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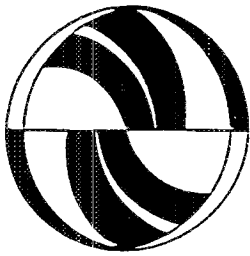
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Reprint
UCTC No. 415

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Analyzing the Travel Behavior of Home-Based Workers in the 1991 CALTRANS Statewide Travel Survey

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ABSTRACT

This study compares the travel patterns of three different groups of workers identified in the 1991 Caltrans Statewide Travel Survey: home-based business (HBB) workers, home-based telecommuters (HBT), and non-home-based (NHB) workers. HBB workers have the highest average daily trip rate of the three groups, while rates for HBTs and NHB workers are statistically equivalent. Differences in drive-alone trip rates and time spent traveling are similar to those of other studies, with HBTs making 0.6 (18%) fewer trips and traveling 46% less time than NHB workers. Although HBB workers have the highest work-related trip rate, the NHB group makes nearly twice as many work and work-related trips combined as the HBB group, and more than three times as many as HBTs. The temporal distribution of HBB trips is unimodal, in contrast to the traditional bi-modal distribution for NHB trips and a flat distribution (from 9 a.m. to 6 p.m.) for HBTs. The HBB group is quite heterogeneous, with distinct differences across industry in overall trip rates, freeway use, and rates by purpose.

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INTRODUCTION

Home-based work is a multifaceted phenomenon, encompassing full- and part-time home-based businesses as primary sources of income (whether on a fully self-employed or contract-work basis); moonlighting at a home-based business (HBB) as a secondary source of income; working overtime on evenings and weekends, whose practitioners are sometimes referred to as supplementers (Kraut 1988, 1989) or *work permeators* (Salomon 1990); and home-based telecommuting, in which a salaried employee works at home part or full time instead of commuting to a conventional workplace at the usual time (Mokhtarian 1991).

Definitions and measurement are problematic, but home-based work in all its forms appears to constitute a sizable and growing component of the labor market. Growth in home-based work is related to the increased use of contingent workers (Giuliano 1998), which in turn is driven by a variety of economic and demographic forces, and facilitated by advances in information and communications technologies. The same factors are driving and facilitating a rise in the number of mobile workers, whether home-based or non-home-based—that is, individuals with heavy work-related travel demands (Pratt 1997). Figure 1 illustrates a range of estimates of the number of home-based workers in the United States in recent years, taken from a variety of sources.

To date, most research in this area has focused on the first and last types of home-based work—primary home-based businesses and telecommuting—and this paper is no exception. A number of studies have examined characteristics of home-based workers (Pratt 1984, 1993a; Pratt and Davis 1985; Horvath 1986; Deming 1994; Gurstein et al. 1995), the adoption of home-based work (Bernardino et al. 1993; Mahmassani et al. 1993; Mokhtarian and Salomon 1996, 1997), and impacts of home-based work on the family (Bailyn 1989; Christensen 1988a, 1988b, 1989; Costello 1988; Gurstein 1991; Hall 1989; Mokhtarian et al. 1998; Olson 1988; Salomon and Salomon 1984; Shamir 1991; Shamir and Salomon 1985). Several other studies have analyzed the travel behavior specifically of telecommuters (Kitamura et al. 1990; Pendyala et al. 1991; Hamer et al. 1991; Hamer et

al. 1992; Mokhtarian et al. 1995; Henderson et al. 1996; Koenig et al. 1996; Henderson and Mokhtarian 1996; RTA 1995), although these studies are all based on small, specialized, self-selected samples of fewer than 100 telecommuters.

