Prometheus, Vol. 20, No. 1, 2002

Patterns of Telecommuting Engagement and Frequency: A Cluster Analysis of Telecenter Users[1]

PATRICIA L. MOKHTARIAN & RAVIKUMAR MEENAKSHISUNDARAM

ABSTRACT *Cluster analysis of sign-in log data for 115 users of California telecenters was conducted to identify patterns of telecommuting engagement and frequency over a six-month window. Three engagement clusters were identified: Persisters, Decliners, and Dabblers. Four frequency clusters were identified, classified as Low, Medium, High, and Erratic. Nearly half of the Persisters belonged to the Low Frequency cluster, highlighting the need to count not just telecommuters, but telecommuting occasions. Variables significantly associated with cluster membership were identified. Consistent with other research, management-related issues seem to play a substantial role in affecting both the engagement in, and frequency of, telecommuting.*

Keywords: telecommuting, teleworking, telework centers, cluster analysis.

Introduction

Telecommuting can be defined as the use of information and telecommunication technologies to reduce or eliminate the commute to a conventional office, through working at home or at a telecommuting center ('telecenter') relatively close to home. Attitudes toward telecommuting, characteristics of telecommuters, adoption models and potential transportation impacts of telecommuting have been extensively studied in recent years,[2] and a great deal has been learned about these issues.

One gap in our knowledge, however, relates to the dynamic aspect of telecommuting. Most empirical studies (probably due to funding and time constraints) are cross-sectional in nature, and explore the status and impacts of telecommuting at a single point in an individual's and/or organization's life. Thus, little is known about how telecommuting changes over time, at the disaggregate level. Many questions can be raised in this regard: how do employees', household members', managers', and organizations' attitudes toward telecommuting change over time? How long does telecommuting last for an individual, and what causes some to stop? Are there often multiple episodes of telecommuting in an individual's career? How do engagement in, and frequencies of, telecommuting

Prometheus ISSN 0810-9028 print/ISSN 1470-1030 online © 2002 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/08109020110110907

change over time, and what causes them to change? Does long-term telecommuting affect organizational advancement? What are the impacts on corporate culture, on non-telecommuters? What are the impacts on residential and job location, on neighborhood cohesion?

The set of questions above can be sorted into two categories: those focusing on describing and explaining dynamic aspects of telecommuting itself, and those relating to long-term impacts of telecommuting. Improving our understanding in the first category is critical both to our ability to forecast the participation in telecommuting, and to our understanding of the long-term impacts constituting the second category of questions. Thus, for example, it is insufficient to correctly predict that a given number of people will begin telecommuting. To properly assess impacts it is important to know how many of those people will actually telecommute at a certain time (in the case of transportation impacts, on a given day).

At least three useful descriptive measures of the dynamic aspects of telecommuting can be identified. *Engagement* refers to whether or not an individual telecommutes at all during a given period. *Frequency* refers to the number of times, or rate at which, an individual telecommutes during a given period, and thus can be considered a measure of intensity of engagement. *Duration* refers to how long a person telecommutes before stopping. It is closely related to engagement, but can be distinguished from it. Engagement would be measured as a binary indicator for a fixed period of time—'off' or 'on'—whereas duration would be measured as the length of time—varying across individuals—during which telecommuting occurred. Thus, the actual duration may be longer or shorter than the fixed period over which engagement is assessed, and if the fixed period of interest is short relative to typical durations, a single telecommuting episode may have (short) periods of non-engagement as well as engagement. While measuring engagement is relatively unambiguous once the fixed period of interest is defined, measuring duration is somewhat more judgmental: if someone telecommutes about once a month, but skips three months and then resumes telecommuting at the same rate, does that constitute one telecommuting episode or two?

This paper focuses on two of these three descriptive measures of the dynamic aspects of telecommuting—engagement and frequency—and identifies typical patterns with respect to these measures. It also identifies some factors associated with differences in engagement and frequency across the available sample. Telecommuting durations for a sample from the same dataset are analyzed in Varma *et al.*[3] The emphasis of this paper is on understanding patterns of telecommuting, for those who are currently telecommuting.

The organization of this paper is as follows. First, the empirical context of this study, and the analysis methodology are described. The results of a cluster analysis of patterns of telecommuting engagement and frequency follow. Second, the relationship of attitudinal and demographic variables to telecommuting engagement and frequency (as measured by cluster membership) is assessed. The final section summarizes the results and offers suggestions for further research.

Empirical Context and Analysis Methodology

Description of the Study Setting and Data Collection

The data used in this study were collected as part of the Residential Area-Based Offices (RABO) Project. This project, known informally as the Neighborhood

Telecenters Project, was a multi-year program conducted by the Institute of Transportation Studies, University of California, Davis. Sponsored by the Federal Highway Administration and the California Department of Transportation, the program was undertaken to evaluate the effectiveness of multi-employer telecommuting centers as a work arrangement and as a transportation demand management strategy. Details of the implementation and evaluation of the project are provided in Mokhtarian, *et al.*,[4] among other documents.

The RABO project established a total of 16 telecenters, and limited evaluation data were collected from an additional five centers that operated outside the project—all based in urban areas of California. The major aims of the project were to study the impacts of telecommuting center use on work performance, job satisfaction, travel behavior and telecommuting patterns. The data for the project were collected from four instruments: an attitudinal survey, a travel diary, an attendance (or sign-in) log, and an exit interview. The attitudinal survey and travel diary were administered to the participants once before and once about 6 months after the start of telecommuting, the attendance log was used throughout the period of telecommuting, and the exit interviews were conducted for the telecommuters who quit the program. The study reported here is based on data mainly from the sign-in log, and secondarily from the attitudinal survey.

