuting". It is believed that even this simplified approach can approximate reality to a useful degree, and in any case it is practical to start with basics and build a foundation on which to elaborate over time.

Even with this binary approach, different dependent variables can be defined: preference or actual choice, and telecommuting from the home or from a center. Each of these models can be defined along a third dimension: whether the alternatives are binary (yes or no) or multinomial (frequency of telecommuting, from not at all to full-time).

On the binary versus multinomial dimension, the simplest way to view the choice situation is to assume the individual is choosing between the new work arrangement of telecommuting and the "do-nothing" option, namely not to telecommute (that is to continue the present normal work arrangement). This is a binary choice situation which is attractive in its simplicity, and it is plausible that for many individuals it is a reasonable representation of the actual choice process.

However, given that telecommuting in most cases is not considered to be a full time alternative to the prevailing work arrangement of the individual, it is also plausible that the individual does not follow a simple binary choice but actually views the situation as having multiple options, varying by the frequency of telecommuting. Thus, he or she may select among the choices of telecommuting not at all, or once, twice or more times per week, as a simultaneous decision rather than sequentially deciding first to telecommute and then what amount.

The second dimension which affects the definition of the dependent variable is the nature of telecommuting considered. Many people seem to think of telecommuting as synonymous with working from home. But telecommuting can also be done from a satellite work center, which is currently the subject of a great deal of experimentation in California and elsewhere in the United States and around the world (Bagley, *et al.*, 1994). It is possible to address both forms in the same model by creating a variable that takes on a non-zero value if *either* the home or the center is involved. However, telecommuting from a center is in many ways very different from the home-based option. Ignoring the distinction between the two forms of telecommuting may introduce significant errors into the analysis, as respondents may be relating to two very distinct arrangements.

The final dimension along which the dependent variable can be constructed is that of stated versus revealed preference, or preference versus choice. Attitude-behavior models with an intermediate preference formation stage are well-established in the marketing research and travel behavior modeling literatures (see, for example, Koppelman and Pas, 1980). Individuals are assumed to transform objective information from the environment into subjective attitudes, and to form preferences among alternatives based on those attitudes. The most-preferred alternative is assumed to be chosen unless situational constraints prevent it.

Much of this earlier work focused on a conventional choice context involving alternatives that were generally if not universally available. Stated preference modeling has assumed

greater importance to transportation planning in recent years as a way of analyzing the demand for alternatives that do not currently exist (Bates, 1988). In this context, respondents are given descriptions of hypothetical alternatives, with attributes that are systematically varied, and asked to rate or rank their preference for those alternatives.

Telecommuting falls somewhere in between the case of an alternative that is generally available and one that is completely hypothetical. As telecommuting is a relatively new phenomenon, the actual number of people who have chosen this work arrangement may be very small, or even null in a sample taken from the general population. In this study we have, as noted above, sampled from a population of employees who are mostly aware of telecommuting and some of whom have adopted telecommuting or at least have been offered the option. Nevertheless, telecommuting is not a widely experienced option. Consequently, in attempting to analyze the choice of this arrangement, it is appropriate to identify the stated desire to telecommute as the dependent variable, in addition to modeling the actual (relatively infrequent) choice of this option.

While the stated preference approach is commonly criticized for its lack of realism in the hypothetical choice situation, the data collection instrument used in this research enumerates a long array of factors which present both the advantages and disadvantages of telecommuting. This, plus the relatively high levels of familiarity and experience with telecommuting within the sample, suggests that many respondents are capable of evaluating their desire to telecommute based on quite a realistic comparison of the attributes of the choice alternatives. Yet there is still a potential for error, as some people are acting on hearsay or vague information rather than accurate knowledge.

For this paper, we have adopted the simplest definitions of the dependent variable: the binary preference for, and choice of, telecommuting from home. Telecommuting from home was selected because it has a much higher share, not only of choice but also of preference, compared to telecommuting from a center. In the raw data set, 88.1% of the sample preferred to telecommute from home, compared to 53.0% from a center, and 16.1% chose to telecommute from home, compared to 1.8% from a center. Because it is a more familiar alternative, both in perception and in actual experience, it is expected to be easier to model telecommuting from home than from a center. Other definitions of the dependent variable will be explored in later extensions of this research.

