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The impact of the residential built environment on work at home adoption and frequency

An example from Northern California

Wei (Laura) Tang
University of California, Davis [a]

Patricia L. Mokhtarian
University of California, Davis [b]

Susan L. Handy
University of California, Davis [c]

Abstract: Working at home is widely viewed as a useful travel-reduction strategy, and it is partly for that reason that considerable research related to telecommuting and home-based work has been conducted in the last two decades. This study examines the effect of residential neighborhood built environment (BE) factors on working at home. After systematically presenting and categorizing various relevant elements of the BE and reviewing related studies, we develop a multinomial logit (MNL) model of work-at-home (WAH) frequency using data from a survey of eight neighborhoods in Northern California. Potential explanatory variables include sociodemographic traits, neighborhood preferences and perceptions, objective neighborhood characteristics, and travel attitudes and behavior. The results clearly demonstrate the contribution of built environment variables to WAH choices, in addition to previously-identified influences such as sociodemographic predictors and commute time. BE factors associated with (neo)traditional neighborhoods were associated both positively and negatively with working at home. The findings suggest that land use and transportation strategies that are desirable from some perspectives will tend to weaken the motivation to work at home, and conversely, some factors that seem to increase the motivation to work at home are widely viewed as less sustainable. Accordingly, this research points to the complexity of trying to find the right balance among demand management strategies that sometimes act in competition rather than in synergy.

Keywords: Work at home; telecommuting; teleworking; multinomial logit; residential location; built environment

1 Introduction

Despite increases in nonwork travel over the past few decades, the journey to work arguably remains the most important trip purpose in urban areas. In the United States, it constituted about 22 percent of passenger trips and 27 percent of passenger vehicle miles traveled in 2001 (Hu and Reuscher 2004). Another estimated 27.3 percent of trips were chained to the commute (Federal Highway Administration 2005). Commute travel continues to contribute to the rising levels of congestion in major metropolitan areas, particularly given its concentration during particular times of day (Texas Transportation Institute 2005). Accordingly, finding ways to alter the temporal or spatial patterns of the work trip is a high priority for transportation planners and policymakers.

Working at home (WAH) is widely viewed as one promising strategy for reducing peak-period commute travel. WAH, however, comprises at least three relatively distinct segments. There is no consensus on definitions, but in keeping with previous distinctions made by one of the authors (Mokhtarian 1991; Mokhtarian *et al.* 2005), we distinguish telecommuters, home-based business (HBB) workers, and those whose home work is primarily overflow from the regular workplace. "Telecommuters" refers to salaried employees working at home or at a location close to home instead of commuting to a conventional workplace at the usual time, communicating with the office by telephone and computer. "Home-based business (HBB) workers" refers to self-employed individuals whose business is primarily operated or managed from home. "Overtime home-workers" (also referred to as "supplementers", e.g. by Kraut 1988; or "work permeators"

[a] wtang@ucdavis.edu.
[b] Professor, Dept. of Civil and Environmental Engineering and Faculty Associate, Institute of Transportation Studies, plmokhtarian@ucdavis.edu.
[c] Professor, Dept. of Environmental Science and Policy, slhandy@ucdavis.edu.

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by Salomon 1990) are those who conduct work at home on evenings or weekends, after making a conventional commute during the workweek. Since they have little or no impact on transportation, the last group is of no further interest in this study, except to note that they are generally included in publicized estimates of the number of people who work at home, and thereby contribute to an exaggerated view of the potential for WAH to reduce commute travel. For example, among the 20.7 million people reported to "usually" (at least once a week) do "some work at home as part of their primary job" by the U.S. Bureau of Labor Statistics Work at Home 2004 study, about 10.2 million were described as "just taking work home from the job" (U.S. Bureau of Labor Statistics 2005).

To better understand the potential transportation impacts of WAH, it is necessary to understand the kinds of people most likely to work at home, and how often they choose to do so. A number of studies (reviewed in the next section) have analyzed characteristics of home workers, and the adoption and frequency of telecommuting in particular. For the most part, however, those WAH-related choices have been related to sociodemographic characteristics, and occasionally to telecommuting and travel-related attitudes and lifestyle orientations. We are not aware of any studies that have investigated the impact of the built environment (BE) (aside from commute distance, time, and sometimes speed for salaried employees) on WAH choices. Yet, it is plausible to expect the built environment to matter. Characteristics of one's surroundings heavily influence how easy it is to travel, both locally and regionally, and how appealing it is to be at a particular location, such as one's residential neighborhood. Thus, such characteristics could also influence one's choice to travel or to stay at home more. Under the assumption that the BE does matter, policymakers have adopted land-use-related policies such as promoting neo-traditional development and smart growth principles in order to change travel behavior.

The purpose of this paper, then, is to explore the influence of the built environment on the decision to work at home, and on the frequency of doing so. The remainder of this paper is organized as follows: The next section briefly reviews previous related research. The subsequent section describes the data available to the study, followed by a discussion of our specific hypotheses, the conceptual model structure, and the estimation methodology. We then present and interpret a multinomial logit model of WAH adoption/frequency. The last section summarizes the study and suggests future research directions.

2 Literature Review

A number of studies have analyzed the characteristics of home workers (Kuenzi and Reschovsky 2001; Mokhtarian and Henderson 1998; Plaut 2005; Safirova and Walls 2004), adoption of telecommuting (Bernardino *et al.* 1993; Mahmassani *et al.* 1993; Mokhtarian and Salomon 1996, 1997; Walls *et al.* 2007), and frequency of telecommuting (Mannering and Mokhtarian 1995; Olszewski and Mokhtarian 1994; Sullivan *et al.* 1993; Varma *et al.* 1998; Walls *et al.* 2007) in the last two decades.

In reviewing the first of these aspects, namely home workers' characteristics, we will focus on HBB workers and telecommuters, and (in view of length considerations) report results only from studies using large-sample, general-purpose surveys in which an effort was made to achieve representativeness. Such surveys show that telecommuters tend to have the highest personal and household incomes, followed by, on average, HBB workers and non-home-based workers in turn (Kuenzi and Reschovsky 2001; Mokhtarian and Henderson 1998; Safirova and Walls 2004; Yeraguntla and Bhat 2005). Compared to conventional workers, telecommuters are more likely to be males, well-educated, employed in the finance, insurance, and real estate (FIRE) industry, older (Safirova and Walls 2004), and work part-time (Drucker and Khattak 2000; Popuri and Bhat 2003; Yeraguntla and Bhat 2005); HBB workers are no more likely to have health limitations (Pratt 1993); and on the whole, those who work at home are more computer-proficient and use computers more heavily (Drucker and Khattak 2000), are more likely to be female and well-educated (Kuenzi and Reschovsky 2001), are less likely to be 25 or younger, and are more likely to be 55 or older (Plaut 2005).