Telecommuters were asked to make an entry in the attendance (sign-in) log each day they used the telecenter. The entry included date, name of the respondent, transportation mode used to get to the telecenter and estimated work time to be spent at various workplaces, including telecenter, main office, home and any other work location. It is possible that participants forgot or declined to sign in on some occasions and thus the data may somewhat undercount the usage of the telecenter. However, site administrators had a contractual incentive to maximize center occupancy and hence to ensure the most accurate reporting possible, so we expect this effect to be small. For this study, sign-in data collected through 30 June 1996 from 15 telecenters (13 RABO sites and two non-RABO sites) are used. The starting points of the sign-in data vary by site, with the earliest date being November 1993.

From an initial total of 367 telecenter users, 92 were dropped because they telecommuted only once or twice and hence valid frequency measures could not be obtained (that 25% of the users only telecommuted once or twice is a finding of interest in its own right, explored further in Varma *et al.*[5]). Of the remaining 274 respondents, 81, 110, and 148 had telecommuting durations of more than a year, more than nine months, and more than six months, respectively. To maximize the sample size available for analysis, we initially decided to retain the participants having telecommuting durations of more than six months.

In analyzing telecommuting engagement and frequency patterns, two factors should ideally be controlled for. The first is the length of time since beginning to telecommute. For many people, telecommuting may be erratic at first, and then settle into a relatively stable pattern. Two people may end up with relatively similar equilibrium frequencies, but if they are compared in their early stages of telecommuting, or compared at different stages, their patterns may not match well. Hence, ideally we would want to compare patterns after some initial break-in period of, say, three months. On the other hand, some people may take longer to achieve equilibrium than others, some may never achieve it even though they continue to telecommute, and many will stop telecommuting after just a few months.[6] So this effect is difficult to control for in practice.

The second factor that should be controlled for is the temporal distribution of the telecommuting occasions of each participant. Suppose one participant started telecommuting in November and stopped in June, and another participant started telecommuting in February and stopped in October. Then the telecommuting patterns for these two participants might be different purely because of the different times of the year. To control for the effects of seasonality on the patterns, it was decided to include only those participants whose telecommuting durations spanned a 6-month period between January and June. Thus, to be included in the study, a participant must have had:

- more than six months of telecommuting data; and
- a telecommuting duration spanning a six-month period between January and June.

To control for both duration of telecommuting experience and seasonality simultaneously would require a sample of people who either: (1) (preferably) all started telecommuting at about the same time; or (2) (less preferably) had been telecommuting long enough to enable us to discard the first several months of observations and still retain a several-month-long contiguous segment of telecommuting during the same time of the year for everyone. We did not have a large enough sample meeting either of these conditions, and so we were only able to control for the duration and seasonality effects separately but not together.

Out of the 148 participants who satisfied the first condition of telecommuting for more than six months, only 115 satisfied the second condition of having a duration that spanned January to June (this is in fact nearly equivalent to the group of 110 people who telecommuted for more than nine months). For everyone included in this analysis, there was evidence of either more or less continuous telecommuting throughout January to June, or presence of telecommuting before January and after June, so that the entire duration of their telecommuting enclosed the January–June window (one included participant fit the latter condition without telecommuting at all within the January–June window). Two parallel sets of analyses were conducted for these 115 participants, using their telecommuting patterns for: (1) the first six months of telecommuting (to control for the duration effect); and (2) the first January–June window of telecommuting (to control for the seasonality effect).

Analysis Methodology

Two types of questions are of interest to this study:

- Did the respondent telecommute at all in some specified time interval?
- How many times did the respondent telecommute in that time interval?

The first question addresses whether or not the respondent is engaged in telecommuting at all, whereas the second question addresses the intensity of that engagement.

It was necessary to consider the definition of an appropriate time interval. The broader the time interval of analysis (e.g. one month), the cruder the patterns that can be analyzed and the shorter the pattern sequence available. The narrower the time unit (e.g. one week), the more subject a case is to random fluctuations that

might obscure some regularity. As a middle ground, we selected a two-week unit of analysis. Thus, our two six-month windows of interest—the respondents' first six months of telecommuting, and the first January–June segment—were each divided into 13 two-week segments.

For each respondent and each six-month window of interest, two 13-dimensional vectors were created. In the first vector, all entries were binary: equal to 1 if telecommuting occurred during the corresponding two-week period, and 0 if not. Thus, two binary vectors were obtained for each of the 115 respondents, referred to as the *binary-initial* vector and the *binary-janjune* vector, respectively. A binary-initial vector of 111 111 111 111 1 means that the respondent had at least one telecommuting occasion in each of the two-week segments of the first six months of telecommuting, and similarly for the binary-janjune vector.

In the second vector for each six-month window, the *i*th element was the number of telecommuting occasions during the *i*th two-week period. Thus, we obtained a 13-dimensional count vector for the first six months of telecommuting and another 13-dimensional count vector for the first January–June telecommuting period for each of the 115 respondents. We refer to these as the *count-initial* and the *count-janjune* vectors, respectively. If the binary variable in a particular two-week segment is 0, then the count variable in the same segment will also be 0. A count vector such as 015 678 345 012 6 would mean that the respondent had no telecommuting occasions in the first and tenth two-week segments, six occasions in the fourth and thirteenth two-week segments and so on.

Thus, each of the 115 respondents is characterized by four 13-dimensional vectors. Meenakshisundaram[7] discusses the analysis of each of these four vectors in equal detail. Here, for economy of presentation we focus on the Jan–June results in each case, but briefly mention similarities and differences with the first-six-months window.