4. CONSTRAINT VARIABLES

4.1 The Role of Constraints

Choice is often constrained due to the presence of factors which eliminate one or more alternatives from the choice set. Constraints have drawn some attention in past research (Brög and Erl, 1981; Burnett, 1980) but seem to have been *understudied* in discrete choice models. **B**i.e. models are often built as though everyone has the same choice set. We attribute significant explanatory power to the understanding of the role constraints play in the choice of telecommuting. We elaborate on two aspects of constraints: first, where in the process constraints are taking effect, and second, the distinction between dichotomous and continuous constraints. In the discussion below, it is convenient to distinguish an individual's "preference set" from his or her "choice set". The choice set, as conventionally defined, includes all alternatives that could be chosen (i.e. perceived as possible) by the individual, regardless of whether they are preferred. The preference set, conversely, contains all alternatives that could be preferred, regardless of whether they are possible.

Constraints enter the process at three points. First, some constraints, namely lack of awareness and misunderstanding, can act as a screening mechanism and eliminate information about viable options for change. This screening takes place outside the internal decision-making process, before preferences have a chance to be formed. For example, telecommuting cannot be considered if the individual is not aware of its availability, or believes one's job is not suitable for it. In this case, the alternative can be neither in the preference nor the choice set.

The second point is when binding constraints eliminate the possibility of translating a preference to an action. This elimination again takes place outside the internal decision-making process, this time occurring after the preference was formed. For example, a person may generate a preference to telecommute, but cannot exercise it because it is not facilitated by the employer. In this case, the alternative is in the preference set but eliminated from the choice set.

Note that the same constraint may be in effect at either end of the preference formation process. The two situations differ in the timing of the information input. A person may not have any information about his or her employer's position, and may thus produce a preference, which only then is subjected to the new information on the unavailability of telecommuting. Alternatively, a person may have *a priori* knowledge about the employer's

position and therefore will eliminate telecommuting as an option in the choice set (although it may still be in the preference set).

Third, the one type of constraint which may enter the preference formation process is an internal constraint. These are rooted in attitudinal and personality attributes, such as lack of self-discipline or a need for boundary setting between work and home. Thus, an individual may indicate that he or she does not want to telecommute because of expected distractions from other household members. In this case, telecommuting may or may not be in the choice set of feasible alternatives (depending on whether external constraints are active or not), but it is not in the preference set. Similarly, for employees with a strong trait of risk aversion, telecommuting may not even be in their preference sets if they know *a priori* that their supervisor would not approve.

The second aspect of constraints requiring discussion is the distinction between dichotomous and continuous effects. Clearly, there are some constraints that in theory are "black or white". That is, their presence eliminates an option from the choice set altogether. If one's job is totally unsuitable to remote work, then this would be a binding constraint. Other constraints may be acting in a continuous fashion. Either the constraint itself may be present in varying degrees, or its presence reduces the propensity to telecommute, but does not preclude it. For example, an organizational or managerial policy toward telecommuting may range from outright prohibition to active support. A position falling between these two extremes may have a non-binding, continuous effect on the choice (as well as the preference) probability.

Identification of discrete active constraints is very important in the context of understanding and predicting telecommuting, as these constraints eliminate the choice of telecommuting altogether. As will be seen below, however, realization of the theory is subject to some measurement error. With regard to continuous constraints, we are not likely to be able to tell for each individual whether those constraints are strong enough to eliminate telecommuting from the choice set; there will be a latent threshold which will vary by individual. Obviously if telecommuting is chosen it *is* in the choice set, but if telecommuting is not chosen it may not be possible to determine if it is in the choice set based on continuous constraints alone. Thus, it is logical to treat telecommuting as if it is in the choice set, but with continuous constraints acting to reduce the probability of choice.

Constraints are in most cases subjective factors, and ideally it would be desirable to identify the individual's perception of constraints. In some cases, a constraint may be perceived as

binding, while for other individuals or situations it can be viewed as a temporary or minor hurdle. For example, telecommuting is sometimes still thought of as a full-time alternative, and based on that misunderstanding it may be entirely precluded for some people but not for others. Alternatively, the cost of buying one's own computer may be prohibitive for some individuals and negligible for others.

4.2 Three Key Dichotomous Constraints

In examining the types of constraints that can potentially inhibit telecommuting, three in particular seem to have a dichotomous aspect to their nature. These are lack of awareness, job unsuitability, and lack of manager support. Other constraints identified in Mokhtarian and Salomon (1994) — misunderstanding, lack of organization support, technology unavailability, and cost — can be viewed as continuous in nature. The first three also have a continuous aspect; for example, varying proportions of a job may be unsuitable for telecommuting, making it proportionately less likely that telecommuting will be chosen (or reducing its frequency). But for these three factors, in contrast to the others, the threshold points at which they are unequivocally active are in theory readily identifiable.

