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Duration and frequency of telecenter use: once a telecommuter, always a telecommuter?

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Abstract

The study of temporal patterns of telecommuting is essential in understanding the adoption of telecommuting and, hence, the impacts of telecommuting on the demand for equipment and services as well as the demand for travel. This research examines, in the context of center-based telecommuting, how often individuals telecommute, the duration of their telecommuting participation, and causes of attrition among telecommuters. It also presents related findings from previous studies of home-based telecommuting. Attrition at the telecenters studied was relatively high, with 50% of all telecommuters quitting within the first 9 months. The average telecommuting frequency across the sample was 22% or about 1.1 days per week. Nearly 64% of the participants telecommuted less than 1 day per week on average. The relationship between frequency and duration appears to be complex, with partially counteracting trends. The results suggest that there is a stable segment of the sample (stayers) who are committed higher-frequency telecommuters, but that within the segment having a propensity to quit, there is a slight but statistically significant tendency for higher-frequency telecommuters to quit sooner. The motivations of participants for quitting the program were investigated. The most frequent type of reason given was job-related (cited by more than a third of all quitters). Other important reasons were supervisor-related (16%) and closure of the center (12%). No one cited dissatisfaction with telecommuting as a reason for quitting, and most quitters expressed a desire to continue telecommuting from the center. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: Telecommuting; Telecommuting center; Transportation demand management; Survival theory; Response bias.

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1. Introduction

Many studies have examined attitudes toward telecommuting (DeSanctis, 1984; Duxbury et al., 1987), preference for telecommuting (Bagley and Mokhtarian, 1997; Mokhtarian and Salomon, 1997; Stanek and Mokhtarian, 1998), choice of telecommuting (Bernardino et al., 1993; Mahmassani et al., 1993; Mokhtarian and Salomon, 1996b), and characteristics of telecommuters (Yap and Tng, 1990; Hartman et al., 1991). To date, however, perhaps no studies have attempted empirically to explore temporal patterns of telecommuting behavior in detail (Fireman, 1998, has developed a conceptual approach which is currently being operationalized). Factors of primary interest include how often individuals telecommute, the duration of their telecommuting participation, and causes of attrition among telecommuters.

The study of telecommuting duration and frequency is fundamentally important to our understanding of the adoption of telecommuting and, hence, the impacts of telecommuting—on the demand for equipment and services, and on the demand for travel and related issues. We may perfectly predict that a certain group of individuals will telecommute. But if we falsely assume that they will telecommute in perpetuity (when in fact they, say, telecommute in a 1-year-on, 2-years-off cycle), and/or if we assume that they will telecommute (hypothetically) one day per week when the average is close to once every 2 weeks, we will greatly overestimate the number of people telecommuting on any given day, and therefore the travel–related and other impacts of that number of people telecommuting overall.

Predicting telecommuting duration will require a knowledge of causes for attrition from telecommuting programs. Apparently very few organized programs examine attrition carefully; certainly attrition rates are seldom presented in evaluation reports, or causes of attrition addressed if such rates are presented. Thus, while the specific people who participate in a pilot program (at least long enough to complete 'after' surveys) are studied in depth, those who drop out along the way are not always captured in the evaluation. It is even more uncommon to go back a year after the pilot and count how many of the original participants are still telecommuting after the spotlight is turned off. To argue that dropouts are replaced by an equal or larger number of new entrants misses the point. Both the dropouts and their replacements can be correctly forecast to be telecommuters, but only through a knowledge of the dynamics of telecommuting patterns can it be estimated how many of those former, present, and eventual telecommuters will be engaged in the practice at the same time.

Perhaps one reason that attrition is understudied is that it presents several measurement difficulties. Is someone who enrolls in a telecommuting program, attends a training session, and/or completes a 'before' survey but never begins to telecommute considered a dropout? Whether yes or no, it is obviously desirable to know if a sizable proportion of those who imply by such strong indications that they want to telecommute in fact do not *choose* to (whether voluntarily or because of external constraints).

Another problem relates to the phased entry of participants. When provided at all, measures of attrition and its opposite, retention, are generally presented as the proportion of participants who have left (or remain in) the program as of a certain calendar date, say one year after the start of the program. But some participants will have joined at the very beginning, whereas others will have entered 3 or 6 months later. An early joiner who has had the opportunity to telecommute for a year but who leaves after 9 months will be counted as a dropout, whereas a late joiner who

has only had the opportunity to telecommute 6 months (and who will drop out the month after the measurement is taken) will be considered a 'stayer'. Measures of retention can be distorted by the relative proportions of early versus late entrants.

Finally, in terms of measuring the related indicator of telecommuting duration, even if everyone started telecommuting simultaneously, or if duration were measured from each person's start date instead of from a single calendar date, the problem of right-censored data would remain. That is, at the point of measurement, duration cannot be captured for those who are still telecommuting; it can only be inferred that duration exceeds the currently-measured length of time. Thus, measurement of duration is always a 'moving target'.

2. Attrition in previous studies of home-based telecommuting

With these caveats in mind, it is instructive to review some evaluation reports which do treat attrition in some detail. Table 1 compares the attrition findings from three telecommuting programs undertaken in the late 1980s and early 1990s. All three programs focused on home–based telecommuting. However, it should be noted that in the State of California project, some of the original recruits were considered by the consultant to be suitable only for center-based telecommuting, and that alternative did not materialize as planned during the demonstration project. This may have influenced the number who were selected but never trained. Also, a very small number of participants in the Puget Sound (Seattle, WA area) project telecommuted from a center.

The following facts can be inferred from Table 1. As few as 17% (Puget Sound) and as many as 53% (State of California) of people originally selected to participate (generally meaning that the person volunteered, that the manager agreed the employee was suitable, and that both employee and manager completed background surveys) failed to start telecommuting. The City of Los Angeles falls in the middle at 38%, and since the Puget Sound proportion is conservative (due to incomplete reporting) and the State of California proportion is high (since a number of people were selected only for center-based telecommuting), Los Angeles may be the most typical of the three. Thus, perhaps a third of would-be telecommuters drop out before they even start.

Of those who were trained and started telecommuting, the percentage who were still telecommuting at the end of the two-year pilot was fairly stable at 61–68% across the three studies. Those rates represent 32 and 38% of the original selected totals for the two California studies, and 66% for the Puget Sound study. Thus, attrition can be conservatively estimated to run 32–41% (based only on those who actually start telecommuting), and liberally estimated (based on all who were originally selected) at 40–68% (where 40% represents the higher value for Puget Sound indicated in footnote 9 of Table 1) across the studies.

Additional evidence on attrition from home-based telecommuting is available through new analysis of the data collected for another study directed by the fourth author of this paper. That dataset contains survey responses for 628 employees of the City of San Diego, 90 employees of the California Franchise Tax Board, and 90 employees of the California Public Utilities Commission (for other analyses of this data, see Mokhtarian and Salomon, 1996a,b, 1997; and Mokhtarian et al., 1996a). It is possible that some of the respondents in the latter two groups are also respondents to the evaluation of the State of California program portrayed in Table 1.