Although descriptive studies comparing home workers to conventional commuters on a variable-by-variable basis are useful, such comparisons can be misleading. Differences that are significant when viewed in isolation may be confounded with other variables that are the true sources of the difference; when controls are introduced for these third-party variables, the initial differences are no longer significant. Conversely, differences that are not significant in isolation may become so when other factors are taken into account. Accordingly, it is important to develop models of WAH adoption that include multiple explanatory variables simultaneously. Empirical findings of previous models (of either stated hypothetical choice or revealed preference for telecommuting) are summarized in Table 1. Not surprisingly, factors that increase the monetary cost of telecommuting decrease the propensity to prefer or choose it, as do variables indicating job unsuitability, manager unwillingness, and a preference for social interaction. Long or stressful commutes increase the utility of telecommuting, as do perceptions that telecommuting will offer flexibility and other personal benefits, children at home, and the presence of support infrastructure (such as computers) at home.

Arguably, WAH frequency is even more important than the adoption choice itself: from the standpoint of transportation, air quality, and other impacts, it matters a great deal whether the adopted choice to WAH occurs five days a week or less than once a month. Aside from some descriptive studies (including those cited in Section 3.2), we are not aware of any empirical analyses of WAH frequency for HBB workers. However, several models of telecommuting frequency have been developed, as summarized in Table 1. Naturally, telecommuting cost still works as a constraint on frequency, as it does in the adoption context. The need for social interaction with coworkers, telecommuting experience (ironically), and taking transit to work all have negative effects on telecommuting frequency. On the other hand, age, the presence of children in the household, and intensity of computer usage tend to increase telecommuting frequency. Interestingly, even discounting the study by Olszewski and Mokhtarian (1994), which involved a small sample, mixed results are found for gender and commute length: they are not always significant, nor do they always have impacts in the same direction. A few studies have simply examined patterns of telecommuting frequency over time, without modeling frequency as a function of explanatory variables. In addition to the finding by Bernardino *et al.* (1993) that prior experience with telecommuting decreased its preferred frequency, several other studies found that actual telecommuting frequency decreased over time (Mokhtarian *et al.* 2004; Mokhtarian and Meenakshisundaram 2002; Wernick and Khattak 2005). Mokhtarian *et al.* (2004) found that people (at least in their specific sample) telecommuted often enough to more than compensate for their longer commutes, so that the total commute distance traveled for telecommuters was (on average) equal to or less than that of non-telecommuters.

Since the focus of this study is the impact of residential built environment on WAH adoption and frequency, it is important to specify what comprises the built environment. The TRB Committee on Physical Activity, Health, Transportation, and Land Use 2005, xiii defines the built environment "broadly to include land-use patterns, the transportation system, and design features that together provide opportunities for travel and physical activity," and categorizes the BE in terms of three geographic scales: building/site, neighborhood, and region. Table 2 identifies detailed elements of the residential BE at each of these three scales that could be expected to affect WAH adoption and/or frequency, together with the expected sign of the influence. Major findings of the reviewed studies involving those elements are also summarized. Note that the direction of causality with respect to the identified empirical relationships is uncertain (Moos and Skaburskis 2008; Muhammad *et al.* 2007a, 2008), and thus we refer to them as associations rather than impacts.

In theory, we assume that all of the BE elements in Table 2 could influence WAH adoption or frequency to some degree, by affecting either the desirability of commuting or the attractiveness of WAH. However, note that relatively few of the elements hypothesized to influence WAH have been tested empirically, illustrating a gap in the literature which invites further investigation. The present study addresses that gap, but by no means purports to fill it. Because the survey from which our data was obtained was not designed for this particular study, measures concerning many of those detailed elements are not available. In this study, we focus on the elements belonging to the neighborhood and region scales. The variables available to us will be discussed in Section 3.3, and hypotheses with respect to those BE variables in particular are presented in Table 5.

3 Data, Hypotheses, and Methodology

As noted earlier, the general purpose of this study is to explore the effect of residential neighborhood built environment (BE) traits (including preferences, perceptions and objective characteristics), as well as attitudes toward transportation, on WAH adoption and frequency. In some previous studies, attitudinal factors were included in telecommuting adoption models, but they were extracted from surveys specifically designed to analyze telecommuting. For example, both Mokhtarian and Salomon (1997) and Yen and Mahmassani (1997) found that attitudes related to the personal benefits, family effects, and workplace interaction effects of telecommuting were important to the preference for that option. Since the present study is based on a survey not originally designed for this purpose, we lack a number of variables relevant to telecommuting. Instead, however, we have a rich collection of attitudinal and objective measures of the built environment, as well as general transportation-related attitudes, which have not previously been studied in the context of telecommuting. In the remainder of this section, we first describe the available data, then present some specific hypotheses

Table 1: Empirical results of previous telecommuting adoption and frequency studies.

Telecommuting Adoption		
Study	Dependent variable	Significant explanatory variables (impact on propensity to adopt)
Bernardino and Ben-Akiva (1996)	Actual choice of commuting	Positive impact: Desire to improve lifestyle quality (flexibility to adjust one's schedule to the work load and personal needs and to avoid commuting); higher salary to telecommuters Negative impact: Increase in work-related costs; lower salary to telecommuters
Mokhtarian and Salomon (1996)	Actual choice of telecommuting	Positive impact: Overtime; commute stress (attitudinal factor) Negative impact: Misunderstanding; lack of manager support; job unsuitability; technology requirements and office discipline (attitudinal factor relating to the negative aspects of working away from the normal office)
Yen and Mahmassani (1997)	Stated preference for telecommuting	Positive impact: 5% salary increase; number of children in the household; number of personal computers at home; commute distance; job suitability; family orientation (attitudinal factor) Negative impact: 5% salary decrease; telecommuting cost; need for face-to-face communication with co-workers; importance of social interactions with co-workers
Mokhtarian and Salomon (1997)	Preference for telecommuting	Positive impact: Perception of telecommuting as important in situations of disability/parental leave; stress; perception of telecommuting providing personal benefits; commute stress; commute time; job suitability Negative impact: Importance of workplace interaction; household distractions; perception of the commute as beneficial
Popuri and Bhat (2003)	Actual choice of telecommuting	Positive impact: Female with children; licensed driver; drive to work; work in a private company; length of service; fax availability Negative impact: Female; transit to work
Walls *et al.* (2007)	Actual choice of telecommuting	Positive impact: Older than 30; college degree; white; other adult in HH; job in architecture/engineering/"other professional", sales, or management Negative impact: Children ages 6–17; working in transportation, communications, retail trade industries; employer having 25–249 employees; job in health services

to be tested in the study, and finally discuss potential methodological approaches together with the one finally selected.