Accordingly, we discuss in this section the operationalization of these three constraints and the degree to which they appear to be present in our sample. First, consider the operational definitions of each measure in turn.

1. **Lack of awareness:** This variable was operationalized most simply of the three. The first question on the survey asked, "Had you heard of telecommuting before receiving this survey?" We define the binary variable UNAWARE to be equal to unity if this question elicited a negative answer.
2. **Job unsuitability:** The survey contained four indicators of job unsuitability. One question asked, "Based only on the characteristics of your job, can *any* part of your job be done from home?" (As the latter qualification indicates, job unsuitability is one factor on which measurements may vary depending on whether telecommuting from home or from a center is the focus. That is, some jobs, such as those requiring specialized equipment or strict security, may be suitable for telecommuting from a center but not from home). Another question asked, "Considering the characteristics of your current job, how much do you think the nature of your job would allow you to telecommute from home?" Possible responses included "not at all", five categories of increasing frequency, and "occasional partial days". The final indicators of job

unsuitability were responses of "My job is not suitable" or "My present work responsibilities don't permit it" to the question, "If you are not currently telecommuting, why not?" The latter case presumably represents a more temporary situation than the former, but can still effectively preclude the choice to telecommute at the time the respondent was surveyed. The binary variable JOBCONST was set equal to unity if either the first indicator was "no", the second one was "not at all", or either of the last two were active.

3. **Lack of manager support:** Similarly, there were three indicators of lack of manager support for telecommuting. One question asked, "Considering the characteristics of your current supervisor, how much do you think your supervisor would let you telecommute from home?" The potential responses are the same categories as for the second indicator of job unsuitability discussed above. The other two indicators were responses to the question, "If you are not currently telecommuting, why not?" of either, "I have discussed it with my supervisor, and s/he will not (yet) allow it" or "I have *not* discussed it with my supervisor, but I don't think s/he will permit it". In the latter case, the assumption is that the respondent's perception of manager disapproval is just as relevant to choice as actual evidence of that disapproval. The binary variable MANCONST was set equal to unity if the response to the first question was "not at all" or if either of the other two indicators were active.

These three dichotomous constraint variables (and their constituent indicators) were tabulated against the choice variable (defined as the binary variable which is set equal to one if the individual gave any response other than "not at all" to the question, "How much do you currently telecommute from home?"). Doing this made apparent some logical inconsistencies in the data. Among the 101 respondents identifying themselves as currently telecommuting, nearly one-third of them (29) allegedly had one or more constraints in effect: 3 were measured as not aware, 15 had unsuitable jobs, and 17 had unwilling managers.

There are several possible explanations for these anomalous results, including the simplest one of data entry error. The error could lie in the measurement of the choice variable: respondents could be telecommuting very infrequently or view themselves as currently telecommuting even though they hadn't been able to do so for some time due to job or manager constraints, or it could be a "wishful thinking" misreading of the question **B** that is a response to how much they would currently *like to be* telecommuting even though they were not able to. They may be answering the "If you are not currently telecommuting, why not?" question in terms of why they are not telecommuting *as much as they would like to be*. It

is conceivable that some respondents were telecommuting without knowing to call it that (indicating that they had never heard of telecommuting) until being sensitized by completing our survey. It is also possible that some respondents were telecommuting without their supervisors' knowledge or consent. Finally, the existence of respondents providing frivolous or deliberately inconsistent answers cannot be dismissed.

For each inconsistent response on these and other potential constraint variables, the original survey was manually examined. The above considerations led us in 19 cases (including four in which none of the three dichotomous constraints were active) to recode the choice variable from one to zero, that is to conclude that the respondent was not, in fact, currently telecommuting (a few data entry errors in the choice variable had also been found and corrected before performing the tabulations described above). Most of those 19 individuals identified themselves as telecommuting either "less than once a month" or on "occasional partial days".