Of those 808 cases, 100 indicated that they had telecommuted in the past but stopped. More than half (54%) of those 100, however, were currently telecommuting, meaning that they had started again sometime after stopping. Examined from the other direction, 54 (30%) of the 180 current telecommuters in the sample had stopped telecommuting at some previous point and started again. However, these results are subject to selection bias in that those who stopped telecommuting permanently (or at least were not doing so at the time of the survey) would be less likely to respond to a survey on telecommuting than those who were currently doing so. Thus, 54% may overstate the population proportion of those who start telecommuting again after stopping.

Table 1
Attrition findings from three home-based telecommuting studies

	State of California 2 years (1988–1989)[a]			City of Los Angeles 2 years (1991–1993)[b]			Puget Sound 2 years (1990–1992)[c]		
	No.	% of selected	% of subtotal	No.	% of selected	% of subtotal	No.	% of selected	% of subtotal
Selected	330[d]	100		541	100		286	100	
Never trained	167	51		100	18		NR[g]		
Trained but never started	8[e]	2		109	20		NR[h]		
Trained and started	155	47	100	332[f]	62	100	NR		
Continued	106	32	68	203	38	61	190[i]	66	
Quit	49	15	32	135	25	41	96[j]	34	
Reasons for quitting (no. and % of all quitters)									
Job change	30		61	85		63			30
Voluntary	13		27	13		10			8
Manager	–			37		27			–
Equipment	–			–					17
Office problems	–			–					15
Personal absence	–			–					11
Non-participant in research	–			–					13
Other/unspecified	6		12	–					6

[a] Source: JALA Associates (1990).
[b] Source: JALA International (1993).
[c] Source: Ulberg et al. (1993).
[d] An average of 329 (Table 2 of JALA) and 331 (Table 3).
[e] Inferred.
[f] Sub-categories of 'trained but never started' and other reasons for quitting sum to 447 instead of 441, suggesting some double-counting of reasons for quitting.
[g] Not reported.
[h] Not reported separately; it was stated that some of those classified as dropouts never started. Fifty (17%) of the 286 people originally selected to participate failed to return the first survey and therefore presumably never started, but some of the remaining 236 may also fit that category.
[i] Nine percent (17) of these indicated that they would not continue to telecommute past the end of the pilot. Adding those 17 to the 96 dropouts would give an attrition rate of 40%.
[j] The distribution of reasons for quitting is presumably taken over those dropouts who could be interviewed; the number or proportion of dropouts who were reached is not reported. Hence, we report only the percentages as given in the source, rather than the raw numbers which were not provided.

The average duration of telecommuting for the 100 individuals who had quit was 17.1 months: 15.6 months for those who quit and never started again, and 18.2 months for those who had quit in the past but were currently telecommuting. The reasons given (by all 100) for quitting are shown in Table 2. Almost everyone (94%) quit due to external reasons related to their job (70%), their employer (45%), or both (21%). Only three people quit because of dissatisfaction with telecommuting, and two of those also cited job-related reasons for quitting.

These results confirm that attrition is an extensive enough problem to warrant further study. Whereas at least the little shown in Tables 1 and 2 is known about home-based telecommuting, center-based telecommuting is young enough that nothing at all has yet been reported about temporal patterns of use of that form of telecommuting. This paper takes a first look at the temporal patterns of center-based telecommuting, including attrition, duration, and frequency. The initial analysis presented here is primarily descriptive, which, in this new area of inquiry, both offers a useful contribution in its own right and lays the foundation for more advanced modeling work in the future. The following section describes the data collected for this study. Section 4 offers a disaggregate analysis of telecommuting duration. Section 5 analyzes individual telecommuting frequencies, including a comparison of different measures of frequency taken from different survey instruments. Section 6 examines the causes of attrition among center-based telecommuters. Finally, Section 7 summarizes the key findings of the paper and suggests areas for further research.

3. The research context and data

The context of this study is the Residential Area-Based Offices Project, known informally as the Neighborhood Telecenters Project (NTP), a multi-year program underway at the University

Table 2
Reasons for quitting home-based telecommuting: City of San Diego and State of California data (n = 100)

Reason[a]		Number (same as %)
Any job-related reason		70
Job title changed	[Specific job-related reasons]	20
Job duties changed		36
Need for me to be in the main workplace		37
Didn't have the right equipment or support		14
Any employer-related reason		45
Employer changed	[Specific employer-related reasons]	15
Supervisor changed		13
Supervisor didn't want me to telecommute		27
Situation at home changed		5
Didn't like telecommuting		3
Other[b]		9
No reason given		2

[a] More than one reason could be given.

[b] At least six of these respondents indicated that telecommuting was only intended to be temporary, e.g.: "parental leave ended; returned to work", "requested authorization was for three months only", "was only allowed to while I was ill", "worked at home specifically to get project done".

of California, Davis. This research program is designed to evaluate the effectiveness of telecommuting centers, or telecenters, as an alternative work arrangement and as a transportation demand management strategy. In this study, a telecommuting center is an office facility shared by remotely-supervised staff of multiple employers, generally on a part-time basis. The center is furnished conventionally (with computers, fax, photocopier, conference room, and so on), and is much closer to participants' homes than is their regular workplace. The program has established a total of 15 telecenters (referred to as NTP sites), and evaluation data were collected from an additional five centers (non-NTP sites), all in California. The research presented here is based on the 15 of these 20 centers which had a sufficient length of operation and completeness of reporting to offer usable data. The analysis described in this paper is based on data collected from the opening of each center (ranging from November 1991 to February 1996) through to 30 June 1996.

Four types of survey instruments were developed to measure telecenter use and its effects: an attitudinal survey, a travel diary, an attendance log (sign-in log), and an exit interview. The survey and diary were administered to participants once before and once several months after the start of telecommuting, the sign-in log was used throughout the study period, and the exit interview was conducted when participants left the program. Aspects of the evaluation other than those reported here (e.g. preference models, employee and manager attitudes toward telecommuting, and transportation impacts) are presented in Stanek (1995), Stanek and Mokhtarian (1998), Mokhtarian et al. (1997), Mokhtarian and Varma (1998), Balepur et al. (forthcoming), and Varma (1997). As various related research projects using the same data are still in progress, additional analyses will be forthcoming as well.

The data needed for analyzing the telecommuting patterns of telecenter users were obtained from three sources, namely, attitudinal surveys, sign-in logs and exit interviews. The attitudinal survey is a 16-page questionnaire that asks about participants' characteristics and their attitudes toward telecommuting. Prior to the commencement of telecommuting from the center, the prospective telecenter user completed the before-wave version of the attitudinal survey. Approximately 6 months after the start of telecenter use, the center-based telecommuters were again surveyed. The after-wave version of the attitudinal survey contained some new questions about experiences at the telecommuting center but most other questions did not change from the initial version (see Mokhtarian et al., 1997 for a detailed discussion of the attitudinal survey).