3.1 Data collection

The data used in this study came from a self-administered 12-page survey mailed in two rounds in late 2003 to households in eight neighborhoods in Northern California. (For additional details suppressed here due to length limitations, see Handy *et al.* 2005). The neighborhoods were selected to capture variation on three dimensions—neighborhood type (traditional vs. suburban), size of the metropolitan area (larger vs. smaller city), and region of the state (Bay Area vs. Central Valley)—in a full factorial design (all eight possible combinations represented). For each neighborhood, two databases of residents were purchased from a commercial provider: a database of movers and a database of non-movers. The movers included all current residents of the neighborhood who had changed residences within the previous year. From this database, we drew a random sample of 500 residents for each neighborhood. The database of non-movers consisted of a random sample of 500 residents not included in the movers list for each neighborhood. The survey was administered using a mail-out, mail-back approach. The initial survey was mailed out at the end of September 2003, with reminder postcards, a second mailing of the survey, and a second reminder postcard. As an incentive to complete the survey, respondents were told they would be entered into a drawing to receive one of five $100 cash prizes; the winners were selected in December.

Table 1: Empirical results of previous telecommuting adoption and frequency studies.

Telecommuting Frequency		
Study	Dependent variable[a]	Explanatory variables (impact on frequency)
Bernardino *et al.* (1993)	Stated telecommuting frequency preference	Positive impact: Income increase; number of children in the household; commuting time savings; not offered chance to telecommute Negative impact: Telecommuting cost; 10% income reduction; prior experience with telecommuting
Sullivan *et al.* (1993)	Stated telecommuting frequency preference	Positive impact: Round-trip commute time; commute stops per week; average time using computer per day; being female with children; being female; being married Negative impact: Length of time with firm; need for face-to-face communication; work end time
Olszewski and Mokhtarian (1994)	Actual frequency of telecommuting	Positive impact: Work as information professional Negative impact: Profession in policy/engineering/financial field No significant impact: Age; gender; commute length; presence of children
Mannering and Mokhtarian (1995)	Actual frequency of telecommuting	Positive impact: Small children in household; household income per capita; work computer availability indicator; family orientation indicator Negative impact: Prefer to work with team rather than solo; adoption of flextime; need for face-to-face control over work No significant impact: Commute length; recent departure time change in response to congestion; managerial/professional occupation; amount of time spent on face-to-face contacts
Mokhtarian and Meenakshisundaram (2002)	Actual freqency of telecommuting	Positive impact: Age; commute length Negative impact: Being female No significant impact: Education; income
Popuri and Bhat (2003)	Actual freqency of telecommuting	Positive impact: Female with children; age; being married; no. of vehicles; work in a private company; fax availability; multiple phone lines at home Negative impact: Transit to work
Walls *et al.* (2007)	Actual frequency of telecommuting	Positive impact: College degree; company has formal telework program; commute time; days worked in survey week; holding two or more jobs Negative impact: Full-time employee

[a] Frequency reflects how many days people choose to telecommute over a specific time period. Different studies use different definitions; normally, it is an ordinal variable such as: "[never, once per month, 1 or 2 days a week, more than 2 days a week]" or "[never, infrequently, frequently, full time]."

Table 2: Built environment elements hypothesized to influence working at home.

Scale	Element [expected sign]	Related studies	Findings [a]
Building/home	• Home size (availability of private office space) [+] • Dwelling type (single-family) [+] • Interior layout (separate room) [+] • Thickness of walls/soundproof [+] • Space for storage [+] • Computer availability [+] • Internet accessibility and speed [+]	Moos and Skaburskis (2007, 2008); Yen (2000)	Positive association: Household size; larger single-family detached house; log house size Negative association: Small living space
Neighborhood	• Population density [±] • Street pattern (connectivity) [±] • Green/open space [+] • Land use mix (e.g. variety and number of destinations) [±] • Availability of parks [+] • Walkability/bikeability [±]	Ettema (2010); Moos and Skaburskis (2007, 2008); Muhammad *et al.* (2007a, 2008, 2007b)	Positive association: Inner city; suburban if the spouse is also a home worker
Region	• Commute distance [+] • Regional accessibility [±] • Transportation supply (e.g. highways [−]; public transit [−]; bicycle paths [+])	Ettema (2010); Moos and Skaburskis (2008); Muhammad *et al.* (2008, 2007b)	Positive association: Longer commute distance Negative association: Rural center residential area

[a] We report the results in terms of the association of the explanatory variables with the adoption of WAH.
Source: The three scales and several of the specific BE elements were drawn from Figure 1-2 of TRB (TRB Committee on Physical Activity, Health, Transportation 2005).

The original database consisted of 8000 addresses but only 6746 addresses turned out to be valid. The number of responses totaled 1682, for a response rate of 24.5 percent. This is within expectations for a survey of this length; typical response rates for a survey administered to the general population are 10-40 percent (Sommer and Sommer 1997). A comparison of sample characteristics to population characteristics (based on the 2000 U.S. Census) shows that survey respondents tend to be older on average than residents of their neighborhood as a whole, and that households with children are underrepresented for most neighborhoods (Handy *et al.* 2005, Table 1). Median household income for survey respondents was higher than the census median for all but one neighborhood, a typical result for voluntary self-administered surveys. However, since the intent of our study is to model relationships among variables (rather than to estimate distributions of variables), and sociodemographic differences are explicitly controlled for in the model, it is not necessary that our sample be strictly representative (Singleton and Straits 1999).

For the purposes of the present study, we first screened out the 408 cases that were missing data on the WAH question (described in detail in Section 3.2).[1] We also screened out 27 retired and unemployed respondents, and one whose work status could not be ascertained, to leave 1246 workers constituting our study sample. Some key sociodemographic character-

[1] Of those 408 cases, 328 were missing data on both commute and work-status questions (respondents were asked to skip the commute questions if they were not employed), and hence were presumed to be unemployed and thus not in the population of interest to this study. For the 49 of those 408 cases that provided commute information, the mean commute times and distances did not significantly differ from those of the included sample. Thus, we do not believe that the omission of this group substantively biases the results.

istics for the study sample as a whole and for the WAH subset of the sample are shown in Table 3. The table shows that relatively fewer females adopt WAH than males, since they constitute a lower share of the WAH adopters sample than for the sample as a whole. WAH adopters are also slightly (though significantly) more likely to be part-time employees, but have higher household income and education levels than non-adopters. The remaining characteristics—age, commute distance, and commute time—are similar for both groups.

3.2 Variables

Dependent variables

The purpose of this study is to model WAH adoption and frequency. The assortment of dependent variables we investigated was created from the survey question asking, "How often do you work at home instead of making the trip to work? ___ days per month". Although we deliberately focused on home work as a substitute for commuting (i.e. the salaried telecommuter form of WAH), it is likely that many respondents who work exclusively at home and would not otherwise have a conventional commute would answer this question as well (because if one does work at home at all, it could be unsatisfying to answer "0" to this question). Unfortunately, the survey did not ask the relevant question about the nature of the respondent's employment, and thus we are unable to tell with certainty which form of WAH is involved in each case.