In the remaining cases, the evidence was inconclusive. There was reason to believe the respondents were telecommuting (with self-reported frequencies of "about 1 - 3 days a month" or higher), but not as often as they would like. The data in these cases were left unchanged, on the belief that such information could be important to a model of telecommuting *frequency* (the multinomial dependent variable described in Section 3). As a result, there are still a few seemingly inconsistent cases in Table 2, which summarizes the tabulation of the recoded choice variable against all three dichotomous constraints. These responses, and the original ones, are useful reminders that self-reported data such as these cannot be taken completely at face value.

In discussing Table 2, it is important to remember that this sample is not representative of the workforce as a whole, and thus the proportions given here cannot be expected to hold precisely in a more random sample. However, the empirical results are of intrinsic interest for this relatively large and diverse sample.

Perhaps not surprisingly, lack of awareness is the weakest of the three dichotomous constraints, in force for only 4.3% of the sample (combining the U, UJ, UM, and UJM categories in Table 2). Lack of awareness is the simplest constraint to overcome, and (unlike either of the other constraints) its removal is a necessary condition for telecommuting to be in the preference set. However, for more than three-quarters of that group, other constraints are also active. That is, lack of awareness is the *sole* constraint for only one percent of the sample.

Table 2
The Extent to Which Each Dichotomous Constraint is Active

Active Constraints*	Non-choosers	Choosers	Total Sample
U only	5 (0.8%)	1 (0.2%)	6 (1.0%)
J only	92 (14.6%)	7 (1.1%)	99 (15.8%)
M only	138 (22.0%)	4 (0.6%)	142 (22.6%)
U and J	3 (0.5%)	--	3 (0.5%)
U and M	3 (0.5%)	1 (0.2%)	4 (0.6%)
J and M	156 (24.8%)	1 (0.2%)	157 (25.0%)
U, J, and M	14 (2.2%)	--	14 (2.2%)
none	135 (21.5%)	68 (10.8%)	203 (32.3%)
Total	546 (86.9%)	82 (13.1%)	628 (100.0%)
* U = Unaware, J = Job unsuitable, M = Manager disapproval			

Job unsuitability is the next strongest constraint of the three, present for 43.5% of the sample. This seems notably high, considering that the sample is predominantly composed of information workers, who are often casually assumed to constitute the universe of potential telecommuters. This finding suggests that using "information worker" status as an indicator of job suitability may seriously overestimate the potential for telecommuting. In the short term the job suitability constraint is difficult to remove. In the medium term a highly-motivated individual can address this constraint by changing to a more suitable job. However in the longer term, it is expected that many currently location-dependent jobs will be partially or completely replaced by automation, and that more and more of the remaining jobs will come to rely on telecommunications and computer technology to the extent that some portion of them will be telecommutable.

It is again perhaps not surprising that manager unwillingness is the strongest of the three dichotomous constraints, active for fully half (50.5%) of the entire sample. It is often remarked that management resistance is the biggest barrier to increasing telecommuting (Gordon and Kelly, 1986; Olson, 1988). Conceptually, JOBCONST and MANCONST should be correlated to some extent — that is, the manager may be unwilling *because* the job is unsuitable. But empirically, that correlation is relatively small at 0.21 (albeit significant at the 0.001 level), and for nearly a quarter (23.2%) of the sample, the manager constraint is present in the absence of the job constraint. Practitioners note that overcoming this barrier continues to be difficult, although visible progress is occurring.

Finally, for 32.3% of the sample, none of these three constraints are active. That is, they are aware, their jobs are suitable (to some degree), and their managers are willing (to some degree). Other than the few inconsistent cases previously mentioned, these are the only people who have the choice to telecommute. Interestingly, of those who apparently have a choice, only one-third (68 out of 203) actually choose to telecommute. For some of those who do not telecommute, continuous constraints are lowering the propensity to choose past the latent threshold. The rest simply do not want to telecommute. These groups will be discussed further in the next section.

5. PREFERENCE, CHOICE, AND POSSIBILITY

5.1 Classification of the Sample by These Three Dimensions

Studies of telecommuting (Salomon, 1986; Olson, 1988; Gold, 1991; Christensen, 1988) have criticized the wide gap between forecasts which have suggested wide scale adoption of this option (such as Nilles, 1988 and Boghani, *et al.*, 1991) and the actual low adoption rates experienced to date. It seems that telecommuting is perceived as a very attractive option to many individuals, at least at first sight, but that in practice, a series of constraints, both external and internal to the individual, coupled with the effects of various drives, account for these wide gaps.