The sign-in logs captured the use of the telecommuting centers on a daily basis. Telecommuters were instructed to make an entry in the attendance log each day they used the telecenter. The entry included date, name, transportation mode used to get to the telecenter, and estimated work time of that day to be spent at various workplaces, including telecenter, main office, home and any other work location.

To the extent participants forgot or declined to sign in on every occasion, these data may somewhat undercount the usage of the telecenter by telecommuters. However, NTP site administrators had an incentive to ensure the most accurate reporting possible, as occupancy levels were calculated based on the sign-in data and each NTP site had a contractual obligation to meet certain occupancy levels. Non-NTP sites did not have the same obligation, and so it is likely that data for those sites are less complete. However, even non-NTP site participants were aware of the demonstration status of the program and of the value to the continuation of the program of documenting as high an occupancy as possible. Thus, it is believed that these data constitute a

relatively complete record of center-based telecommuting occasions by the participants. As such, they offer a unique opportunity to examine temporal patterns in greater depth than has been possible with home-based telecommuting programs, in which occasion-by-occasion data are seldom collected.

Table 3 lists the availability of attendance log data at the 15 telecenters studied. The data comprise more than 10,500 telecommuting occasions, from sites that had been open as little as about 16 weeks and as long as 4.6 years (a median of 74 weeks or 1 year and 5 months) as of 30 June 1996. The proportion of data contributed by each site is a function of (i) the operating length of the center, (ii) the number of telecommuters, and (iii) the frequency of use by each telecommuter. Thus, the activity at the long-standing Ontario site dominates the data set, accounting for more than a third of all occasions registered. Attendance logs for a total of 6 center-months were not available because the site administrators for four centers failed to provide the information. No attempt was made to estimate the number of telecommuting occasions or any of the other information for these months.

Exit interviews were conducted with the participants who were identified as quitters to determine the reason(s) for leaving. The administration of an exit interview was prompted by one of two circumstances. In some cases, participants informed their site administrator of their intention

Table 3
Data availability by site

Site	Start date	End date	Total number of weeks	Total occasions[a] n (%)	Total number of users	Number of workstations
Neighborhood Telecenter Project (NTP) sites						
Coronado	11/01/1993	06/30/1996	138.9	452 (9.3)	17	4
Grass Valley	02/08/1994	06/30/1996	124.7	819 (16.8)	13	6
Anaheim	06/30/1994	03/01/1995	34.9	108 (2.2)	10	15
Vacaville—Alamo	07/01/1994	06/30/1996	104.3	514 (10.6)	29	8
Vacaville—Ulatis	08/01/1994	06/30/1995	47.6	229 (4.7)	27	7
Davis	08/11/1994	01/12/1995	22.0	15 (0.3)	4	10
Chula Vista—H St.	09/19/1994	06/30/1996	92.9	880 (18.1)	19	10
Modesto	10/18/1994	10/27/1995	53.4	262 (5.4)	10	10
Chula Vista—F St.	11/01/1994	06/30/1996	86.7	493 (10.1)	12	8
Ventura Community College	02/01/1995	06/30/1996	73.6	481 (9.9)	11	5
La Mesa	03/07/1995	06/30/1995	16.4	36 (0.7)	5	6
Moorpark Community College	04/17/1995	06/30/1996	62.9	469 (9.6)	6	5
San Juan Capistrano	02/18/1996	06/30/1996	20.5	104 (2.1)	5	10
NTP Total			878.8	4862 (100)	153[b]	104
Non-NTP sites						
Ontario	11/27/1991	06/26/1996	237.0	3644 (63.8)	190	24 (18[c])
Highland	12/08/1992	06/30/1996	185.7	2069 (36.2)	23	6
Non-NTP Total			422.7	5713 (100)	213	30 (24[c])

[a] Denotes total number of person-day telecommuting occasions.

[b] Denotes total number of individuals: 13 telecommuters attended both of the Vacaville telecenters and two telecommuters attended both of the Chula Vista telecenters. They are counted under each site but not double-counted in the total.

[c] Eighteen workstations were available at Ontario after 1 March 1994.

to quit. Other participants were contacted about their project status if they had failed to sign the attendance log for a long period. The interview obtained information primarily about the motivation for quitting and the current preferences for work locations.

The non-NTP sites had been in operation for some time before joining the evaluation program described in this section. Non-NTP site participants who quit telecommuting before the site joined the program will not have completed the attitudinal survey or the exit interview. In addition, a number of participants at both NTP and non-NTP sites either quit before completing an after attitudinal survey, or had not been telecommuting long enough by the cutoff date to receive one. Hence, sample sizes for the other two evaluation instruments used in this paper are considerably smaller than those for the attendance log data: 69 for the (after-wave) attitudinal survey and 114 for the exit interview, compared to a usable sample (see Section 4) of 274 for the sign-in log. No demographic or attitudinal data were available for respondents who were only in the attendance log data base.

4. Telecommuting duration

In this section we examine the length of time over which individuals telecommute from a center, or their telecommuting duration. Telecommuting frequency is analyzed in Section 5. For 30 (19.6%) of the individuals at NTP sites and 62 (29.1%) at non-NTP sites, frequency and duration could not be meaningfully computed. These participants either telecommuted (i) once only (13.7% at NTP sites; 25.4% at non-NTP sites); (ii) twice only, with less than 2 weeks between the two occasions (5.9% at NTP sites; 3.8% at non-NTP sites); or (iii) twice only, with more than a year between the two occasions (one user at a non-NTP site).

Some of these 92 individuals were new entrants to the program who had not had a chance to telecommute more often by the 30 June 1996 cutoff date, and others may have been drop-in users who were not expected to be regular telecommuters. However, at least 20 of these people were registered program participants who dropped out after one or two telecommuting occasions. Participants who quit the program are discussed further in Section 6.

All one-time telecommuters, and the specific two-time telecommuters mentioned above were excluded from the analysis. (Other participants who only telecommuted twice were retained, and will appear with relatively small duration and/or frequency in the subsequent discussion). The remaining 123 telecommuters at NTP sites and 151 individuals at non-NTP sites comprise the primary sample for the study of telecommuting duration and frequency.

In our analysis of telecommuting duration, we assume that there is no missing attendance information, that is, that each telecommuter signed in properly on each telecommuting day. It is also assumed that no left-censoring of the data occurs, that is, that the individual had not been telecommuting (from a center) prior to the first recorded use of the center (many participants did have previous home-based telecommuting experience).