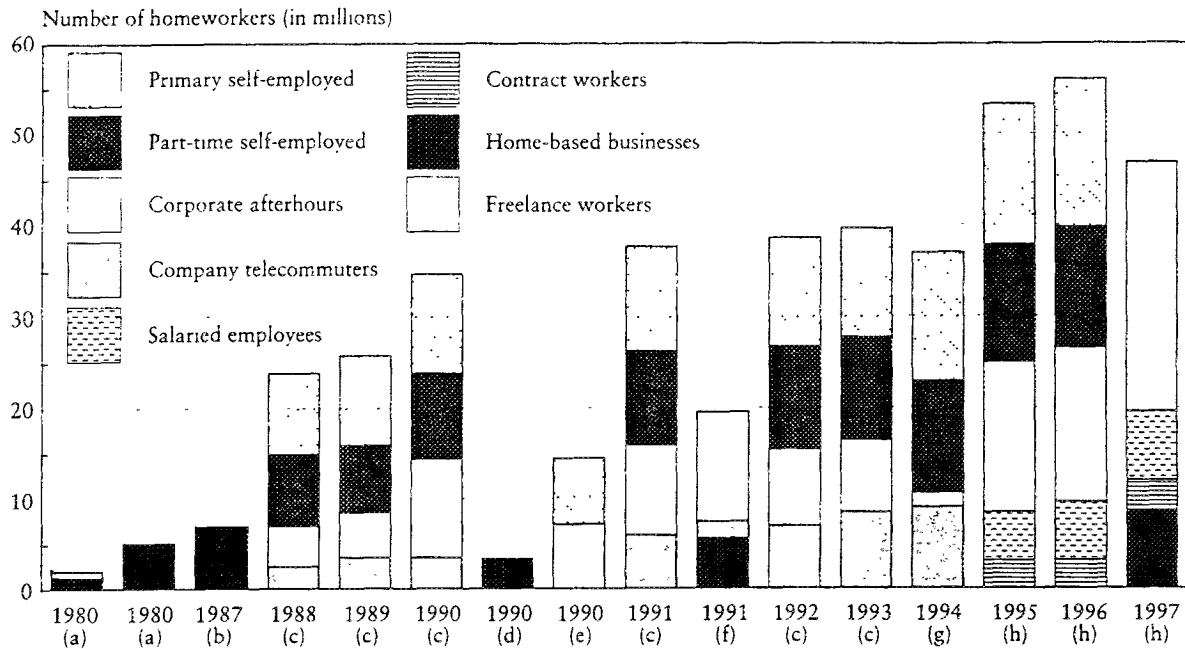
Little or no study has been performed of the travel behavior of HBB workers, even though their behavior may differ from that of conventional, non-home-based (NHB) workers in important ways.¹ For example, HBB workers typically would not have a commute trip *per se*, but their work-related travel may exceed that of NHB workers on average. HBB work-related trips may tend to occur off-peak, but it is not known whether their temporal distribution differs significantly from that of NHB workers' work-related travel. It is not even known how simple indicators such as number of total trips and vehicle-miles traveled (VMT) differ among types of workers.

Typical urban travel demand forecasting practice (Harvey et al. 1993) is to model trip generation rates separately by purposes such as home-based work, home-based other, and non-home-based.² Home-based trip generation is modeled as a function of demographic characteristics such as household size and vehicle ownership, and non-home-based trip generation is often estimated simply by factoring home-based trips according to the relative proportions of these types in the calibration sample. Nowhere in the typical trip generation process are the work location (in-home or out-of-home) or employment type (self-employed or salaried) used as explanatory variables, which could be an important omission. For example, if home-based workers tend to replace conventional commute trips with shorter but more numerous work-related trips occurring predominantly off-peak, then a marked increase in the number of home-based businesses may appreciably alter the ratio of commute trips to other trips, as well as the spatial and temporal characteristics of travel for the population as a whole. Thus, in view of the

¹ Although this study focuses on the comparison of home-based and non-home-based workers, the same comment could be made for the overlapping groups of contingent and mobile workers.

² These descriptions refer to *trips* rather than *workers*, unlike the usage throughout the rest of this paper.

FIGURE 1 Estimates of the Number of U.S. Homeworkers



General note: Different terms are used from one source to the next. There may be overlap between terms taken from different sources, and the same term may mean different things for different sources. The top four categories in the figure legend are mutually exclusive with each other but not always with the bottom two categories, which were generally used in studies different from the first four (1997 being an exception). The fifth and sixth categories form a partition of the fourth category. To reduce the number of category labels used, in some cases the authors of this paper judgmentally classified workers into an existing category. The notes below attempt to use the sources' original language as much as possible.

(a) In the 1980 census, 2.1 million paid workers reported that they "usually got to work the previous week" by "working at home," as cited in Pratt and Davis (1995). Of these, 1.3 million were employees of their own company or self-employed but unincorporated. The remainder were salaried employees of public or private organizations. A 1980 taxpayer usage study of federal income tax returns, cited by the same source, estimated the number of nonfarm proprietors located at home to be 5.1 million. Many of these are likely to constitute moonlighting or hobby activities rather than primary jobs.