In the remainder of the discussion, therefore, we assume the non-zero responses to this question constitute a mixture of telecommuters and HBB workers. The remaining 944 cases, who work at home zero days per month, are classified in the "not at all" category for our final adoption/frequency model (see Section 3.4). A number of options were considered for representing WAH frequency (see Tang *et al.* 2008, for additional details). When WAH adopters are grouped into frequency categories, the distribution is somewhat bimodal, with peaks at both low and high levels of frequency. This frequency distribution, expressed on a days-per-week basis, resembles one obtained from the U.S. Census Bureau, Survey of Income and Program Participation (SIPP) (Kuenzi and Reschovsky 2001). Those data show that the higher-frequency group is dominated by those who work exclusively at home, whereas the lower-frequency group is dominated by "mixed" workers who work elsewhere as well as at home. Although the SIPP study did not formally classify home workers as telecommuters or home-based business workers according to our definitions, it seems plausible to infer that the high-frequency WAH cases tend to be self-employed HBB workers, while the low-frequency ones are more likely to be salaried telecommuters.

Similarly, the 2004 Work at Home survey (U.S. Bureau of Labor Statistics 2005) showed that among salaried employees, only about 14 percent worked at home for 35 hours or more per week, compared to almost 22 percent of self-employed workers. The average weekly time worked at home for salaried and self-employed workers in that study was 19 and 25 hours, respectively. These findings are also consistent with data from numerous small-sample studies of telecommuting (Handy and Mokhtarian 1995; Mokhtarian *et al.* 2005; Safirova and Walls 2004; Varma *et al.* 1998), in which the average telecommuting frequency falls around 1.2 days a week (or five days a month). Unfortunately, our data do not permit us to make those classifications definitively, and using frequency alone is certainly not definitive (since some telecommuters work at home virtually full-time, and some self-employed workers only work at home a limited amount). However, as a reasonable approximation, in the discussions that follow we will treat the lower-frequency groups (1–8 days/month) as being predominantly telecommuters, and the highest-frequency group (nine or more days/month) as being a mixture of telecommuters and HBB workers.

Given the differences between telecommuters and HBB workers that were discussed in Section 2, we experimented with excluding the higher-frequency group from the modeling exercise, thereby focusing mainly on telecommuters (see Tang *et al.* 2008, for details). However, by retaining both groups, we obtained satisfying results that made the most efficient use of the available information, while still providing insights into distinctions between the choices of each type of WAH. We also experimented with keeping the dependent variable as the ratio-scaled number of days per month, versus various combinations into ordinal categories. Ultimately, the best results (balancing conceptual interpretability and goodness-of-fit considerations) were obtained by dividing the responses into five frequency categories: zero days, one day, 2–4 days, 5–8 days, and nine or more days a month (respectively labeled as Alternatives 0–4 in the discussion of results below).

Explanatory variables

The explanatory variables can be grouped into the following four categories:

Commute trip attributes Both intuition (as expressed by our hypothesis in Table 5) and previous research (e.g. Bernardino *et al.* 1993; Mahmassani *et al.* 1993; Mokhtarian and Salomon 1997; Nilles 1988; Sullivan *et al.* 1993; Yen and Mahmassani

Table 3: Sample sociodemographic characteristics.

	Pooled data (sample for WAH adoption model)	WAH adopters only (sample for WAH frequency model)
Number of cases	1246	302
Percentage female	51.1	47.8
Average age (years)	43.2	43.7
Median total annual household income	$75 000	$90 000
Average work status[a]	0.89	0.85
Average education level[b]	3.2	3.6
Mean commute distance (miles)[c]	12.3	12.9
Mean commute time (min.)[c]	20.0	20.4

[a] 1=Full-time; 0=Part-time.

[b] 1=High school diploma or less; 2=College or technical school; 3=Four-year college degree or technical school degree/certificate; 4=Graduate school; 5=Completed graduate degree(s).

[c] For those respondents who initially supplied commute information (see discussion in Section 3.2). Sample sizes for these two variables are 1225 and 1235 for the pooled data; 283 and 284 for the WAH adopters only.

1997) indicate that commute characteristics, particularly distance or time to work, influence the choice to work at home, at least for telecommuters. Thus, we consider the distance to the primary work place, travel time (minutes) needed to get to there, and travel speed to potentially affect the choice to work at home. However, this variable is somewhat troublesome, since individuals who are self-employed and work at home do not have a commute. Indeed, among the 50 highest-frequency home workers in the sample (those working at home nine or more days a month), 26 had either responded "0" to the commute miles and minutes questions (16 cases), or left them blank (10 cases). For the 10 respondents who left those questions blank, we filled in zeroes on the assumption that they were self-employed and worked at home. This means, however, that we can expect a different role of commute length for telecommuters than for HBB workers: for the former group, the longer the commute, the more likely they are to work at home, and the more frequently they are inclined to do so, whereas for the latter group, a short (in fact, zero) commute is associated with working at home, and doing so very frequently. Accordingly, commute variables in the models should be interpreted as interaction variables (the commute variable multiplied by a dummy variable that equals 1 for salaried employees who commute, and 0 otherwise), and thus their coefficients (together with those of the accompanying "main effects" dummy variables) interpreted as representing the impact of commute characteristics for those who have a commute.

BE characteristics and neighborhood preferences Respondents were questioned about their perceptions of their current residential neighborhoods and about their preferences for residential neighborhood characteristics. Thirty-four neighborhood characteristics were presented to respondents, who were asked to rate each characteristic on a four-point scale from "not at all true" (1) to "entirely true" (4) (perceptions of current neighborhoods), and on a four-point scale from "not at all important" (1) to "extremely important" (4) (preferences for residential neighborhood traits). A previous factor analysis of these characteristics had produced six factors (Handy *et al.* 2005). For this study, we conducted separate factor analyses of the characteristics related to accessibility, in the expectation that regional and local accessibility are distinct concepts (Handy 1993) and could have opposite impacts (negative and positive, respectively) on WAH. This yielded one factor for regional accessibility and three factors capturing local characteristics: "safety and quietness," "diversity," and "outdoor appeal" (Table 4). The latter two local factors relate particularly well to local accessibility, as well as other traits such as density and aesthetic qualities.

In addition, objective measures of accessibility were estimated for each respondent based on distance along the street network from home to a variety of destinations classified as institutional (bank, church, library, and post office), maintenance (grocery store and pharmacy), eating-out (bakery, pizza, ice cream, and take-out), and leisure (health club, bookstore, bar, theater, and video rental). Specific accessibility

Table 4: Factors for perceived neighborhood characteristics.