There is a difficulty, however, in similarly assuming that the last attendance date is the day the individual quit telecommuting. If this were the case, all telecommuters would be considered to have quit using the telecenter on or before 30 June 1996 (the cutoff date for data to be included in this study). In reality, of course, some participants will have quit before 30 June and others will not have quit. Since most of the participants did not telecommute every working day, or even

with a constant frequency, it is difficult to determine whether a telecommuter had quit the program or was simply between uses of the telecenter.

Therefore, two decision rules were utilized to identify the status of the telecommuters as either quitters or stayers: one based on the existence of an exit interview and the other based on average length of time between telecommuting occasions. Telecommuters who were known to have stopped telecommuting were asked to participate in an exit interview as part of this project. Those who completed an exit interview were easily identified as quitters. For the rest of the telecenter users, the following rule was devised to define their telecommuting status. If the period of time from the last telecommuting date to the cutoff date (30 June 1996) was more than three times the average length of time between two successive telecommuting occasions for that person, the telecommuter was regarded as a quitter. Otherwise, s/he was a stayer, meaning that the actual exit time-point had not yet been observed for that individual. Thus, the telecommuting durations of stayers are right-censored. Although arbitrary, using three times the average period between telecommuting occasions as the basis for a decision rule is based on the concern that the telecenter users may reduce their telecommuting frequency but still remain in the program. Nevertheless, applying this rule runs some risk of falsely classifying as stayers people who quit telecommuting shortly before 30 June, as well as a risk of misclassification in the opposite direction.

Using both decision rules, 77 (62.6%) of the 123 NTP telecenter users and 131 (86.8%) of the 151 non-NTP users were identified as quitters. Seventy-two of the 208 quitters were identified as such on the basis of the first decision rule, the existence of an exit interview (most non-NTP participants quit before their site joined the evaluation program). Application of the second rule to an interim sample using a 30 June 1995 cutoff date (see Mokhtarian et al., 1996b) was found, one year later, to have correctly classified 93% of the subsample for whom exit interviews were not available.

The definition of telecommuting duration is based on whether the telecommuter is a quitter or stayer. For quitters, the last day of telecommuting is considered to be the date of their final attendance log entry. However, stayers are considered to be telecommuting up to the cutoff date of 30 June 1996 instead of up to the last recorded day of telecommuting. For example, if a stayer's last recorded telecommuting occasion before the cutoff date was on 21 June 1996, the duration is counted from the first telecommuting date to 30 June 1996. In addition, the duration is rounded down to the nearest month. For example, if an individual telecommuted for 3.8 months, s/he is classified as a stayer for the first 3 months and as a quitter for the fourth month.

Participants still telecommuting at the time a center closed are also classified as stayers with censored durations for this analysis. The closure of a center would be outside the control of individual employees and their organizations, and hence models predicting duration as a function of employee and manager characteristics could not be expected to capture that effect. The tabulation of reasons for quitting provided in Section 6, however, includes center closings.

Telecommuting duration here is similar to the survival time of an individual in a conventional medical study: those who quit telecommuting are analogous to the patients who die and the stayers are analogous to those who are still alive at the end of the observation period. The data possess two features which correspond to the typical characteristics of survival data. First, telecommuting duration is not symmetrically distributed: some telecenter users quit within a very short time but some continue to telecommute for more than 3 years (at non-NTP sites). Second, as discussed above, the telecommuting duration is frequently right-censored.

A basic element in the analysis of duration times is the survival function. The following discussion relies on the model formulation found in Miller (1981), Cox and Oakes (1984), and Collett (1994). In our context, the survival function is defined as the proportion of telecenter users telecommuting beyond time t:

$$\hat{S}(t) = \frac{\text{number of telecenter users telecommuting longer than } t \text{ months}}{\text{total number of telecenter users}}.$$

Suppose that there are n telecommuters for whom telecommuting durations or exit times $t_1, t_2, \ldots, t_n$ are observed. Some of these observations are right-censored, and there is also more than one telecommuter with the same observed exit time. Therefore, suppose there are r distinct exit times among the individuals, where $r \leqslant n$. Then these exit times are arranged in ascending order: $t_{(1)} < t_{(2)} < \ldots < t_{(r)}$. The probability of surviving at a specific time $t_{(j)}$ given that the individual has already survived past time $t_{(j-1)}$ could be estimated as

$$P\left(t_{(j)}\right) = \text{Prob}\left(T \geqslant t_{(j)} | T \geqslant t_{(j-1)}\right) = \frac{n_j - q_j}{n_j}$$

where T is the observed telecommuting duration, n_j is the number of individuals who were still telecommuting just before $t_{(j)}$ and q_j is the number of individuals who quit in the time interval $\left[t_{(j)}, t_{(j+1)}\right)$. The number of telecommuters n_j is governed by the equation

$$n_j = n_{j-1} - q_{j-1} - c_{j-1}$$

where c_{j-1} is the number of censored observations in the time interval $\left[t_{(j-1)}, t_{(j)}\right)$. The status of observations that are censored at time $t_{(j-1)}$ cannot be determined for later times, and hence these censored observations must be removed from the number of people n_j known to be telecommuting at times $t_{(j)}$ and later.

Suppose the exit times of telecommuters are assumed to occur independently. A series of time intervals can be constructed based on the observed exit times of the telecommuters. The cumulative probability of surviving beyond the kth exit time is the product of these k interval-specific survival probabilities:

$$\hat{S}\left(t_{(k)}\right) = \prod_{j=1}^{k} \frac{n_j - q_j}{n_j}.$$

Tables 4 and 5 illustrate the estimated survival functions for the telecommuters at NTP sites and non-NTP sites, respectively. These functions indicate the probabilities that an individual continues to telecommute after each time interval. From Table 4, for example, the probability of telecommuting beyond 6 months (through the six intervals) is $\hat{S}\left(t_{(6)}\right) = 0.567$. That is, there is a 56.7% chance that an individual will telecommute longer than 6 months. From the $P\left(t_{(j)}\right)$ column of Table 4 it is seen, for example, that there is a 94.2% chance of continuing to telecommute past 6 months given that the individual has lasted 5 months. The graph of the estimated survival functions obtained using BMDP software is shown in Fig. 1.