In our sample, in response to the question "Assuming that there are no work related constraints, how much would you like to telecommute?", 88.1% of the respondents indicated a desire to telecommute at least some amount from home. However, in the sample as a whole (after the recoding discussed above) only 13.1% are currently telecommuting some amount from home. In the context of choice theory, we suggest that this wide

gap is a result of the existence of a "preferred impossible alternative" **B** that is an alternative which is in the preference set and is actually preferred, but which is not in the choice set.

In this study, we are focusing on the investigation of the discrepancy between preference and choice and we attempt to quantify the contribution of both dichotomous and continuous constraints to that discrepancy. Three key dichotomous constraints were identified above. In the discussion that follows, telecommuting is considered to be not possible **B** that is, not in the choice set **B** for an individual if any of those constraints are active for him or her. If none of them are active, telecommuting is considered to be possible (in the choice set), in which case continuous constraints are able to act to affect the probability of choosing that alternative.

Table 3 tabulates the various combinations of preference, choice and possibility in our sample. Cells 1 through 4 represent feasible choice situations, while cells 5 through 8 indicate impossible choices. As seen here and from Table 2, telecommuting is not possible for a full two-thirds (68%) of the sample. Cells 5 and 7 are theoretically empty sets, since an impossible alternative cannot be chosen. Nevertheless, due to measurement error of some kind, 2.2% of the sample falls into cell 5, as discussed in Section 4.2. Importantly, however, an alternative which is not feasible due to active dichotomous constraints may still be preferred, as represented by cell 6. We refer to this case as the Preferred Impossible Alternative (PIA); it constitutes by far the largest group of people in the sample (57%). Cell 8 represents those cases for whom telecommuting is neither possible nor desired (9% of the sample).

Cells 1 (11%) and 4 (3%) represent the straightforward situations in which a possible alternative is preferred and chosen or not preferred and not chosen, respectively. Cell 3 represents the case in which telecommuting is not preferred but chosen anyway **B** that is, the case in which an employee is required to telecommute involuntarily. This is the case in some companies for sales and other field workers (Pacelle, 1993; Shellenbarger, 1994), but does not apply to our sample and is not of primary interest in this research. Cell 2 (18%) involves a situation in which telecommuting is possible (considering only the dichotomous constraints) and preferred but not chosen. This occurs when some constraint, possibly temporary, reduces the propensity to telecommute.

Conventional choice models have typically focused on choice without regard to the intermediate preference formation stage. Further, they often do not address the issue of availability of alternatives. Such models would in effect be analyzing the difference

between respondents falling in cells 1, 3, 5, and 7 combined, and those in cells 2, 4, 6, and 8 combined. It is obvious that such a practice will introduce a great deal of imprecision into the results, since the unmeasured possibility and preference factors clearly affect choice. When a stated preference approach is used to model the acceptance of hypothetical new alternatives (as in the case of new technologies), cells 6 and 8 are the focus. As mentioned above, telecommuting falls in between the case in which an alternative may be assumed to be universally available and that in which an alternative is purely hypothetical.

Table 3
The Relationships among Preference, Choice and Possibility

Preferred	Chosen	Possible	
		Yes 203 (32.3%)	No 425 (67.7%)
Yes 553 (88.1%)	Yes 82 (13.1%)	1 Possible, desired, and chosen 68 (10.8%)	5 Theoretically empty 14 (2.2%)
	No 471 (75.0%)	2 Continuous con- straints active 116 (18.5%)	6 Preferred Impossible Alternative 355 (56.5%)
No 75 (11.9%)	Yes 0 (0.0%)	3 Involuntary telecommuting 0 (0.0%)	7 Theoretically empty 0 (0.0%)
	No 75 (11.9%)	4 Not-preferred available alternative 19 (3.0%)	8 Neither possible nor desired 56 (8.9%)

5.2 Who Prefers to Telecommute?

Twelve percent of the sample did not want to telecommute. It can be noted that for three-quarters of those cases (56 out of 75), telecommuting was not possible anyway. Only for the 19 people in cell 4 was telecommuting possible but not desired. Another way to look at cell 4 is in the context of the column of cells for which telecommuting is possible. The 203 people for whom telecommuting was possible (based on the dichotomous constraints alone) can be divided into three groups: those who wanted and chose to telecommute

(33%), those who wanted to telecommute but still did not do so because of continuous constraints (57%), and those who did not want to telecommute (9%).