(b) The 1987 Characteristics of Business Owners survey cited in Pratt (1993b) found 7 million home-based businesses, "including the majority of women-owned businesses (54.6%) and nearly half of all non-minority male-owned businesses (49.8%)." Note that the number of home-based businesses will not equal the number of home-based business workers, because a single individual may work in more than one home-based business (Pratt and Davis 1985) and a single business may employ more than one worker in the home.

(c) The number of home-based workers of all kinds (including afterhours work) increased from nearly 25 million in 1988 to 39 million in 1993, according to the Annual Work at Home Survey conducted by Link Resources, cited in Braus (1993). Braus discusses the discrepancy between the Link Resources numbers and the CPS numbers (see note f).

(d) The 1990 census reported 3.4 million workers who "usually got to work the previous week" by "working at home," as cited in USDOT (1994).

(e) A 1990 proprietary survey cited in Pratt (1993b) found 7.4 million home business owners (including moonlighters), plus 7.2 million freelance workers.

(f) The May 1991 Current Population Survey (Deming 1994) found 20.0 million nonfarm employees (18.3% of the workforce) doing some work at home for the primary job: 12.2 million of these were work permeators doing overtime work at home for no extra pay, 1.9 million were telecommuters, and the remaining 5.6 million were home-based businesses. However, despite the fact that the work at home was to be associated with the primary job for all of these workers, only 3 million of the 5.6 million self-employed homeworkers worked eight hours a week or more, and only 976,000 of them worked 35 hours a week or more.

(g) Source: Find/SVP Annual Work-at-Home Survey, personal communication with Joanne H. Pratt representing Find/SVP. The 1994 data for company telecommuters (defined by Find/SVP to include contract workers as well as salaried employees) is also cited in Russell (1996).

(h) Source: Undated (1997) press release on the Find/SVP web site at <http://etrg.findsvp.com/prls/pr97/telecom.html>. At the time of this writing, this source was difficult to interpret: e.g., it states that 52.1 million Americans do some form of work at home, but the following subcategories "bring work home" (27.5 million), "telecommute" (11.1 million, earlier disaggregated into 7.7 million conventional salaried employees and 3.4 million contract workers, but the current version is confusing on this point) and "operate a home business" (8.7 million) only add to 47.3 million. Separately, 18.3 million Americans are projected to be self-employed and do some work at home, but this group partially overlaps the previous one.

growing popularity of both types of home-based work, it is important to increase our understanding of their travel characteristics.

This paper describes a first effort to analyze the travel behavior of HBB workers. It also offers the first representative-sample investigation of the telecommuting-day travel behavior of telecommuters. Due to limitations of the data it is not the definitive study, but the findings presented here constitute a useful foundation on which to pursue further research. This paper uses the 1991 California State Department of Transportation (Caltrans) Statewide Travel Survey data to compare key travel indicators across three groups: home-based business workers, home-based telecommuters (HBT), and non-home-based or conventional workers. The next section describes the data set and how the sample used in this study was defined. The following section presents the comparison of travel measures (trips and travel time in total and by purpose, mode, and time of day) across the three study groups, and the final section offers some conclusions and directions for further research.

DATA AND SAMPLE SELECTION

Overview of the Data Set

In 1991, Caltrans conducted a statewide travel survey (Ochoa and Jones 1993). Nearly 34,000 individuals provided travel information for a 24-hour period on a weekday. Respondents recorded trip data in a "memory jogger" format, later retrieved through telephone interviews. Each respondent was weighted appropriately to replicate the 1990 Census distributions in terms of household vehicle ownership, owner/renter status, and geographical location.

The data were collected for general transportation analysis purposes, and not specifically for the study of home-based work. This constitutes both a strength and a weakness for the current study. The strength lies in the fact that the sample is large and representative. Empirical telecommuting research to date has been based primarily on specific small-scale demonstration programs that usually have an explicit goal of reducing travel. Participants in these programs tend to be geographically localized

and self-selected, and may be biased in favor of demonstrating positive transportation impacts of telecommuting. Such a bias is not likely to be present in the statewide data, which were not gathered in the context of a telecommuting program. Thus, it will be of interest to compare the telecommuting-day travel patterns found for telecommuters in this sample, and differences between telecommuters and conventional workers, with those of previously published specialized-sample studies. Any similarities of findings will provide greater confidence in the robustness of both previous and current results. Differences in findings may suggest avenues of further research.