The main purpose of this study is to identify similar patterns of telecommuting engagement and frequency, which we accomplish through cluster-analyzing each of the four sets of vectors. A secondary purpose is to examine other characteristics associated with the telecommuting patterns identified in the first step, which we accomplish through chi-squared tests and analysis of variance of cluster membership against other characteristics obtained from the attitudinal surveys completed by participants.

Analysis of Engagement and Frequency Patterns

Descriptive Statistics Describing the Engagement and Frequency Patterns

Before conducting the cluster analysis, it is useful to examine some summary statistics representing the data being analyzed. Table 1 presents the distribution of telecommuting engagement for both the initial and the Jan–June windows. Focusing on the Jan–June window, it can be seen that nearly a quarter of the sample engaged in telecommuting at least once during each of the 13, two-week periods under study. However, another quarter of the sample did not telecommute at all during more than half of the 13 periods. Comparing the Jan–June results to those for the initial six-month window, similar proportions of full engagement are seen, but the Jan–June results show a somewhat higher concentration of the sample in the lower-engagement categories. Since the Jan–June window is either coincident with or (in most cases) later than the start-of-telecommuting window,

Table 1. Distribution of telecommuting engagement ($N = 115$)

Number of two-week segments containing any telecommuting	Mean (proportion of pds. with any telecommuting)	Number (%) of respondents	
		First six months	January–June
13	1.00	29 (25.2%)	27 (23.5%)
12	0.92	15 (13.0%)	17 (14.8%)
11	0.85	11 (9.6%)	8 (6.9%)
10	0.77	14 (12.2%)	11 (9.6%)
9	0.69	7 (6.1%)	13 (11.3%)
8	0.62	8 (6.9%)	6 (5.2%)
7	0.54	4 (3.5%)	5 (4.4%)
6	0.46	3 (2.6%)	6 (5.2%)
5	0.38	10 (8.7%)	2 (1.7%)
4	0.31	4 (3.5%)	3 (2.6%)
3	0.23	3 (2.6%)	0 (0.0%)
2	0.15	2 (1.7%)	8 (6.9%)
1	0.08	5 (4.3%)	8 (6.9%)
0	0.00	0 (0.0%)	1 (0.9%)

these results suggest that telecommuting engagement is attenuating over time for some of the sample. We return to this point later.

For the count vectors, representing frequency of telecommuting during each two-week period, each element of the vector can take on a number of different values (theoretically, the set of integers from 0 to 14, assuming weekends are counted and no more than one telecommuting occasion per day is counted). One way to summarize the information in each vector is to compute the mean and variance of the 13 elements comprising the vector. The mean indicates an average intensity of telecommuting across the six-month period, and the variance indicates the degree of variability of that intensity. The mean and variance of each of the 115

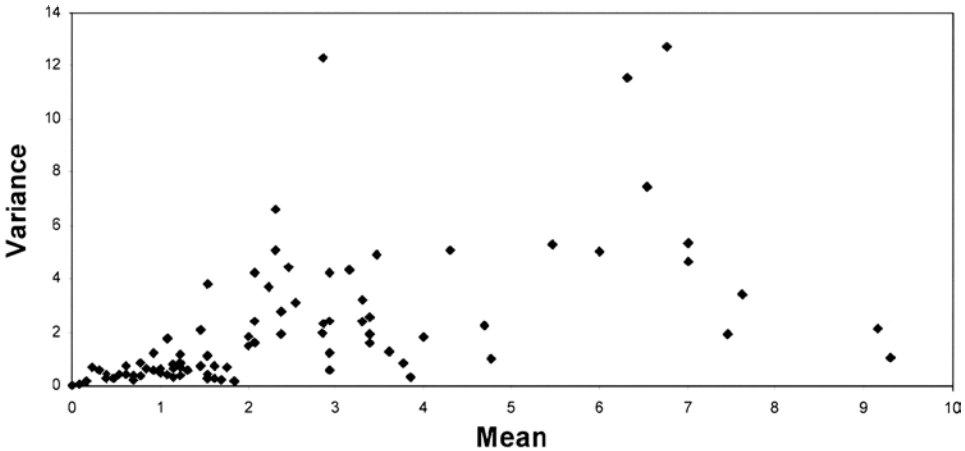

Figure 1. Mean and variance of number of telecommuting occasions per two-week interval—January to June ($N = 115$).

count-janjune vectors was calculated and the mean–variance pair for each case is plotted in Figure 1. From the plot, it can be seen that most of the respondents have low means and low variances, indicating a uniformly light intensity of telecommuting over the six-month period. Some respondents have high means, indicating heavy participation in telecommuting throughout. These patterns are analyzed in greater detail through the cluster analysis.

Cluster Analysis of the Engagement and Frequency Patterns

Cluster analysis is a technique for identifying cases having common patterns of variation on a set of p characteristics of interest.[8] Those p characteristics for a given case can be arrayed as a vector in p-dimensional space, and cluster analysis identifies groups of cases that are close together in that space. In this context, the characteristics of interest are the variables describing each participant's telecommuting patterns. To analyze telecommuting engagement, those variables were the 13 elements of the binary-initial and binary-janjune vectors. For telecommuting frequency, we analyzed not only the 13-dimensional vectors containing the counts of telecommuting occasions in each two-week period, but also the two-dimensional vectors containing the means and variances (across the 13 periods) of the number of each respondent's telecommuting occasions in each period (i.e. for the Jan–June window, the two-dimensional vectors plotted as points in Figure 1). The 13-dimensional and two-dimensional cluster analyses yielded similar results; we report the two-dimensional results for the Jan–June window. In all cases we used the K-means non-hierarchical clustering algorithm of SPSS.