Factor [a]	Statement	Loading [b]
Regional accessibility	Easy access to downtown	0.667
	Easy access to a regional shopping mall	0.659
	Easy access to freeway	0.626
	Good public transit service (bus or rail)	0.507
	Good bicycle routes beyond the neighborhood	0.448
Safety and quietness	Quiet neighborhood	0.736
	Low level of car traffic on neighborhood streets	0.673
	Safe neighborhood for walking	0.575
	Good street lighting	0.554
	Attractive appearance of neighborhood	0.434
	High level of upkeep in neighborhood	0.397
	High quality living unit	0.395
	Safe neighborhood for kids to play outdoors	0.380
Diversity	Diverse neighbors in terms of ethnicity, race, and age	0.530
	Other amenities such as a pool or a community center available nearby	0.521
	High quality K-12 schools	0.496
	Lots of people out and about within the neighborhood	0.486
	Shopping areas within walking distance	0.485
	Parks and open spaces nearby	0.475
	Sidewalks throughout the neighborhood	0.471
	Economic level of neighbors similar to my level	0.459
	Safe neighborhood for children to play outdoors	0.396
	Lots of interaction among neighbors	0.385
Outdoor appeal	Large front yards	0.689
	Big street trees	0.543
	Large back yards	0.510
	Variety in housing style	0.490
	Attractive appearance of neighborhood	0.414
	Lots of off-street parking (garages or driveways)	0.356

[a] To ensure the separation of factors, statements relating to regional accessibility were analyzed separately from the others. Principal axis factoring with varimax rotation was employed in both cases.

[b] Represents the correlation between the statement and the factor.

measures included the number of different types of businesses within specified distances, the distance to the nearest establishment of each type, and the number of establishments of each business type within specified distances. Commercial establishments were identified using online business directory listings, and ArcGIS was used to calculate network distances between addresses for survey respondents and commercial establishments.

Travel attitudes The survey asked respondents whether they agreed or disagreed with a series of 32 travel-related statements on a five-point scale from 1 ("strongly disagree") to 5 ("strongly agree"). Again, a previous factor analysis had been conducted, in which six underlying dimensions were identified: pro-bike/walk, pro-travel, travel minimizing, pro-transit/walking, safety of car, and car dependent (Handy *et al.* 2005). Using this factor analysis, however, we found it difficult to explain the effect of pro-transit/walking on WAH adoption and frequency: a pro-transit attitude is more related to regional accessibility and may decrease the propensity to work at home, as Popuri and Bhat (Popuri and Bhat 2003) found for actual transit usage (Table 1) (because seeing or using transit as an option may make the commute less stressful); whereas pro-walking is more related to local BE characteristics (pro-walkers may be more inclined to work at home so that saved commute time can be spent on walking, perhaps in their pleasant local neighborhood). Because this factor was based on a series of statements comparing either walking or transit to driving, it was relatively easy to split it into two variables by averaging the responses to the walking versus driving statements separately from those to the transit versus driving statements, and naming the two new variables pro-walking and pro-transit. Similarly, we also created a new pro-bicycling variable, using the statements comparing bicycling to driving (see Tang *et al.* 2008, for details).

Sociodemographics The survey also captured variables including gender, age, employment status (part-time or full-time), educational background, household income, household size, number of children in the household, mobility constraints and residential tenure.

3.3 Hypotheses

Before outlining our hypotheses regarding impacts of the built environment onworking at home, it is appropriate to address first the question of causal direction. Specifically, it is reasonable to wonder whether the decision to work at home at a certain frequency could also affect the built environment, in the sense that planning to work at home may influence the choice of residential location. To the extent that it does, the coefficients in our model, which only embodies the opposite direction of causality (residential location influencing WAH frequency) are subject to endogeneity bias. A number of studies (Ellen and Hempstead 2002; Ettema 2010; Mokhtarian 1998; Muhammad *et al.* 2007a,b) have analyzed the relationships between residential location and telecommuting, and several (Ellen and Hempstead 2002; Mokhtarian *et al.* 2004; Moos and Skaburskis 2008; Muhammad *et al.* 2007a) have alluded to uncertainty regarding the direction of causality. We are only aware of one empirical study that examined this question with (quasi-) longitudinal data, but that study (Ory and Mokhtarian 2006) found that those who are telecommuting and then move tended to relocate *closer* to their workplaces, whereas those who began telecommuting following a residential relocation tended to have moved much farther from their workplaces. This result weakens the common assumption behind the endogeneity concern (i.e. that telecommuters tend to self-select more distant neighborhoods in which to live). More importantly, their data support the hypothesis that telecommuting more often follows rather than precedes the relocations. As has been remarked elsewhere (Mokhtarian 1998), given that most telecommuting appears to be relatively low-frequency and short-lived (or at least episodic rather than continuous), we consider it quite reasonable that WAH is not prompting large numbers of people to move, and therefore plausible that the dominant direction of causality is the one we model in this paper (BE → WAH). Nevertheless, it would certainly be desirable to obtain additional empirical evidence on this question. In particular, working at home may exert a stronger influence on residential location for those who WAH essentially full-time than for those who do so only one day a week or so. Even for the former group, however, many (though not all) operators of home-based businesses will find it important to live near their customer base, and thus may be more likely to choose a central, regionally accessible residential location rather than the stereotypically decentralized, exurban one.

With respect to the direction of causality modeled in this study, Tang *et al.* (2008) present a number of hypothesized relationships between the available variables and WAH adoption. With respect to commute and sociodemographic variables, our hypotheses correspond to the previous findings summarized in Table 1 and the literature review of Section 2. Here, to save space, we focus on our primary interest: variables representing the built environment. Because those who mix WAH with regular commuting constitute a different segment from those who work at home full-time, we separate our hypotheses according to those two categories. Table 5 presents hypotheses we are interested in exploring in this study. We acknowledge that, given the exploratory nature of this research, some of them were developed *post hoc*. Note that for many BE characteristics, both positive and negative associations with WAH are plausible.

3.4 Methodological approaches

There are several reasonable approaches for modeling the decisions of WAH adoption and frequency. Some studies (e.g. Mokhtarian and Salomon 1996, 1997) have modeled adoption alone, as a binary preference or choice. However, in many cases, it seems likely that the decisions to WAH and how frequently to do so are made simultaneously rather than sequentially, suggesting the desirability of addressing the two decisions jointly rather than separately. The simplest method for addressing both adoption and frequency together is to model the two decisions as a single choice, using a frequency variable whose alternative values consist of "not at all" together with non-zero frequency levels (e.g. Sullivan *et al.* 1993). With our frequency variable comprising count data rather than just ordinal categories, as is often the case, we actually had at least three modeling approaches open to us under this single-choice method: the ordinal response (probit or logit) model (e.g. Bernardino *et al.* 1993); the multinomial logit model (MNL, potentially with nested logit (NL) variations, e.g. Mannering and Mokhtarian 1995); and the negative binomial regression model (with Poisson regression as a special case, e.g. Ho 1997). Among these three approaches, the first and third make explicit use of the respectively ordinal and interval (actually ratio) nature of the data. The second approach (MNL) treats each frequency category as nominal and makes no ordinal assumptions; although this may seem to be a less desirable approach, it is actually a more flexible one in some ways, since it allows the influence of a given explanatory variable to differ by category. At least in the context of auto ownership modeling, two studies comparing MNL to ordered logit (Bhat and Pulugurta 1998; Potoglou and Susilo 2008)—which collectively tested models on seven independent data sets—found MNL to offer superior results; a third study (Matas and Raymond 2008, 187) found the forecasting performance of ordinal response and MNL models to be "almost indistinguishable."