Such a comparison will not be definitive, however, due to the weakness of the statewide data set. Because the data were not collected specifically with home-based workers in mind, identification of these workers is indirect and approximate, as discussed below. Another weakness of the data set that limits the insight that can be obtained into the travel patterns of HBB workers is the lack of information on the occupation of the tripmaker. HBB workers are quite heterogeneous—including, for example, farmers, live-in domestics, artists and craft workers, providers of services within the worker's home (e.g., beauty shops, child care, or electronics repair), providers of external but location-dependent services (e.g., plumbing, electrical, and painting), providers of products prepared in the home and delivered (catering), professional consultants (e.g., accounting/tax, legal, management, planning), and clerical workers (e.g., word processing, transcription, data entry). Travel characteristics will vary across these segments. Some information is available on the industry in which the tripmaker works (the five categories of retail trade, services, education, government, and other), but as occupations may vary widely within industry, this variable is of limited value. Finally, a major shortcoming of the database is that trip lengths were not directly collected, so it is not possible to analyze VMT, person-miles traveled, or emissions across the study groups. Travel times and proportion of trips using the freeway are analyzed as surrogates for distances.

Definition and Selection of Comparison Groups

Although the statewide data were not collected specifically for a study of home-based work, the survey had one uncommon and critical feature. Telephone interviewers were instructed to ask respondents who were employed, but who did not report a work trip, whether they worked at home on the designated day. The response to that question formed the basis for identifying the comparison groups to be used in this study. Figure 2 illustrates the filtering process used to create the final sample. Three responses to the question were coded: yes, no, and had a work trip. It is assumed that those with no response coded are for the most part not employed. To reduce the group having a work-trip to a manageable size, an initial 1-in-10 sample of this group was selected before applying any further screens.

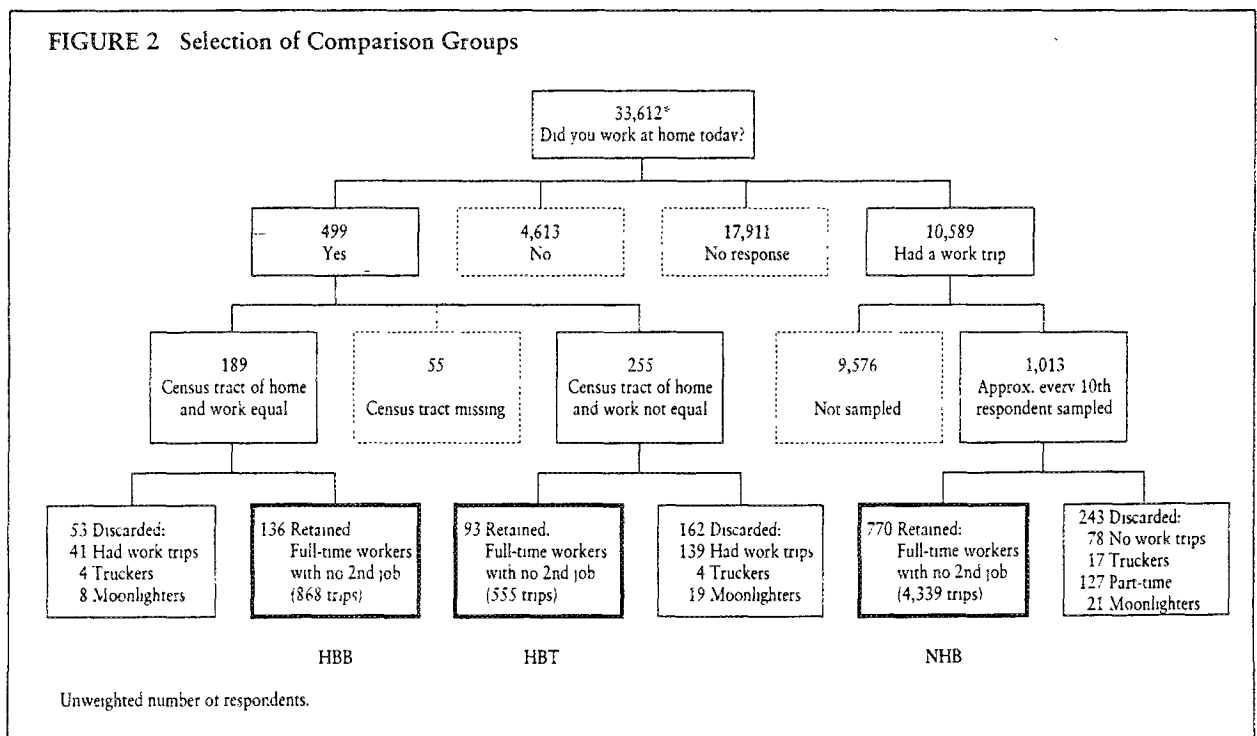
To distinguish between home-based businesses and telecommuters, the census tracts of the home and workplace were compared. Those who indicated working at home were classified as HBB workers if the census tract of their home matched the census tract of their workplace, and were classified as telecommuters if the two census tracts did not match (see Handy and Mokhtarian 1995 for