Telecommuting Engagement. Analysis of the 13-dimensional binary-janjune vectors identified three clusters. The centroids of these three clusters (that is, the average across cases in the cluster, on each of the 13 dimensions) are presented in Table 2.

The average member of the first cluster (i.e. the centroid) shows a high level of telecommuting engagement across the entire six-month window, with 85–100% of the group telecommuting at least once in any given two-week period of the window. These sustained-engagement telecommuters are labeled *Persisters*, and they constitute 45% of the sample.

Based on the centroid, the second cluster is characterized by high engagement in telecommuting initially, followed by periods of fluctuating involvement with a generally downward trend. Thus, while in the first half of the window 80–90% of the group telecommutes at least once in any given period, this proportion drops to two-thirds on average (excluding the final period) in the last half of the window. The precipitous drop in engagement in the very last period (with only 8% of the group telecommuting even once) is probably due to a vacation slump at the end of June. This group is labeled *Decliners*, and constitutes about a third (31%) of the sample.

The third cluster contains individuals with a fluctuating but relatively low engagement in telecommuting: only 4–37% of the group telecommutes at least once in any given two-week period, 22% on average. Put another way, members of this group telecommute in less than one two-week period out of four, or in one or two weeks out of every two months, on average. This cluster is labeled *Dabblers*, and comprises about a fourth (24%) of the sample.

Table 2. Telecommuting engagement cluster centroids, January–June window ($N = 115$)

Two-week period number	Cluster 1 *Persisters* $N = 52$ (45%)	Cluster 2 *Decliners* $N = 36$ (31%)	Cluster 3 *Dabblers* $N = 27$ (24%)
1	0.85	0.89	0.37
2	0.87	0.89	0.26
3	0.90	0.81	0.15
4	0.87	0.83	0.04
5	0.92	0.94	0.19
6	0.88	0.86	0.30
7	0.96	0.78	0.07
8	0.96	0.58	0.15
9	0.96	0.61	0.22
10	0.96	0.78	0.22
11	0.88	0.69	0.19
12	0.88	0.67	0.37
13	1.00	0.08	0.33
Average	0.91	0.72	0.22

Note: Each respondent is represented by a 13-dimensional vector whose *i*th entry is equal to 1 if s/he telecommuted at all during the *i*th two-week period, and 0 otherwise. The *i*th element of the cluster centroid is the average of the *i*th elements across all members of the cluster, which represents the proportion of respondents in that cluster who telecommuted at all during the *i*th two-week period.

The binary-janjune cluster solution presented here is similar but not identical to the binary-initial solution. The latter solution (see Meenakshisundaram[9] for details) also identified three clusters, labeled *Persisters* (56%), *Burnouts* (24%), and *Dabblers* (20%). The middle group was labeled *Burnouts* (in contrast to the *Decliners* of the Jan–June solution) because in the second half of the six-month window, only 25–46% of the group engaged in telecommuting in any given period.

Since the January–June window generally starts later than the initial six-month window, cross-tabulating the membership in each of the two sets of clusters provides an indication of how telecommuting patterns might be shifting over time. That cross-tabulation (not shown here for brevity) indicates that nearly two-thirds (63%) of the sample falls into the same (or corresponding) group in both cases, indicating some stability between solutions. However, some migration is evident. For example, about a third of the 64 respondents in the *Persisters* group in the binary-initial solution moved to the *Decliners* group in the binary-janjune solution. This probably accounts for the higher average engagement in later periods in the *Decliners* group than in the *Burnouts* group of the initial solution, but this group might still be on its way to burnout in view of the declining average engagement across the six-month period. Interestingly, however, about a third of the smaller (28) *Burnouts* group migrated to *Persister* status in the January–June window, with a similar number of *Burnouts* settling down to *Dabbler* status. There was very little shifting from the initial *Dabblers* group, indicating that this was a relatively stable telecommuting pattern for the people starting out in that group.

Table 3. Telecommuting frequency cluster centroids, January–June window ($N = 115$)

Telecommuting frequency in two-week period	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
	Low frequency	*Medium frequency*	*High frequency*	*Erratic*
	$N = 73$ (63%)	$N = 30$ (26%)	$N = 9$ (8%)	$N = 3$ (3%)
Mean	0.87	3.04	7.28	5.31
Variance	0.54	2.85	4.03	12.19

Note: Each respondent is represented by a two-dimensional vector. The first entry is the mean number of telecommuting occasions per two-week period, where the average is taken over the 13 two-week periods constituting the six-month window under study. The second entry is the variance of the number of telecommuting occasions per two-week period, across the same window. Thus, the first element of the cluster centroid is the average (over the members of the cluster) mean number of telecommuting occasions per two-week period, and the second element is the average variance in telecommuting occasions.

Telecommuting Frequency. Analysis of the two-dimensional mean-variance vectors of telecommuting frequency identified four clusters, whose centroids are shown in Table 3. It can be noted immediately that although one cluster only contains three cases, it is important to segregate those cases since they differ substantially from all the others. They are the highest three points on Figure 1, and constitute participants with extremely high variability in their telecommuting frequency. Thus, this cluster is labeled *Erratic*.