Alternatively, adoption and frequency can be specified as two separate choices, modeled either one at a time or jointly. To our knowledge, only two studies (Popuri and Bhat 2003; Sener and Bhat 2010) have modeled the two decisions as separate but joint choices, while others have modeled them either together as one single choice or as unconnected choices. Table 6 compares the single-choice and two-choice approaches to modeling adoption and frequency.

Our own original intention was to model adoption and frequency (conditioned on adoption) as a simultaneous two-choice system. We initially explored separate models for each choice, and in the case of frequency explored all three approaches described above. The results for the ordinal response and negative binomial regression models were decidedly unsatisfactory, with few significant variables and low goodness of fit (GOF).[2] In contrast, the MNL approach provided meaningful results and a GOF within the typical range for disaggregate travel behavior models, and accordingly, we chose to retain this approach. However, in contrast to the cases for ordinal response (Greene 2002) and negative binomial regression models (Greene 1994; Hilbe 2007), the theory pairing an MNL outcome model with a binary selection model has been developed only relatively recently (personal communication with Chandra Bhat, July 27, 2006). Accordingly, in adopting the MNL approach we were limited to estimating a single model on the full sample, having "0" as the lowest frequency category. A key theoretical drawback to this approach, the sometimes-restrictive Independence of Irrelevant Alternatives (IIA) assumption (Ben-Akiva and Lerman 1985) can be empirically tested. If IIA is empirically shown not to be violated, then there may in fact be little or no advantage to the two-choice approach, given the flexibility of the MNL model mentioned above.

In Section 4 below, we present and discuss our preferred MNL model (and tests for violations of the IIA assumption). Several alternative model structures are presented in Tang *et al.* (2008).

4 Results

4.1 MNL adoption/frequency model interpretation

Table 7 summarizes the estimation results of the combined adoption/frequency MNL model, taking "0 days/month" WAH as the lowest frequency category. The ρ^2 value (Ben-Akiva and Lerman 1985) is 0.501, which is considered quite acceptable in the context of disaggregate discrete choice models. The 0.501 value is based on the equally likely model, and

[2] We estimated these models on WAH adopters: given the disproportionate number of zero-frequency cases in the sample, i.e. non-adopters, it did not seem prudent to combine them with the positive-frequency cases. We also tried the zero-inflated Poisson model but it gave unsatisfactory results as well.

Table 5: Hypothesized relationships between BE-related variables and WAH adoption.

Variable	Hypothesis for mixed (home and elsewhere) workers	Hypothesis for full-time home workers
Commute trip attributes:		
Distance to work/ Minutes to work	The longer the commute, the more onerous it may be, and the more likely WAH will be chosen.	Not applicable.
Average speed of commute trip	Higher commute speeds imply less congestion and hence less motivation to WAH.	Not applicable.
Neighborhood characteristics:		
Neighborhood type	**Urban:** a) More convenient public transportation and shorter distances mitigate the propensity to choose WAH; b) Heavy traffic and advanced telecommunication facilities make WAH more attractive.	**1. Suburban:** a) The lower availability of public transportation in suburban areas may have little impact on fully home-based workers since they do not engage in regular commutes; b) People living in suburban areas might be less likely to be HBB owners, since such people may need to interact with their customers often, in which case a more centrally located urban neighborhood becomes more convenient. **2. Urban:** a) More convenient public transportation and shorter distances may mitigate the propensity to WAH full-time; however, the greater centrality of urban neighborhoods could be more attractive to HBB workers; b) Heavy traffic and advanced telecommunication facilities make full-time WAH more attractive.
Preferences and perceptions regarding the BE	**1. Regional accessibility:** The better the regional accessibility, the easier the commute trip is likely to be (and hence the less likely to WAH). **2. The other three BE factors:** for the most part, higher values could be presumed to reflect a more appealing residential neighborhood, which would make WAH more attractive. However, there could be some heterogeneity; e.g. quietness may be more conducive to WAH for some people, while liveliness would make it more appealing to WAH for others.	**1. Regional accessibility:** a) The better the regional accessibility, the easier commuting is likely to be (and hence the less necessary/ attractive to WAH full-time); b) Greater regional accessibility supports a larger client base, which makes a home-based business more feasible. **2. The other three BE factors:** for the most part, higher values could be presumed to reflect a more appealing residential neighborhood, which will make WAH full-time more attractive/feasible.
Objective BE characteristics	1. More convenient and diversified activity opportunities make the neighborhood more appealing, which will make WAH more attractive; 2. Too much local activity might be considered a distraction if WAH.	1. More convenient and diversified activity opportunities make the neighborhood more appealing, which will make WAH full-time more attractive; 2. Too much local activity might be considered a distraction, so people are less likely to WAH full-time.

Table 6: Comparison of approaches to modeling adoption and freqency together.

	As a single choice	As two choices
Conception of the choice	Selection among frequency levels, including zero as just another frequency choice.	• Conceptually separate (even if temporally simultaneous) choices (1) to adopt or not, and (2) of frequency given adoption. • The zero ("non-adopt") alternative is directly compared only to a generalized "adopt" alternative in which different frequencies are not distinguished. • Falls naturally into the selection-model family of methods (e.g. Heckman 1990), in which the binary adoption model represents the classic "participation" equation and the frequency model represents the "outcome" equation.
Influence of observed variables	• With ordinal response or count models, not allowed to differ by alternative. • With multinomial response models (e.g. MNL or NL), can differ by alternative.	• Allowed to differ between adoption and frequency. • Possibilities for different (non-zero) frequencies same as for the single choice model.
Unobserved variables	• With ordinal response or count models, effects not allowed to differ by alternative. • With MNL models, not allowed to be correlated across alternatives. • With NL models, not allowed to be correlated across nests; in particular (in a structure having the "adopt"/"not adopt" choice as the upper level, and the frequency categories in the lower level of the "adopt" branch), not allowed to be correlated between adoption and frequency choices.	Allowed to be correlated between adoption and frequency choices.

since the market shares are unbalanced (76.4%, 6.8%, 10.2%, 3.3% and 3.3% for the five categories respectively), the market-share model alone (the model containing just the constant terms) has a ρ^2 of 0.474. Re-estimating the final model without constant terms (not shown), however, yields a ρ^2 of 0.428 (the final log-likelihood is -980.001), indicating that most of the explanatory power of the model lies in the "true" variables (i.e. they are helping to explain why the shares are unbalanced), not just the constant terms. All coefficient estimates show the expected signs, and are significant at the 0.06 level or better, except for the one on the dummy variable for having a commute (which, for proper specification, should accompany the commute time variable with which it is interacted).