The median duration of telecommuting was 9 months at NTP sites and 8 months at non-NTP sites. This means that 50% of the participants telecommuted at least 9 and 8 months, respectively. Put negatively, it also means that half of the participants stopped telecommuting within 9 months after starting. About 21% of the non-NTP telecommuters used the telecenter for at least 2 years,

Table 4
Estimated survival function for NTP telecommuters

Telecommuting duration, j (months)	Initial number, n_j	Number of quitters, q_j	Number of censored observations, c_j	Conditional probability of surviving beyond, $t_{(j)}P(t_{(j)})$	Cumulative probability of surviving beyond, $t_{(j)}\hat{S}(t_{(j)})$
0	123	0	0	1.000	1.000
1–2	123	10	4	0.919	0.919
2–3	109	13	2	0.881	0.809
3–4	94	9	3	0.904	0.732
4–5	82	10	3	0.878	0.642
5–6	69	4	1	0.942	0.605
6–7	64	4	1	0.938	0.567
7–8	59	4	1	0.932	0.529
8–9	54	2	3	0.963	0.509
9–10	49	3	4	0.939	0.478
10–11	42	4	2	0.905	0.433
11–12	36	2	2	0.944	0.409
12–14	32	2	3	0.938	0.383
14–15	27	2	2	0.926	0.355
15–16	23	1	1	0.957	0.339
16–17	21	2	3	0.905	0.307
17–19	16	2	3	0.875	0.269
19–20	11	1	1	0.909	0.244
20–27	9	1	6	0.889	0.217
27+	2	1	1	0.500	0.109

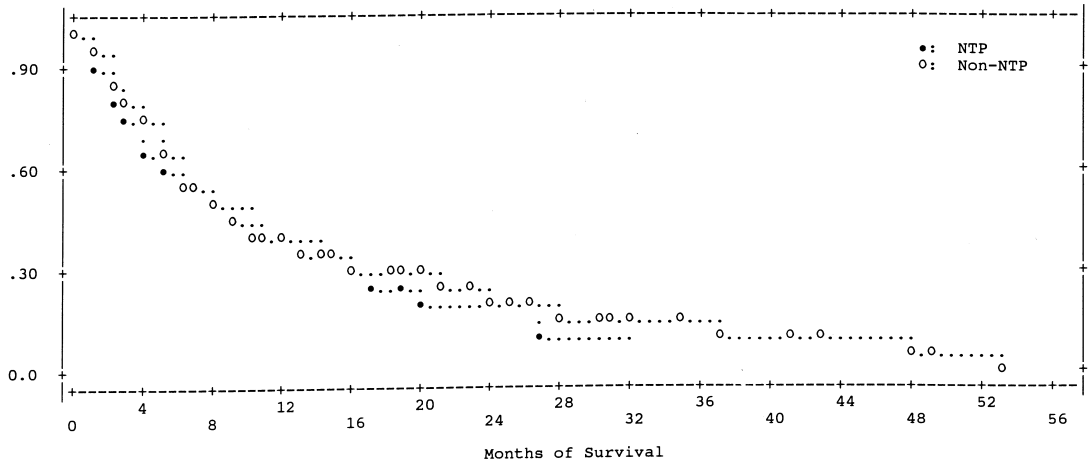

Fig. 1. Survival function for telecommuting by 123 NTP and 151 non-NTP users.

compared to 10% of NTP users. Despite the difference in telecommuting duration between NTP and non-NTP individuals, the two survival functions were not statistically different at a 0.10 level of significance. This means that at any time t, the estimated survival probability of telecommuting beyond t is statistically the same for telecommuters at both NTP and non-NTP sites. This result suggests that the operating length of the telecenter may not be an important factor in determining telecommuting duration. Rather, duration is probably a function of the characteristics of the individual telecommuter.

Table 5
Estimated survival function for non-NTP telecommuters

Telecommuting duration, j (months)	Initial number, n_j	Number of quitters, q_j	Number of censored observations, c_j	Conditional probability of surviving beyond, $t_{(j)}P(t_{(j)})$	Cumulative probability of surviving beyond, $t_{(j)}\hat{S}(t_{(j)})$
0–1	151	0	0	1.000	1.000
1–2	151	8	0	0.947	0.947
2–3	143	14	0	0.902	0.854
3–4	129	8	1	0.938	0.801
4–5	120	11	0	0.908	0.728
5–6	109	15	1	0.862	0.628
6–7	93	8	0	0.914	0.574
7–8	85	5	2	0.941	0.533
8–9	77	5	0	0.935	0.499
9–10	72	7	0	0.903	0.450
10–11	65	5	0	0.923	0.416
11–12	60	3	3	0.950	0.395
12–13	54	2	1	0.963	0.380
13–14	51	2	0	0.961	0.365
14–15	49	2	0	0.959	0.350
15–16	47	1	1	0.979	0.343
16–18	45	3	1	0.933	0.320
18–19	41	2	1	0.951	0.304
19–20	38	2	0	0.947	0.288
20–21	36	1	0	0.972	0.280
21–23	35	4	2	0.886	0.248
23–24	29	1	0	0.966	0.234
24–25	28	3	0	0.893	0.214
25–26	25	1	1	0.960	0.206
26–28	23	3	0	0.870	0.179
28–30	20	1	0	0.950	0.170
30–31	19	1	0	0.947	0.161
31–32	18	1	0	0.944	0.152
32–35	17	1	0	0.941	0.143
35–37	16	2	0	0.875	0.125
37–41	14	1	2	0.929	0.116
41–43	11	2	2	0.818	0.095
43–48	7	1	2	0.857	0.082
48–49	4	1	0	0.750	0.061
49–53	3	1	0	0.667	0.041
53+	2	2	0	0.000	0.000

This relatively short median duration of telecommuting is an important finding. The attrition rate seen here, of 50% within 9 months, is not directly comparable to the rates for the studies shown in Table 1, because the rate here is calculated based on the start dates that are allowed to be different for each individual rather than based on the start of the telecommuting program itself. Nor is it directly comparable to the average duration of 16 months reported by quitters in the California database analyzed in Section 2. However it does appear that attrition is higher in this study of center-based telecommuting than in the previously reported studies of home–based telecommuting, a preliminary observation which merits further research. On the other hand, the attrition seen here, and indeed in all the studies reviewed here, is consistent with the informal observation of telecommuting consultant Gil Gordon, who notes that "few workers remain telecommuters for more than six to 18 months" (Jones, 1996, p. B2).

Based on the analysis presented in this paper, 'once a telecommuter, always a telecommuter' is clearly not true. Reasons for quitting telecommuting are discussed in Section 6. In any case, analyses of telecommuting frequency (as in the following section) and the travel impacts of telecommuting (as in Mokhtarian et al., 1995; Balepur et al., forthcoming, and elsewhere) should be interpreted in the light of the information that those frequencies and impacts may only be achieved for a relatively short period of time by any given individual.

5. Telecommuting frequency

5.1. Analysis of frequency based on attendance log data

To measure how often a telecommuter used the telecenter, an individual's average telecommuting frequency is taken to be the ratio of telecommuting days to the total working days during his/her telecommuting duration. The number of working days includes the first and last telecenter visit but excludes Saturdays, Sundays, and eight federal holidays per year.

Fig. 2 shows the distribution of the average frequency of telecommuting for the 123 telecommuters at NTP sites and the 151 telecommuters at non-NTP sites. Since there are about 21 working days per month on average, a 5% telecommuting frequency is approximately equivalent to one telecommuting day per month. A 20% telecommuting frequency represents telecommuting once per week and 40% means twice per week. At NTP sites, about 8% of the telecommuters telecommuted on fewer than 5% of their working days. This implies that, for them, the average length of time between two telecommuting occasions was more than a month. Nearly half of the NTP telecommuters telecommuted less than 1 day per week, and about 29% telecommuted 1 to 2 days per week, on average.