Thus, cell 4 contains those individuals for whom telecommuting is a not-preferred available alternative. These people are of interest because of the often implicit assumption that telecommuting is so attractive that (nearly) everyone will want to do it. Our sample appears to confirm that assumption, given that only 3% of it falls into cell 4. Here the self-selection bias in the sample is important, however: those who are not interested in telecommuting would be much less likely to return the survey. Therefore, this group of people will be larger in the population as a whole, by an unknown amount. Even if telecommuting becomes widely supported, then, there could still be a significant number of people who decline the option. For forecasting purposes, it is necessary to identify what motivates their preferences. This is where the presence or absence of drives comes into play, which will be explored more fully in other papers in this series.

There is reason to believe that desiring to telecommute may be associated with various socio-demographic and economic characteristics. We tested the hypotheses that preferrers differ from non-preferrers on several of these traits. T-tests performed to examine differences between these groups with regard to mean commute distance found that preferrers had a longer trip (13.2 miles vs. 10.4 miles, $p = 0.002$). But, no significant difference was found for mean household size (2.6 for preferrers; 2.7 for non-preferrers) or for the mean number of vehicles per driver (1.0 for both groups). For categorical variables, using χ^2 tests we found that age and gender were significantly different between groups. Preferrers were younger on average than non-preferrers ($p = 0.00002$), with mean ages of 38 and 44, respectively (estimated from the midpoint of the age category checked by each respondent). As for gender, although high proportions of both sexes preferred to telecommute, more women (92%) wanted to than men (83%, $p = 0.00077$). The presence of children or someone else who needs special care, education, occupation and income were not significantly different between preferrers and non-preferrers. These findings lead us to suggest that conventional socio-demographic and economic characteristics are not important factors in telecommuting preference with the exception of gender, age, and commute length. However, it must be borne in mind that the sample is not representative of the entire population, in which some of these other factors can be of significance.

The fact that commute distance is important in forming the preference is consistent with the hypothesis that travel costs are an important drive for telecommuting. The preference of women for telecommuting can be interpreted in a number of ways. First, women are more

likely to be burdened by both household and job responsibilities than men. Hence they experience a more severe "time-space" pressure which leads them to be more sensitive to travel costs. Thus, this is another form of the travel drive mentioned above. However, women may also believe that telecommuting from home offers them a desired solution for simultaneously caring for household needs while being able to participate in the paid labor market. Although this belief is disputed (Shamir and Salomon, 1985), some women may adhere to it.

5.3 Why Aren't Preferrers Always Choosers?

The empirical data in the individual cells of Table 3 can be combined in other interesting ways. For example, only 82 (15%) of the 553 people who prefer to telecommute actually choose to do so. For the 471 people who want to telecommute but do not do so, one or more of the dichotomous constraints is present in 355 (75%) of those cases, whereas active continuous constraints are the reason in the remaining 116 (25%) cases. Those 116 people in cell 2 are an important reminder that even if key active constraints are removed, not everyone who wants to telecommute will be able to. Comparing cells 1 and 2 indicates that even when telecommuting is both possible (according to the dichotomous constraints) and preferred, it is still only chosen less than half the time (68 out of 184 times, or 37%).

As almost one fifth of the sample belongs to the cell 2 group, for whom choice of telecommuting seems to be likely (preferrers who do not have an active dichotomous constraint), we examined the reasons they gave for not telecommuting. In response to the question, "Why aren't you currently telecommuting?", five reasons were checked off or written in as most important by 82% of the 116 people in this group. First, the lack of resources was cited as being most important by 33 individuals (28%). Second, 24 individuals (21%) mentioned as the most important reason the simple fact that they have never really thought about it. Given that they were aware of telecommuting, we suggest that these individuals are content with their present situation and thus do not have a drive to engage in or even consider telecommuting. Some 15 individuals (13%) indicated as the most important reason for not telecommuting the fact that it was not offered to them or discussed with them. This may be a situation similar to the previous one, where the individual "waits" for an offer but her or his situation does not activate an initiation. Another major reason, cited by 14 individuals (12%), was that the disadvantages of telecommuting outweigh the advantages. This could either represent a situation in which the barriers to telecommuting are primarily internal rather than external, or one in which, although none of the specific reasons listed is singlehandedly responsible for a choice not to telecommute, the totality of

reasons still serves as an impediment. Last of the major reasons mentioned was cost: nine people (8%) mentioned that it would cost them too much to telecommute.