The remaining three clusters can readily be labeled *Low*, *Medium*, and *High Frequency*, respectively, based on the 'mean mean' frequency for each cluster. For example, the typical member of the *Low Frequency* cluster telecommuted just under one time on average (with little variation), in each of the two-week periods of the Jan–June window. Nearly two-thirds (63%) of the sample falls into this group. The typical member of the *Medium Frequency* cluster telecommuted about three times per two-week period (or 1.5 times a week), on average, and comprised about a quarter (26%) of the sample. *High Frequency* individuals telecommuted about seven times per period (3.6 times a week) on average. They constituted only 8% of the sample, but 28% of the total number of telecommuting occasions.

Table 4. Cross-tabulation of cluster membership for engagement and frequency clusters ($N = 115$)

		Frequency cluster				
		Low frequency	*Medium frequency*	*High frequency*	*Erratic*	Total (%)
Engagement cluster	*Persisters*	24	17	9	2	52 (45%)
	Decliners	22	13	0	1	36 (31%)
	Dabblers	27	0	0	0	27 (24%)
	Total (%)	73 (63%)	30 (26%)	9 (8%)	3 (3%)	115 (100%)

Cross-tabulation of Engagement and Frequency Cluster Memberships. It is informative to relate the telecommuting engagement and frequency patterns through cross-tabulation of the cluster memberships for the two solutions shown in Tables 2 and 3. That cross-tabulation is shown in Table 4. Not surprisingly, all of the *Dabblers* are *Low Frequency* telecommuters, as are a majority of the *Decliners*. What is interesting is that nearly half of the *Persisters* are also *Low Frequency*, indicating that even when engagement in telecommuting is steady, it is generally at low intensity. A third of the *Persisters* are *Medium Frequency*, only a sixth of them are *High Frequency*, and 4% of them (two cases) fall into the small *Erratic* group.

Relationships of the Clusters to Other Variables

Data Availability

It is naturally of interest to investigate relationships between the indicators of cluster membership and other variables measured in the study, to obtain insight into factors associated with low and high levels of telecommuting engagement and frequency. To do this, we incorporate data from the attitudinal survey mentioned earlier.

The attitudinal survey was a 16-page questionnaire that asked about participant characteristics and their attitudes toward telecommuting. Telecommuters completed the surveys shortly before beginning to use the center, and again about six months later. (Similar surveys were completed by home-based telecommuters and non-telecommuters in comparable positions at the same organizations, as well as by the managers of each of these respondents.) The questionnaire contained 22 attitudinal statements (with a five-point Likert-type response scale) relating to generic job context perceptions, and 30 statements related to workplace perceptions, with each of the latter set of statements presented with respect to the three workplaces home, telecenter, and regular workplace.

The responses to these two sets of statements in these surveys were separately factor analyzed to obtain a smaller set of underlying dimensions representing the main content of the statements, and it is the resulting standardized factor scores that are studied here. Additional details of the factor analysis are presented in Mokhtarian and Bagley,[10] and some analysis of the attitudinal survey data is also found in Stanek and Mokhtarian[11] as well as in Mokhtarian *et al.*[12] For convenience, however, brief definitions of the attitudinal factors are provided in the Appendix to this paper.

The data used for this portion of the analysis comes from the (initially) 133 telecenter users having relatively complete data on the before-wave employee attitudinal survey. The after-wave sample size was not large enough to be included in this study. This is a limitation, since telecommuting frequency several months after starting may be more closely related to the after-wave attitudes than to the before-wave measures.

These 133 respondents were matched with the 115 respondents obtained from the sign-in log data; only 54 respondents were common to both samples. This is because a number of participants, especially at non-RABO sites, had already been telecommuting for some time when the evaluation project began, and hence could not complete before-wave surveys. In addition, a number of those completing the surveys were the one-time and two-time telecommuters mentioned earlier as having been discarded from the analysis.

Using only the 54 common respondents, several of the clusters identified earlier contained fewer than 10 cases and hence statistical analysis including them would not be reliable. Thus, this portion of the analysis focuses on the comparison between the *Persisters* ($N=28$) and *Dabblers* ($N=20$) engagement clusters, and the *Low* ($N=23$) and *Medium* ($N=22$) frequency clusters. Obviously, this is another limitation of this study.

Results

For the continuous factor scores and one-way commute distance, analysis of variance (ANOVA) was used to determine whether the means of those variables differed significantly across clusters. For the four discrete demographic variables gender, age, education, and income, chi-squared tests were conducted to determine whether the distributions of those variables differed significantly across clusters. Table 5 summarizes the results for the January–June window clusters (additional details are available in Meenakshisundaram[13]).

Job Context Perception Factor Scores. None of the job context perception factor score means were significantly different between *Persisters* and *Decliners* at the 0.05 level. That is, perceptions of one's productivity, job satisfaction, relationship with the supervisor, and co-worker interactions do not seem to help explain why some participants telecommute consistently over a period of time, while others do so less and less over time. It is of interest, however, that for the engagement clusters based on the first-six-months window (results not shown here), *Dabblers* have a significantly lower mean score on the supervisor relationship factor (–0.86) than do the *Persisters* (–0.11). This indicates that the low-engagement *Dabblers* had a more negative relationship with their supervisors before telecommuting began, which would be a logical cause contributing to their inability to sustain a high level of engagement in telecommuting.

With respect to the frequency clusters, two somewhat significant relationships are found. *Low Frequency* telecommuters have a higher mean job satisfaction score (0.38) than do *Medium Frequency* telecommuters (–0.32). This higher job satisfaction may result in a weaker desire to telecommute than for those who are more dissatisfied. On the other hand, the mean supervisor relationship score is lower for *Low Frequency* telecommuters (–0.53) than for the *Medium Frequency* group (–0.10). This suggests that, similar to the first-six-months results for telecommuting engagement, the less satisfactory relationship with the supervisor may impede telecommuting at higher frequencies. Although it might have been expected that a negative supervisor relationship would be associated with lower job satisfaction, it is quite possible for those two aspects of the job to be somewhat independent (and indeed the factor analysis is constructed to capture at least roughly independent dimensions—'roughly' because we used oblique rather than orthogonal rotation in identifying the factors). And certainly, the combination of weaker desire and stronger constraint could constitute an important barrier to more frequent telecommuting.