The average telecommuting frequency at non-NTP sites (17.3%) was lower than that at NTP sites (28.2%). Nearly 22% telecommuted less than once per month on average. About 76% telecommuted less than 1 day per week. The longer period of observation available for non-NTP sites may include a period of no telecommuting by the participants since some of the users were found to stop telecommuting for an extended period of time and then restart later on. Another possible explanation of the difference is that non–NTP site users may have been more likely not to sign in on occasions when they actually did use the center, as discussed in Section 3.

The weighted average frequency of NTP and non-NTP telecommuters combined was 22%, or about 1.1 days a week. Nearly 64% of the combined sample telecommuted less than 1 day a week

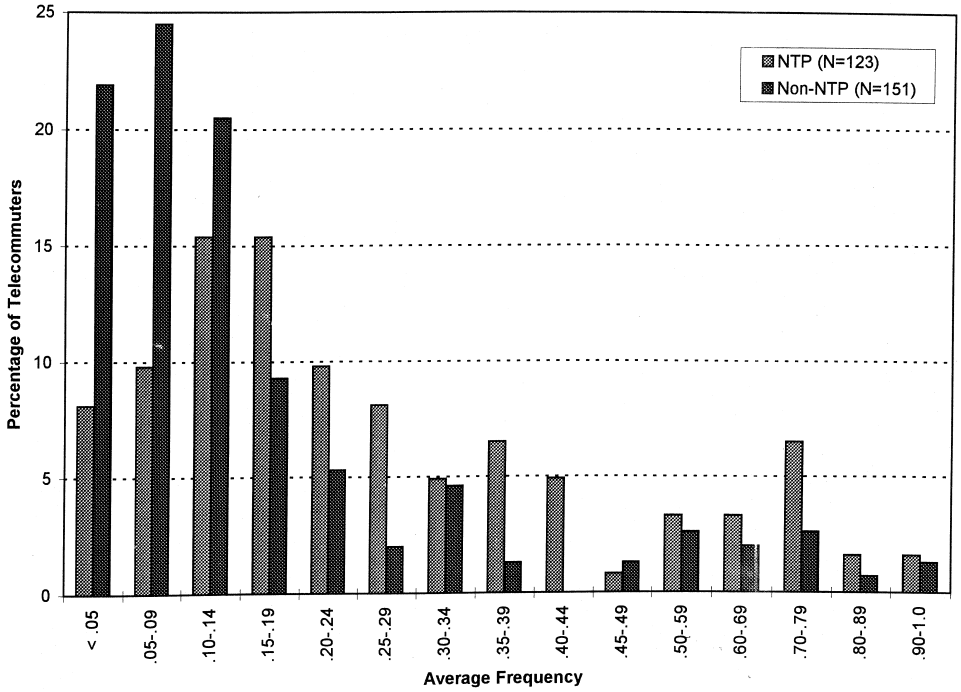

Fig. 2. Distribution of average telecommuting frequency.

on average. From the presentation of the average telecommuting frequency, it should not be inferred that telecommuters had a constant telecommuting frequency. The telecommuters are likely to have had several periods with different telecommuting frequencies during their entire telecommuting duration. Therefore, the average frequency only reflects the aggregate individual telecommuting behavior.

5.1.1. Comparison of telecommuting frequency for stayers and quitters

It is of interest to examine the relationship between telecommuting frequency and retention (stayer/quitter status). Hypotheses in either direction are plausible. Higher-frequency telecommuters may be more subject to burnout and to other disadvantages of telecommuting (isolation, lack of visibility to management) and hence may quit more readily. Hartman et al. (1991) and Tamrat et al. (1997) found a negative correlation between frequency of telecommuting and the employee's perceived productivity, which may lead to having to or choosing to quit. On the other hand, a lower frequency of telecommuting may connote a weaker commitment to the arrangement and hence a greater tendency to quit when an obstacle arises. As shown in Table 6, the average telecommuting frequency of stayers (1.4 days a week) is significantly higher than that of quitters (about 1 day a week). The standard deviations, however, indicate that there is more variability in stayers' frequencies, and the median frequencies are more similar between the two groups (0.7–0.9 days per week). The distributions of telecommuting frequency for stayers and quitters, shown in Fig. 3, are moderately significantly different according to a chi-squared test ($p = 0.07$). Overall, then, these results suggest that lower frequencies of telecommuting are associated with quitting.

5.1.2. Relationship between frequency and duration

In this descriptive initial study, telecommuting duration and frequency are for the most part analyzed separately. This does not necessarily mean that the two variables are independent, however. Similar to the discussion above regarding the relationship between frequency and stayer/quitter status, and for similar reasons, hypotheses in either direction are logical. The relationship may even be non-linear, with moderate frequencies being associated with the longest durations.

Since quitters are the only participants whose true duration is known, we examine the correlation between frequency and duration for the 208 quitters. There is a small but significant (linear) correlation between frequency and duration of −0.23. That is, higher-frequency telecommuters tend to have shorter durations. Superficially, this appears to contradict the previous result, in which quitter status was associated with *lower-frequency* telecommuting. In reality, it illustrates that there are complex and conflicting relationships within the sample. Taken

Table 6
Telecommuting frequency of stayers and quitters

Group	Frequency			
	n	Mean (%)	Median (%)	S.D. (%)
Stayers	66	28.2	17.5	26.2
Quitters	208	20.2	13.1	19.5

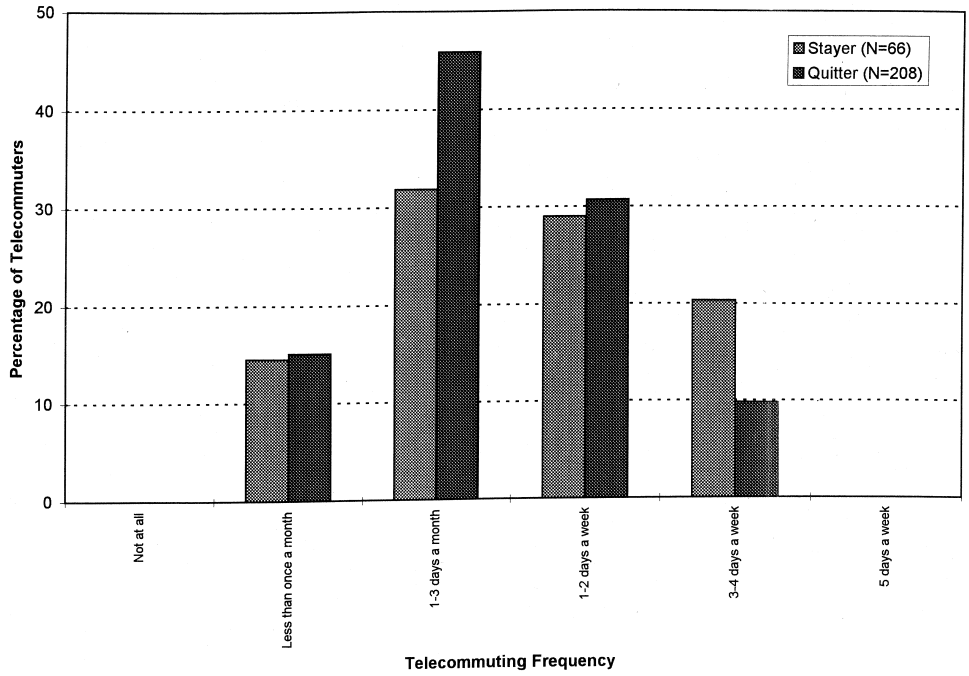

Fig. 3. Frequency distribution of stayers and quitters.