Although a respondent can be classified unambiguously as belonging to cell 1 or 2 after the choice is revealed, a model predicting choice would place respondents on a continuum between the two cells based on the estimated probability of choice as a function of continuous constraints. To accurately predict choice, the model must be well-specified, both in terms of containing the right explanatory variables measured in the right way and having the proper choice set associated with each individual.

Similarly, it is of interest to know what would happen to the large PIA group if the dichotomous constraints were relaxed. In that case, the respondents in cell 6 would move either to cell 1 if telecommuting is chosen, or cell 2 if telecommuting is still not chosen. To understand which factors affect the decision and to forecast how many will adopt telecommuting, it is necessary to develop behavioral models of telecommuting choice.

5.4 Potential Impacts of Self-Selection and Sampling Bias

The impact of self-selection bias on these empirical results was briefly alluded to in Section 5.2, and it is worth elaborating further here. Arguably, the people most likely to return the survey are those who are frustrated in some way **B**either in their desire to telecommute (that is, those in cells 6 **B**the PIA group **B**and 2) or in their desire *not* to telecommute (the involuntary telecommuters of cell 3). Those next most likely to return the survey are those who are telecommuting and therefore interested in the subject (cell 1). Those least likely to return the survey are those who have no interest in telecommuting, especially those for whom it is not even possible (cells 8 and 4).

Interestingly, except for cell 3 (and ignoring the anomalous cell 5), this is exactly the ranking of the actual number of responses received (i.e. from the most in cell 6 to the least in cell 4). This could be purely coincidental, however, as propensity to return the survey and relative population share are two independent dimensions. Unfortunately, we have no way of knowing what the actual proportions of these groups in the population are: they may be in the same order as we observe here, or in an entirely different order. All we can say with relative certainty is that cells 6 and 2 overrepresent the population to some degree, and that cells 8 and 4 underrepresent the population to some degree. (Cell 3 is presumably a roughly accurate representation of this group in the sampling frame, but the sampling

frame probably contained few if any involuntary telecommuters, and thus this group is also underrepresented compared to the population as a whole).

Thus, for cells 1, 2, and 6, the observed proportions are likely to be upper bounds for the true proportions in the population, whereas for cells 4 and 8, the observed proportions are likely to be lower bounds. One way to estimate opposite bounds for these groups is to make the worst case assumption that all 56% of the non-respondents to the survey fall into cells 4 and 8, according to the proportions in our sample (i.e. 19/75 in cell 4 and 56/75 in cell 8). Recalculating the proportions in Table 3 under that assumption leads to the estimated ranges shown in Table 4.

Table 4
Estimated Population Ranges
(Correcting for Self-Selection but Not Sampling Bias) *

Preferred	Chosen	Possible	
		Yes (28.5 - 32.3%)	No (67.7 - 71.5%)
Yes (39.1 - 88.1%)	Yes (5.8 - 13.1%)	1 Possible, desired, and chosen (4.8 - 10.8%)	5 Theoretically empty (1.0 - 2.2%)
	No (33.3 - 75.0%)	2 Continuous constraints active (8.2 - 18.5%)	6 Preferred Impossible Alternative (25.1 - 56.5%)
No (11.9 - 60.9%)	Yes (0.0 - 0.0%)	3 Involuntary telecommuting (0.0 - 0.0%)	7 Theoretically empty (0.0 - 0.0%)
	No (11.9 - 60.9%)	4 Not-preferred available alternative (3.0 - 15.5%)	8 Neither possible nor desired (8.9 - 45.5%)

* Numbers in bold-face type are derived from the sample data, as shown in Table 3. Numbers in italics are based on the worst-case assumption that all non-respondents fall into the lower half of the table (i.e. do not want to telecommute) in the same proportions as in Table 3.

Interestingly, the estimated lower bound for those choosing to telecommute is 5.8%, which is close to the estimated proportion of 6.1% telecommuters in the State of California in 1991 (Handy and Mokhtarian, 1995). This lends some credence to the recalculation described above. Under this redistribution, the size of the PIA group falls to 25.1%, which is still the second largest group after those for whom telecommuting is neither possible nor desired (now at 45.5%). The not-preferred available alternative group is the next largest at 15.5%, and the group for whom continuous constraints keep the telecommuting preference from being exercised constitutes 8.2%. Of the three primary dimensions of the table (possibility, preference, and choice), preference is (by design) most affected, falling to 39.1% under the redistribution.