Workplace-specific Perception Factor Scores. Four workplace perception factors were identified in the factor analysis, with scores for each factor obtained for each workplace. Thus, analyzing this set of variables called for a two-way ANOVA,

Table 5. Relationship of other variables to cluster membership (*p*-values)

	Telecommuting engagement clusters (January–June) *Persisters* ($N=28$) vs. *Decliners* ($N=20$)			Telecommuting frequency clusters (January–June) *Low* ($N=23$) vs. *Medium* ($N=22$)		
Job context perception factor scores						
Productivity		0.461			0.754	
Job satisfaction		0.873			**0.017** (mean score 0.38 vs. –0.32)	
Supervisor relationship		0.133			**0.100** (mean score –0.53 vs. –0.10)	
Co-worker interaction		0.331			0.734	
Workplace-specific perception factor scores	**Workplace main effect**	**Cluster main effect**	**Interaction effect**	**Workplace main effect**	**Cluster main effect**	**Interaction effect**
Personal benefits	**0.000**	0.253	0.169	**0.000**	0.353	0.509
Autonomy	**0.000**	0.953	0.114	**0.000**	0.651	0.498
Work effectiveness	**0.000**	0.957	0.258	**0.000**	0.532	0.460
Professional development	**0.000**	**0.072**	0.948	**0.000**	0.348	0.329
Demographic traits						
Gender*		0.807			**0.100** (61% vs. 36% female)	
Age*		0.679			**0.082** (83% vs. 59% 45 or younger)	
Education*		0.238			0.130	
Income*		0.440			1.000	
One-way commute miles		**0.090** (mean 51 vs. 38 miles)			0.100 (mean 34 vs. 47 miles)	

Note: * indicates chi-squared test; otherwise ANOVA. Effects significant at the 0.1 level or better are in bold.

allowing for workplace and cluster main effects as well as a possible interaction effect (for example, for a given variable, clusters may differ on their assessment of center and home, but not of the regular workplace). For both the engagement and frequency clusters, the workplace main effect was significant for all four factors, meaning that average perceptions of home, telecenter, and regular workplace differed in terms of the personal benefits, autonomy, work-effectiveness, and comfort level with supervisor that they offered. This is a natural and expected result.

More important to the current study is the question of whether there are cluster main effects or interaction effects. In general terms, we would expect that a more positive perception overall on any of these factors, or a more positive perception of the telecenter relative to the other workplaces with respect to any of these factors, would be associated with higher engagement in and frequency of telecommuting (from a center, which is what we are analyzing here). That is, perceiving one's personal benefits or autonomy or work effectiveness to be higher from a telecenter would motivate one to use the center more often, or conversely, higher-engagement or higher-frequency telecommuters could be expected to have more positive views than others of the telecenter as a place to work.

For the engagement clusters, the only (marginally, $p = 0.07$) significant effect is the cluster main effect for professional development. The descriptive statistics show that *Persisters* are more positive about this aspect, with respect to all three workplaces, than are the *Decliners*. This comfort level with supervisor communication and visibility to management may partly account for their choice to telecommute more consistently. The average perceptions of workplace personal benefits, autonomy, and work-effectiveness do not differ between *Persisters* and *Decliners*, nor are there any significant interactions between cluster and workplace, so these variables do not help explain why some people telecommute more consistently than others.

With respect to the frequency clusters, none of the four workplace perception factors showed significant cluster or interaction effects; thus, they do not explain why some people telecommute more frequently than others.

Demographic Traits. As indicated earlier, five demographic variables were analyzed: the four categorical variables of gender, age, education, income, and the continuous variable, one-way commute distance. Due to the small sample size, the age, education, and income variables were collapsed into two categories each, as indicated in the Appendix.

With respect to the engagement clusters, the only variable showing a (marginally, $p = 0.09$) significant difference was commute distance: the average one-way distance for *Persisters* was 51 miles, compared to 38 miles for *Decliners*. This result is consistent with expectations that a longer commute will motivate an individual to telecommute more consistently. Gender, age, education, and income did not help to distinguish *Persisters* from *Decliners*.

With respect to the frequency clusters, however, three variables were significant at the 0.10 level or better: gender, age, and commute distance. *Low Frequency* telecommuters were significantly more likely to be female (61%) than were *Medium Frequency* telecommuters (36%). This is an intriguing finding, especially in view of other studies suggesting that women see more benefit to telecommuting, are more inclined to prefer telecommuting,[14] and telecommute more frequently,[15] than men. It is possible, as has been found elsewhere,[16] that although women see greater

benefits to telecommuting than men do, they are more constrained than men in their ability to telecommute (due to external constraints such as occupational differences or managerial bias, as well as internal constraints such as risk aversion and fear of negative impacts on career advancement).

Low Frequency telecommuters tend to be younger than the *Medium Frequency* ones. Younger employees may be more centered around the social atmosphere of the workplace and hence may want to telecommute less. Finally, again consistent with expectations, *Medium Frequency* telecommuters have a longer average commute distance (47 miles) than do the *Low Frequency* telecommuters (34 miles). This result is especially interesting since, despite expectations, several previous empirical studies[17] failed to identify such a relationship between commute distance and frequency (although the relationship between commute length and the choice to telecommute at all appears to be relatively robust across numerous studies).