together, the two results suggest that there is a stable segment of the sample (stayers) who are committed higher–frequency telecommuters, but that within the segment having a propensity to quit, there is a tendency for higher-frequency telecommuters to quit sooner. However, since frequency alone accounts for only 5.5% of the variance in duration for quitters, there are clearly a number of other factors at play. Exploring the relationship between frequency and duration in greater detail is obviously a fertile subject for future research, as discussed further in Section 7.

5.2. Comparison of different measures of telecommuting frequency

The center-based telecommuting frequency for project participants may be estimated from two sources: the after attitudinal surveys and the sign-in logs. The preceding section discussed the distribution of telecommuting frequencies based on the complete available sign-in log data for 123 NTP and 151 non-NTP telecommuters. Average frequencies of 28.2% for NTP sites and 17.3% for non-NTP sites were found, for telecommuting durations ranging from 1 to 53 months. It is of interest to compare the measures of frequency based on the attendance log to those obtained from the attitudinal survey. The sample size is much smaller here, however, both because many of the non-NTP participants quit telecommuting before their center joined the evaluation program, and because many participants in both groups had not been telecommuting long enough at the cutoff date to receive an after survey.

The attitudinal survey measured telecommuting frequency by asking the question, "How much do you currently telecommute from a telecommuting center?" (with six response categories ranging from "not at all" to "5 days a week"). Using the midpoint of each category to represent the frequency for a person checking that category, a 'current' average telecommuting frequency of 33% was computed for the 69 NTP and non-NTP respondents who completed after surveys. The difference between this measure and the lower values calculated from the attendance logs may be due to differences in the sample (those who completed the after survey may have been higher-frequency telecommuters), changes in the frequency of telecommuting over time, and/or a survey response bias.

We explored further the third possibility (while controlling for the first two), that of a survey response bias. In particular, it is of interest to obtain some insight into how respondents interpreted the attitudinal survey question. Since no specific time frame was given to the word 'currently', several interpretations are plausible. Respondents may have tended to report their most recent frequency (say, over the last month), an average frequency since the start of telecommuting, or some perceived 'typical' frequency which may or may not relate to either of the previous possibilities.

It is hypothesized that responses to the attitudinal survey will tend to overstate the actual amount of telecommuting. There may be a number of reasons for this, including the tendency to 'telescope' less frequent events into a shorter time frame than the actual, a desire to increase the apparent success of the program, and 'wishful thinking'—that is a tendency to confound the actual frequency of telecommuting with a desired, perhaps an explicitly stated target, frequency. To examine this hypothesis, the sign-in log data for the 69 attitudinal survey respondents were used to obtain their actual telecommuting frequencies both during a 1-month and a 6-month window prior to the date on which the respondents filled out the after attitudinal surveys. The details of the analysis are described in Mokhtarian et al. (1997).

T-tests comparing the mean frequency computed from the attitudinal survey to those computed from the 1-month and 6-month attendance log windows found the former measure to be significantly different from (higher than) both of the latter two, in keeping with the response bias hypothesis. Next, however, the *distributions* of responses were compared for each of the three frequency measures, where the frequencies calculated from the sign-in logs were grouped into categories matching those on the attitudinal survey. Although the distribution for the attitudinal survey showed an apparent bias upward (toward higher frequency categories) compared to the sign-in log distributions, chi-squared tests emphatically failed to reject the null hypothesis of no differences among the three sets of measures.

By way of explaining the two different outcomes (*t*-tests showing a difference while chi-squared tests did not), it was shown that the sign-in log frequencies tended to cluster in the lower halves of the categories defined by the attitudinal survey. For example, 18 of the 28 responses (using the one-month sign-in log window) in the '1–2 days a week' category fell into the 1 day a week range. Thus, not only is there no strong evidence to support the hypothesized over–reporting bias, there is clear evidence that using the midpoint of a category to represent the average frequency in that category will (in this case) bias the reported frequencies upward. Given the similarities between measures based on the 6-month vs the 1-month window, the results also suggest that there is relative stability in average telecommuting frequencies over a 6-month period. Individual frequencies may still have fluctuated, however.

6. Reasons for quitting and future desires

In this section, we examine the motivations to quit center-based telecommuting and the extent to which quitters remain interested in telecommuting. An attempt was made to conduct an exit interview with each participant in the evaluation who was known to be a quitter, primarily in order to identify the reason for quitting. However, contacting and eliciting information from all quitters proved to be difficult since they may no longer have felt obliged to cooperate or may have changed phone numbers. Also, as mentioned earlier, many non-NTP participants quit before this evaluation began. Despite these factors, at least some data on reasons for quitting (some of it second-hand) is available for 114 participants.

The reason(s) given for leaving the telecenter program are shown in Table 7. The most frequent type of cause (cited by more than a third of the quitters) was job-related: changing positions within the organization, leaving the organization (whether voluntarily or not), or having an unsuitable job. Anecdotally, it appeared that this was mostly the result of corporate downsizing which required employees to take over some tasks that formerly belonged to other positions. Thus, they needed to be at the main office more or in some other way could not complete their new tasks at the telecommuting center. Technological difficulties and high cost may also be classified as job-related reasons (cited by 4%). These findings are consistent with the results shown in Tables 1 and 2. For all four studies of home-based telecommuting, job change was the most frequently given reason for dropping out, offered by 30–70% of those who quit.

The next most important reasons relate specifically to the supervisor and/or employer. Supervisors' and/or employers' attitudes led 18 (16%) of the participants to quit. Only one of the three home-based telecommuting studies of Table 1 reported manager concerns as a reason for quitting

Table 7
Reasons for quitting center-based telecommuting (n = 114)

Reason	Number[a] (%)
Changed jobs within the organization	16 (14.0)
Left organization	16 (14.0)
Job is unsuitable	5 (4.4)
Laid off	2 (1.8)
Too costly	3 (2.6)
Technological problems	1 (0.9)
Employer/supervisor required worker to quit	13 (11.4)
Employer/supervisor encouraged worker to quit	2 (1.8)
Changed supervisors	3 (2.6)
Moved	9 (7.9)
Situation at home changed	2 (1.8)
Switched to home-based telecommuting	10 (8.8)
Didn't like working at multiple locations	0 (0.0)
Not enough contact with co-workers	0 (0.0)
Problems with others at the center	1 (0.9)
Didn't like evaluation requirements	3 (2.6)
Center closed	14 (12.3)
Other	17 (14.9)

[a] Responses sum to 117 because some people gave more than one reason.