All of these estimates appear to be quite plausible. Two points should be emphasized, however. First, these are conservative estimates of the group sizes within the sampled population, since some of the non-respondents will in fact fall into the top half of the table **B** increasing the proportions there and decreasing them in the bottom half. For example, the proportion of choosers is likely to be higher in the City of San Diego in the survey year of 1992 than the 6.1% estimated for California as a whole in 1991. If the involuntary telecommuters that are in the population but not in the sample were accounted for, the percentages of all other groups would decline slightly. But the proportion of the population *presently* falling into this category is doubtless quite small (although growing), and therefore would have a negligible effect on the estimated ranges for the other groups.

The second point to emphasize, however, is that these are estimates only of relative group sizes within the population determined by the sampling frame **B** that is, the population of the six City departments sampled. The extent to which these six departments reflect the entire population of workers is unknown: several factors are at work, some operating in conflicting directions. For example, public agencies are more likely to support telecommuting than private companies (because of public policy considerations), so the fact that our subject employer is a city government may bias the manager support variable upward. On the other hand, larger organizations are less likely to permit telecommuting than smaller ones (because of greater flexibility, competitiveness, and risk-taking among smaller firms), so the fact that our subject is a large employer may bias manager support downward (even though the City nominally supports telecommuting, there was ample anecdotal evidence in the open-ended comments of the respondents that such support was not ubiquitous among individual managers within the City). In any case, given the City's verbal support of telecommuting and the preponderance of information workers in the sample, people who are aware of telecommuting and who have suitable jobs are probably

overrepresented. All things considered, then, telecommuting is probably only possible for no more than a quarter of the workforce at present.

6. SUMMARY AND NEXT STEPS

A conceptual model of the choice to telecommute was advanced in an earlier paper. In this paper, we have presented empirical data from a non-representative sample of 628 City of San Diego employees on key variables and relationships in that model. Dichotomous and continuous constraints were distinguished, and three dichotomous constraints were defined. Lack of awareness was present for 4%, job unsuitability for 44%, and manager disapproval for 51% of the sample. For 68% of the sample, at least one of these constraints was active.

The relationships among possibility, preference, and choice were examined. A key finding is the existence of a large group of people (57% of the sample) for whom telecommuting is a Preferred Impossible Alternative. The high proportion of people desiring to telecommute may be a result of the novelty of this work arrangement, perceived to offer new, high-tech solutions for day-to-day problems. Even among those for whom none of the dichotomous constraints is active, most people do not choose telecommuting due to the presence of active continuous constraints. For only 11% of the entire sample, telecommuting is possible, preferred, and chosen. This is 33% of the subsample for which telecommuting is possible.

An effort was made to estimate the impacts of self-selection bias on the empirical results observed in our sample. Combining the observed results with the conservative assumption that all non-respondents did not prefer telecommuting permitted the calculation of likely upper and lower bounds on the true proportions in each possibility - preference - choice combination. If the conservative assumption is correct, the size of the PIA group falls to 25.1%, which is still the second largest group after those for whom telecommuting is neither possible nor desired (now at 45.5%). The not-preferred available alternative group is the next largest at 15.5%, and the group for whom continuous constraints keep the telecommuting preference from being exercised constitutes 8.2%. Of the three dimensions of the table, preference is most affected, falling to 39.1% under the redistribution compared to 88.1% in the sample.

Although it was not possible to quantify the sampling bias (that is, the degree to which the sampled population of six City departments fails to reflect the workforce as a whole), the sample is likely to underrepresent people for whom lack of awareness and/or job unsuita-

bility constraints are active. Further, the fact that even within our predominantly information-worker sample 44% considered their jobs unsuitable for telecommuting (at least temporarily) suggests that using "information worker" status as an indication of job suitability may lead to serious overestimation of the potential for telecommuting. Taking all three dichotomous constraints into account, telecommuting is probably only possible for at most one-fourth of the workforce at present.

The next stage in the modeling process is to continue to operationalize key variables, especially drives and continuous constraints. Two sections of the survey contained attitudinal questions which were intended to capture various aspects of the conceptually identified drives and constraints. These questions will be factor-analyzed to reduce a large number of interrelated attributes to a more parsimonious and independent set of dimensions. Other measures of drives and constraints will be formed from socioeconomic and other objective characteristics. These measures will then be incorporated into models of the binary preference and choice of telecommuting from home, and the variables which significantly contribute to explaining those preferences and choices will be analyzed.

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