Education and income did not differ significantly between the clusters (although, for the first-six-months window, it was found that *Low Frequency* telecommuters had significantly higher educational levels than did the *Medium Frequency* participants. It could be that more-educated workers hold more responsible positions that require their on-site presence more often, but more research is needed to reconcile this result with the one indicating that *Low Frequency* telecommuters tend to be younger).

Summary and Conclusions

This study explores some dynamic aspects of telecommuting from the individual's perspective, by analyzing patterns of telecommuting engagement and frequency over a six-month period. Some interesting findings emerge, although they must be considered tentative due to the small sample sizes of the study. For example, the largest engagement cluster (45% of the sample) exhibited persistently high levels of engagement across the analysis window. Cross-tabulation of engagement and frequency cluster memberships, however, shows that nearly half of these *Persisters* telecommuted at relatively low frequencies. Overall, nearly two-thirds of the sample fell into the *Low Frequency* cluster, averaging just under one telecommuting occasion per two-week period (and conversely, the *High Frequency* cluster constituted just 8% of the sample but accounted for 28% of the total telecommuting occasions). There was also some evidence of migration from higher to lower telecommuting frequencies over time.

If these findings are representative of salaried telecommuters as a whole (they are consistent with anecdotal evidence from a number of telecommuting consultants and program organizers), then it is important to calibrate expectations accordingly. In particular, they highlight the need to count not just nominal telecommuters, but actual telecommuting occasions, in analyzing and forecasting the impacts of telecommuting on other areas such as transportation.[18]

In the search for variables associated with different patterns of engagement and frequency, it is striking how few significant relationships were found (although again the sample size is a limitation here, as is the fact that only before-telecommuting measures on the variables of interest could be used). Only two variables were significantly associated (p-values ≤ 0.09) with telecommuting engagement: *Persisters* had more positive perceptions of their professional development prospects at both the regular and telecommuting workplaces than did

Decliners, and they also had one-third longer commutes on average. Perceptions of productivity, job satisfaction, supervisor relationship, co-worker interaction, and workplace-based personal benefits, autonomy, and work-effectiveness did not differ significantly between these groups, nor did gender, age, education, or income. Several variables were significantly associated with frequency: *Low Frequency* telecommuters had higher job satisfaction scores, lower supervisor relationship scores, were more likely to be female or younger, and had shorter commutes compared to *Medium Frequency* telecommuters.

Management-related issues seem to play a substantial role in affecting both the engagement in, and frequency of, telecommuting. The factor labeled 'professional development' is based on statements relating to concerns about communicating with the supervisor, about visibility to management, and about social and professional interaction (all loading negatively, so that a higher score on the factor represents less concern about these issues). The factor labeled 'supervisor relationship' is based on statements related to working well with and being appreciated by the supervisor, and having a fair opportunity for promotion. Having a more positive perception on the professional development dimension appears to be important to sustaining persistent engagement in telecommuting, while having a more positive score on the supervisor relationship dimension is important to maintaining higher frequencies of telecommuting. Previous research[19] has documented the importance of management support to the adoption and ongoing retention of telecommuting programs; the current results indicate that such support is also critical to the level of ongoing individual participation in an already-approved program.

Finally, the cluster analysis methodology employed here appears to be a useful approach to studying the dynamic patterns of telecommuting engagement and frequency. It would be desirable to conduct a similar study with a larger sample and longer time frame, so that both start-up and seasonality effects could be controlled for simultaneously and so that relationships could be tested more rigorously. As Ho[20] recommends, it would be ideal to collect data on perceptions of telecommuting both before and at multiple points of time after telecommuting began, so that it would be possible to model telecommuting engagement, frequency, and duration as functions of time-varying explanatory variables.

Notes and References

1. The Federal Highway Administration and the California Department of Transportation Office of Traffic Operations funded collection of the data analyzed here, under Interagency Agreement No. 60T381/A4. The opinions expressed in this paper are those of the authors and do not reflect official positions of those agencies.
2. Richard I. Hartman, Charles R. Stoner and Raj Arora, 'An investigation of selected variables affecting telecommuting productivity and satisfaction', *Journal of Business and Psychology*, 6, 2, 1991, pp. 207–25; C. S. Yap and H. Tng, 'Factors associated with attitudes towards telecommuting', *Information and Management*, 19, 1990, pp. 227–35; Adriana T. Bernardino, Moshe Ben-Akiva and Ilan Salomon, 'Stated-preference approach to modeling the adoption of telecommuting', *Transportation Research Record*, 1413, 1993, pp. 22–30; Hani S. Mahmassani, Jin-Ru Yen, R. Herman and Mark A. Sullivan, 'Employee attitudes and stated preferences toward telecommuting: an exploratory analysis', *Transportation Research Record*, 1413, 1993, pp. 31–41; Mark A. Sullivan, Hani S. Mahmassani and Jin-Ru Yen, 'Choice model of employee participation in telecommuting under a cost-neutral scenario', *Transportation*

Research Record, 1413, 1993, pp. 42–48; Patricia L. Mokhtarian and Ilan Salomon, 'Modeling the desire to telecommute: the importance of attitudinal factors in behavioral models', *Transportation Research A*, 31, 1, 1997, pp. 35–50; Patricia L. Mokhtarian, 'A synthetic approach to estimating the impacts of telecommuting on travel', *Urban Studies*, 35, 2, 1998, pp. 215–41.