To allow us to compare coefficient magnitudes on a scale-independent basis, we (as endorsed by Miller 2005 for logistic regression models) report the coefficients obtained when all explanatory variables are standardized (analogous to the standardized coefficients in regression), as well as the conventional unstandardized coefficients.

In analyzing the coefficients individually, one immediate observation is that only two variables (perceived regional accessibility and full-time worker) out of ten are significant to more than one frequency category. This illuminates why the ordinal response and negative binomial regression approaches to modeling frequency were not successful: it appears that, in effect, each frequency category represents a distinct segment, motivated by substantially different considerations. Thus, we discuss the variables associated with each frequency category in turn.

Choice of the lowest frequency category (0 days/month) is based on two sociodemographic variables and one objective BE variable. The negative coefficient for income is consistent with most previous studies (Kuenzi and Reschovsky 2001; Mokhtarian and Henderson 1998; Safirova and Walls 2004; Yeraguntla and Bhat 2005). It is probable that income is serving as a proxy for the skill-level of the job, with jobs requiring higher skills potentially being more information-oriented and hence more telecommutable; this finding probably also

Table 7: Combined adoption/frequency MNL model estimation results (base alternative: 1 day/month, or "very low").

Variables	Coefficient/Standardized coefficient[a] (p-value)			
	0 days/mo. (not WAH)	2–4 days/mo. (low)	5–8 days/mo. (medium)	≥9 days/mo. (high)
Constant:				
ASC (model on unstandardized vars)	3.800 (0.000)	−1.964 (0.024)	0.408 (0.298)	0.402 (0.278)
ASC (model on standardized vars)	2.516 (0.000)	0.310 (0.051)	−0.822 (0.000)	−0.785 (0.000)
Subjective BE factors:				
Perceived regional accessibility		−0.288/−0.210 (0.053)	−0.494/−0.361 (0.034)	
Objective BE characteristics:				
No. of institutional establishments	0.102/0.176 (0.048)			
No. of eating-out places w/in 400 m		0.193/0.234 (0.022)		
Travel attitudes:				
Pro-bicycling attitude		0.342/0.300 (0.008)		
Pro-transit attitude		0.243/0.207 (0.062)		
Commute trip attitudes:				
Commute time (one-way, mins.)		0.0105/0.208 (0.021)		
Dummy variable for having a commute [b]		0.557/0.115 (0.456)		
Sociodemographics:				
Current household annual income [c]	−0.0000102/ −0.334 (0.000)			
Education level [d]	−0.187/−0.238 (0.004)			
Full-time worker			−1.132/−0.360 (0.007)	−1.333/−0.424 (0.001)

No. of observations (813, 72, 109, 35, and 35, respectively, in the five frequency categories)	1064
Final log-likelihood, $\ell(\beta)$	−855.357
Log-likelihood for market share model, $\ell(\text{MS})$	−900.012
Log-likelihood for equally likely (EL) model, $\ell(0)$	−1712.442
No. of explanatory variables (including constants)	16
$\rho^2_{\text{ELbase}} = 1 - \ell(\beta)/\ell(0)$	0.501
Adjusted $\rho^2_{\text{ELbase}} = 1 - [\ell(\beta) - 16]/\ell(0)$	0.491
χ^2 (between final model and EL model)	1714.170
χ^2 (between final model and MS model)	89.310

[a] Coefficients for models on unstandardized variables and standardized variables respectively. p-values for all coefficients except the alternative-specific constants (ASCs) do not differ between the two forms.

[b] This variable is included although insignificant, because the commute time variable is the interaction of commute time with the commute DV (see discussion in the text), and thus the main effect of having a commute must also be accounted for.

[c] Income is a continuous number representing the current total annual combined income of all the working adults in the household (the number falls in the range from 0 to $120,000 or more).

[d] As defined in Table 3.

reflects a value-of-time effect, in which those earning higher incomes are more motivated to save commuting time. Education probably also serves as a proxy for skill-level, with the significance in our model consistent with Mahmassani *et al.* (1993) and Walls *et al.* (2007), who found that individuals with higher levels of education are more inclined than others to work independently and to prefer WAH.

Although perceived BE characteristics were not significant in this frequency category, one objective BE characteristic—the number of institutional establishments within 400 meters—is included in our final model. The positive impact of the number of institutional establishments (church, library, post office and bank) on the choice not to work at home is unexpected, but this variable may be a marker for the unpleasant side of a higher-density residential neighborhood: noise, traffic, crowdedness and potentially other disadvantages.

The choice of 2–4 days/month (the most popular of the WAH frequency categories) has the richest set of explanatory variables, including one BE perception variable, an objective BE variable, two travel attitudes (pro-transit and pro-biking), and commute time. Those perceiving their neighborhood to have greater regional accessibility are less likely to work at home at that frequency (and similarly for the 5-8 days/mo., medium-frequency category), compared to the low and high frequency levels. It is reasonable to believe that if perceived regional accessibility is high, there will be less incentive to reduce commuting for the salaried employee (pointing to very low or zero WAH frequencies), and greater access to the market supporting the operation of a home-based business (pointing to very high frequencies).

The objective BE variable—the number of eating-out places within 400 meters—has the expected positive sign, suggesting a neighborhood with appealing coffee break and lunch options. Thus, the availability of nearby dining alternatives is an incentive to work at home at the 2–4 days-a-month frequency level, though other considerations are apparently more important for other frequency categories.

Two attitudes toward transportation are also significant in this WAH frequency category. The pro-bicycling attitude has a positive influence on the choice of this category. High scores on this measure tend to reflect a preference for bicycling over driving. Thus, this variable captures a desire to reduce auto travel by bicycling, and probably to some extent a desire to bicycle for its own sake. Such a person may be more inclined to work at home as yet another way to reduce auto travel and potentially to provide more time for recreational cycling. Further, this variable has a rather high and statistically significant positive correlation (0.63) with the "travel minimizing" factor, suggesting that its presence in the model may also be tapping a desire to reduce the total amount of travel.

Individuals with more positive views about transit are more likely to work at home at this frequency level. This finding is somewhat counter to our expectations: we hypothesized that a positive perception of transit would reduce the motivation to work at home. However, since this factor represents a contrast between transit and driving, a high score means a more negative view of driving, and hence a greater motivation to work at home—at least at this low frequency—is plausible under those circumstances.

Finally for this segment, the longer the commute trip, the more likely a person is to work at home at this frequency, compared with the lowest-frequency base alternative of one day per month. This result is expected, and consistent with the popular image of WAH as a trip reduction strategy.

The choice to work at home at medium frequencies (5–8 days/month) is based on the same perceived regional accessibility factor discussed for the previous category, and work status. Full-time workers are less likely to work at home with medium (or high) frequency. This is consistent with Yeraguntla and Bhat (2005), who also found that part-time employees tend to telework more frequently than full-time employees, as well as (with respect to adoption) Drucker and Khattak (2000) and Popuri and Bhat (2003). This may be because the same considerations motivating individuals to work part time (such as familial and other responsibilities) may also influence them to pursue jobs that provide flexible work opportunities.