(offered by 27% of the City of Los Angeles quitters), but such concerns are likely to be a factor in other reported reasons such as office problems and job change. For the analysis presented in Table 2, employer-related concerns were a factor for 45% of the quitters, the second-most important type of reason.

Residential relocation was another reason for telecenter users to quit (8%). A number (12%) had to quit when the center they had been using closed. Finally, 9% of the quitters gave switching to home-based telecommuting as a reason. Overall, it appears that these telecenter users were generally forced to quit because of outside circumstances (change in job duties or supervisor decision)—no one indicated quitting because of personal dissatisfaction with the arrangement.

Seventy-five people provided responses to the last part of the exit interview, regarding the ideal distribution of work time and the prospects for future telecommuting. At the time of the interview, one-third (25) of these quitters worked at home, an average of 32.6% of the time. Averaging over the full sample of 75, respondents worked primarily at the regular workplace (for 76.6% of their time), with almost equal amounts of time spent at home (10.9%) and at an 'other' work location (11.7%). Only one respondent was utilizing another telecenter. However, according to the respondents (n = 73), the average ideal distribution of their work time at the regular workplace, the telecommuting center, and home would be 53.4%, 20.1%, and 14.2%, respectively. Similarly, when asked specifically about the prospects for future telecommuting (n = 73), only six people (8.2%) categorically refused to consider telecommuting from a center again, while 15 (20.5%) would not consider telecommuting from home. For this subgroup of the quitters, their preference is to continue to use telecommuting centers. The preference for more telecenter

use in the future, as well as the reasons given for quitting, suggest that the continuation of telecommuting by individuals who start is more often limited by external constraints than by personal reasons.

7. Conclusions and directions for future research

This paper examines measures relating to the temporal patterns of center-based telecommuting, including duration, frequency, and retention. The results indicate that attrition at the telecenters is relatively high, with 50% of all telecommuters quitting within the first nine months. This appears to be higher than for home-based programs, although consistent with the informal observation of at least one telecommuting expert who is quite familiar with current practice.

At NTP sites, the average telecommuting frequency was 28%, or nearly $1\frac{1}{2}$ days per week. Almost half of the participants telecommuted less than 1 day per week on average, and about 29% telecommuted 1 to 2 days per week. The non-NTP telecommuters telecommuted less frequently than those who were at NTP sites; the average was 17%, with about 76% of non-NTP telecenter users telecommuting less than 1 day per week.

The attendance log data showed that telecommuting frequency varied widely within the two groups of quitters and stayers. Overall, however, lower frequencies of telecommuting were associated with quitter status. On the other hand, for quitters (the only participants whose true duration was known) the correlation between frequency and duration was -0.23, meaning that high-frequency telecommuters had a slight but significant tendency to quit sooner than those with lower frequencies.

The motivations of participants for quitting the program were investigated. The most frequent type of reason given was job-related (cited by more than a third of all quitters). Other important reasons were supervisor-related (16%) and closure of the center (12%). Thus, external corporate downsizing and reorganization may have been the most likely causes for quitting. No one cited dissatisfaction with telecommuting as a reason for quitting.

A number of interesting research questions remain regarding the patterns of telecenter use. One question of primary interest is the apparently higher attrition rates for center-based telecommuting compared to home-based. The demands of the evaluation, the cost of the center, a preference for home-based telecommuting and the telecenter not meeting expectations in some way could be plausible reasons for the higher attrition rates. It is important to keep in mind that quitting the center does not necessarily mean quitting telecommuting altogether, as home-based telecommuting may still take place. This outcome occurred for one-third of our sample for whom such information was available.

It would also be interesting to explore the reasons behind the fact that a large proportion of people (about 1/3) drop out of programs before ever beginning to telecommute. In some telecommuting demonstration programs, an inability to attend mandatory training sessions may disqualify some people from participating. Some of those who do attend training sessions may discover that telecommuting is not the unmitigated benefit that they had fantasized it to be (in which case the training sessions are arguably doing a successful job in preparing participants for what to expect). In some cases, a period of several months may elapse between the initial expression of interest or completion of a survey, and the eventual selection to participate. Within

that time frame, job responsibilities may have changed in a way that precludes telecommuting. It is quite likely that a number of people drop out after discovering the extent of the evaluation procedures in which they are expected to participate (Table 1 gives this as a reason for 13% of the Puget Sound dropouts reached for interview). Those individuals may well be in the later cohorts who eventually begin telecommuting after the pilot program becomes institutionalized and the evaluation (and perhaps training) procedures are no longer required. In any case, it would be desirable for future studies to interview this large group of non-starters, to determine not only why they dropped out but also what their future intentions are.

Most studies follow people telecommuting only for a year or two. After participants drop out, it is seldom determined whether they ever 'drop back in'. The analysis of California data presented in Section 2 is one exception, where it was reported that slightly more than half the respondents who had quit at one point were now telecommuting again (although that figure is likely to be an overestimate due to self-selection bias). From published reports most dropouts (at least among those who actually started telecommuting) offer reasons for leaving that are based on external constraints such as a change of jobs, manager desires, or technology rather than on an internal dislike of telecommuting. Thus, it seems quite likely that many dropouts will return to telecommuting. On the other hand, a number of people may find telecommuting desirable for a certain point in their work/family lives, but not thereafter. It would be valuable to monitor the telecommuting behavior of individuals over a long period of time, to learn more about the prevalence of various patterns and the types of people engaging in each pattern.

Finally, it is important to develop behavioral models of telecommuting frequency and duration, to support aggregate models of the amount and impacts of telecommuting. To be successful, such behavioral models would likely require the collection of demographic and attitudinal data for a larger sample than was available for this study, but assuming the existence of such data, a number of interesting analyses would theoretically be possible. Telecommuting frequency could be modeled as a function of attitudinal and job-related variables, using regression, Poisson regression, or related methods. In addition to modeling an average frequency for each individual, an examination of how the individual's telecommuting frequency changes over time (and relating different patterns to different types of individuals) would be valuable. (Modeling those temporal variations in frequency would be complex, however, requiring the collection of time-varying data on potential explanatory variables). Duration could be analyzed with hazard models (see, e.g. Hensher and Mannering, 1994) containing similar types of explanatory variables as well as frequency itself. Such studies would offer rich insight into telecommuting behavior and, by extension, into the likely aggregate impacts of telecommuting over time.

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