3. Krishna V. Varma, Chaang-Iuan Ho, David Stanek and Patricia L. Mokhtarian, 'Duration and frequency of telecenter use: once a telecommuter, always a telecommuter?' *Transportation Research C*, 6, 1998, pp. 47–68.
4. Patricia L. Mokhtarian, Chaang-Iuan Ho, Shun Hung, Toan Lam, Elizabeth Raney, Lothlorien Redmond, David Stanek and Krishna Varma, *Residential Area-Based Offices Project: Final Report on the Evaluation of Impacts*, Institute of Transportation Studies, University of California at Davis, Research Report No. UCD-ITS-RR-97–17, September 1997. Available on the Internet at http://www.engr.ucdavis.edu/~its/tcenters/repts/final/Title.htm.
5. Varma *et al., op. cit.*
6. *Ibid.*
7. Ravikumar Meenakshisundaram, *A Cluster Analysis of Telecommuting Frequencies: The Residential Area-Based Offices Project*, Master's Thesis, Department of Civil and Environmental Engineering, University of California, Davis, March 2000.
8. B. Everitt, *Cluster Analysis*, Edward Arnold, London, 1993.
9. Meenakshisundaram, *op. cit.*
10. Patricia L. Mokhtarian and Michael Bagley, 'Modeling employees' perceptions and proportional preference of work locations: the regular workplace and telecommuting alternatives', *Transportation Research A*, 34, 4, 2000, pp. 223–42.
11. David M. Stanek and Patricia L. Mokhtarian, 'Developing models of preference for home-based and center-based telecommuting: findings and forecasts', *Technological Forecasting and Social Change*, 57, 1/2, 1998, pp. 53–74.
12. Mokhtarian *et al.*, *op. cit.*
13. Meenakshisundaram, *op. cit.*
14. Sullivan *et al.*, *op. cit.*
15. Jill S. Mannering and Patricia L. Mokhtarian, 'Modeling the choice of telecommuting frequency in California: an exploratory analysis', *Technological Forecasting and Social Change*, 49, 1, 1995, pp. 49–73.
16. Patricia L. Mokhtarian, Michael N. Bagley and Ilan Salomon, 'The impact of gender, occupation, and presence of children on telecommuting motivations and constraints', *Journal of the American Society for Information Science*, 49, 12 (Special Issue on Social Informatics), 1998, pp. 1115–34.
17. Mannering and Mokhtarian, *op. cit.*; Piotr Olszewski and Patricia L. Mokhtarian, 'Telecommuting frequency and impacts for the State of California pilot project participants', *Technological Forecasting and Social Change*, 45, 2, 1994, pp. 49–73; Patricia L. Mokhtarian, 'The transportation impacts of telecommuting: recent empirical findings', in P. R. Stopher and M. Lee-Gosselin (eds), *Understanding Travel Behaviour in an Era of Change*, Pergamon (Elsevier Science Ltd), Oxford, Great Britain, 1997, pp. 91–106; Chaang-Iuan Ho, *Modeling the Engagement in Center-based Telecommuting*, Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of California, Davis, 1998.
18. Susan L. Handy and Patricia L. Mokhtarian, 'Planning for telecommuting: measurement and policy issues', *Journal of the American Planning Association*, 61, 1 (Winter), 1995, pp. 99–111.
19. Steve Fireman, 'A proposed model for telecommuting withdrawal', in P. J. Jackson and J. M. van der Wielen (eds), *Proceedings of Workshop on New International Perspectives on Telework: From Telecommuting to the Virtual Organization*, Brunel University, UK, 31 July–2 August 1996, pp. 136–52; Ursula Huws and F. E. K. Britton, *Barriers to Teleworking*, Report prepared in support of the European Telework Development Initiative, 1997. Available on the Internet at www.ecoplan.org/ze2/tw/barriers_fs.htm.
20. Ho, *op. cit.*

Appendix: Variable Definitions

Job Context Perception Factors

Productivity: The eight statements loading on this factor represent various aspects of productivity: the quantity, quality, timeliness of work completed and overall perception of productivity, both from the respondent's perspective and the respondent's view of the supervisor's perspective.

Job satisfaction: Statements relating to a sense of accomplishment and satisfaction load positively on this factor, whereas statements relating to the tedium of the job, and lack of appreciation by the supervisor, load negatively.

Supervisor relationship: Positive statements about working well with one's supervisor and having a fair opportunity for promotion load positively on this factor, whereas statements about not being appreciated by the supervisor and not communicating well load negatively.

Co-worker interaction: The statements loading positively on this factor are getting along with one's co-workers and having an effective work team, whereas being frustrated by a lack of adequate resources load negatively.

Workplace-specific Perception Factors

Personal benefits: Statements loading heavily on this factor relate to a variety of potential benefits of a given workplace, including the ability to control one's work environment, have a low-stress commute, minimize distractions and effectively balance work and household responsibilities.

Autonomy: Statements loading on this factor relate to independence from supervision, freedom to adjust one's schedule and having one's work judged by results.

Work-effectiveness: Statements loading positively on this factor relate to being motivated and working effectively at a given workplace. Statements loading negatively include stress, lack of self-discipline and distraction from others.

Professional development: Statements loading negatively on this factor relate to concerns about communicating with the supervisor, visibility to management and professional and social interaction.

Demographic Traits

Gender: Binary variable equal to 1 if respondent is female and 2 if male.

Age: Binary variable equal to 1 if the respondent's age is less than or equal to 45, and 2 otherwise.

Education: Binary variable equal to 1 if the respondent's education level is less than or equal to 'some college or technical school', and 2 if s/he has a four-year college degree or higher.

Income: Binary variable equal to 1 if the annual household pretax income is less than or equal to $55,000, and 2 otherwise.