Finally, WAH at the highest frequency only depends on full-time work status, and the explanation is the same as that discussed for the medium frequency category. The fact that only one variable is significant to high-frequency WAH is probably due to the heterogeneity of this category, as discussed in Section 3.2, with one consequence of that heterogeneity being the plausibility of effects in opposite directions (as indicated in Table 5) cancelling out across this group. Among the 36 cases in this category retained for the model (the remainder being excluded due to missing data on one or more of the significant variables), 22 report commute information while 14 appear to be "pure" HBB workers with no commutes at all. Given the differences between these two forms of WAH, it is not surprising that we have difficulty in predicting a choice in which they are (necessarily) lumped together.

4.2 Nested logit (NL) test for IIA violations

Since the dependent variable consists of five ordinal alternatives, it is reasonable to expect unobserved variables to be correlated across alternatives (especially, e.g., for adjacent alternatives), and thus for the Independence of Irrelevant Alternatives (IIA) assumption of the MNL model to be violated (Ben-Akiva and Lerman 1985). We tested for IIA violations in two ways: with the Hausman-McFadden test (Hausman and McFadden 1984), comparing the coefficients of the model estimated on the full choice set with those of a model estimated on a subset of alternatives; and with the more general nested logit (NL) model formulation having the MNL model as a special case. For every Hausman-McFadden test we conducted, the test statistic could not be computed, a result that is quite common (Small and Hsiao 1985) and suggestive but not conclusive that IIA holds. In addition, we tested numerous nested logit (NL) structures, both by starting from the final MNL model and by building new models from the ground up. In every case, however, after pruning the model of statistically insignificant and/or conceptually unsupported variables, we either obtained estimates of the IV parameter that were greater than one (which is theoretically impermissible), or failed to reject the null hypothesis that the parameter was equal to one (indicating that the model was equivalent to the MNL model). Hence, overall, the evidence of both sets of tests supports the assumption that IIA holds, and thus we retain the MNL structure of Table 7 as our final model.

Although there was a conceptual basis for believing that these alternatives might have correlated error terms, the literature (McFadden *et al.* 1977) reminds us that IIA holding or not is a property of the model specification (i.e. which variables are observed versus unobserved), not of the intrinsic qualities of the alternatives themselves. Changing variables from generic to alternative-specific is one potential remedy for a violation of IIA (Ben-Akiva and Lerman 1985; McFadden *et al.* 1977), and it has been our experience elsewhere (Choo and Mokhtarian 2004; Mokhtarian and Bagley 2000) that MNL models in which all or many variables are alternative-specific to start with often meet the IIA assumption. It has also been pointed out (Horowitz 1991) that the omitted variables that are correlated across alternatives are often attitudes; hence a model (such as ours) in which attitudes are observed tends to reduce the correlations among the unobserved influences on choice.

5 Conclusions and suggestions for future research

This study modeled the adoption and frequency of working at home on the part of more than 1000 residents of eight neighborhoods in northern California, with particular attention to the influence of the residential neighborhood built environment (BE). In our final model distinguishing the "0 days/month" category and four ordered non-zero frequency categories, only two explanatory variables (perceived regional accessibility and full-time worker) were found significant to more than one category, suggesting that each frequency category represents a distinct segment, motivated by substantially different considerations.

In addition to confirming the expected influence of commute time, work status, household income, and education level on adoption and frequency decisions, we found that several subjective and objective BE characteristics were significant for at least one frequency category each. Individuals who perceive high regional accessibility for their neighborhood tend to work at home either very little (perhaps because commuting is less burdensome) or a great deal (perhaps because they operate a HBB that is well-positioned with respect to its customer base). Two objective measures of density, the number of eating-out places and the number of institutional establishments within 400 meters of the residence, had opposite effects. The higher the density of eating-out places in the neighborhood, the greater the frequency of working at home two to four days a month (compared to lower and higher frequencies), whereas the higher the density of institutions (such as churches, libraries, post offices, and banks – likely a proxy for negative aspects of the built environment such as heavy traffic, noise, and crowding), the lower the propensity to work at home at all. The counteracting effects of these two variables are each plausible, but point to the "mixed blessing" offered by higher density neighborhoods.

The pro-bicycling and pro-transit attitude variables significant in the model are indirectly related to the built environment as well. One's preference for bicycling probably depends in part on how pleasant it is to cycle in one's neighborhood, and the positive influence of this attitude on the choice to work at home at low frequencies is consistent with that view, as well as potentially reflecting a general desire to reduce automobile use. On the other hand, those preferring transit over driving are more likely to work at home at low frequencies than at higher frequencies (perhaps because their predilection for transit reduces the stress of commuting) or not at all (reflecting a desire to avoid at least some commute travel, particularly if driving is involved).

Overall, then, we found considerable nuance in the relationships of the built environment to working at home. Although this research should be regarded as exploratory and subject to further confirmation, our results, pending that confirmation, have correspondingly complex policy implications. For example, improving regional accessibility may support home-based businesses but reduce the motivation of salaried employees to telecommute, even though telecommuting would bring other public benefits as well. Increasing the commercial density near residential areas may increase the attractiveness of working at home for some, while diminishing it for others. Thus, land use and transportation strategies that are desirable from some perspectives will tend to weaken the motivation to work at home, and conversely, some factors that seem to increase the motivation to work at home are widely viewed as less sustainable. In an independent study that reinforces this point, Moos *et al.* (2006) found that teleworking tended to increase housing consumption (from investing in non-work-related amenities to increase the comfort of spending much more time at home, to furnishing the home office, to adding another room to the residence, to moving to a larger home). Accordingly, these results point to the complexity of trying to find the right balance among demand management strategies that sometimes act in competition rather than in synergy.

Several directions for future research are indicated. Using the same data set, one could explore refined model specifications, including the more theoretically elegant joint equation system. Perhaps more importantly, however, the limitations of these data point to the need to further investigate the role of the built environment in the choice to work at home through a study particularly designed for that purpose. Such a study would collect data on (a) various aspects of the BE (such as those presented in Table 2); (b) individuals' suitability for WAH—including occupation, which may be correlated with type of residential location (see Ellen and Hempstead 2002) and whose inclusion therefore might alter some of the BE relationships found here; (c) preferences for WAH specifically; and (d) a more clearly delineated categorization of home workers (self-employed home-based business owner versus salaried telecommuter). Ideally, such a study would involve structural equations modeling on longitudinal data to help clarify the directions of causality. In addition, given the existence of latent classes having heterogeneous residential location preferences (Ettema 2010; Walker and Li 2007), it seems likely that taste heterogeneity also exists with respect to the influence of residential location on WAH decisions. For example, it is plausible that the same built environment characteristics would be considered conducive to working at home by some individuals (lively neighborhood), and deleterious to doing so by others (noisy and crowded neighborhood). It would be desirable to better understand those differences.

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