an earlier use of this criterion on the same data set). Obviously it is possible for a telecommuter's regular workplace to be close to home and so this rule may misclassify some HBTs as HBB workers, but such cases are expected to be relatively infrequent as telecommuters' commute distances tend to be longer than average (Mokhtarian et al. 1995) and as census tracts are not generally very large.

Another key decision was to discard from the analysis respondents who indicated that they had a second job (moonlighters). For moonlighters who worked at home, it was not possible to tell whether the home-based work was for their primary or secondary job. If the latter were the case, such workers could be mistakenly classified as telecommuters when in fact they were conventional employees. Further, preliminary exploration indicated that the tripmaking behavior of moonlighters was not typical, with higher average trip rates in every study group than the remainder of the group. To be consistent, moonlighters were eliminated from all three study groups.

Despite written instructions to ask the question "did you work at home today" only when a work trip had not been reported, measurement errors of some kind resulted in a number of respondents in the home-based work category in fact reporting a

FIGURE 2 Selection of Comparison Groups



trip to work (not just work-related, which was coded differently). Since that cast some doubt on the validity of their classification as home-based workers, those respondents were removed from the analysis. Conversely, for several individuals who had been coded as having a work trip, no such trip was found for them. Those respondents were also discarded. Since neither group of home-based workers contained any part-time workers, part-timers were removed from the NHB group as well for consistency. Those who drove or rode in trucks other than pick-ups were also removed from all three groups.

Some of those classified as NHB workers may in fact be telecommuters who were not telecommuting on the designated data-collection day. If telecommuting occurs, say, 1.2 days a week or 24% of the time on average (as found by Handy and Mokhtarian 1995), then this one-day travel diary may have captured only about 24% of telecommuters in the sample on their telecommuting day. First, however, there is no way to identify and remove telecommuters from the NHB group. Second, the 76% of telecommuters who would be misclassified as NHB workers would still constitute a small proportion of the total NHB sample. Third, it may be expected that telecommuters' travel on an ordinary commuting day would not differ greatly from that of nontelecommuters with similar sociodemographic characteristics. Although previous studies (e.g., Henderson et al. 1996; Koenig et al. 1996) found that telecommuters' nontelecommuting-day travel differed from that of a nontelecommuting control group (with telecommuters traveling significantly longer distances), the difference appeared to be primarily due to telecommuters having a longer average commute length rather than to spillover effects of telecommuting onto nontelecommuting days. Fourth, there is little reason to believe that telecommuters who were misclassified in that way differ materially from those who *were* classified as HBT, and if that is true, the group classified as HBT constitutes a representative sample of telecommuters. As such, a representative picture of telecommuters' travel behavior is presented, and it is travel behavior rather than the precise size of the segment that is the focus of this paper.

The groups analyzed here, then, were of the following sizes (unweighted): HBB = 136 people, 868 trips; HBT = 93 people, 555 trips; NHB = 770 people, 4,339 trips. The weights described earlier were applied to each case, with the total weighted sample size normalized to equal the unweighted sample size of 999 to retain the validity of the statistical tests. As the same weight belonging to an individual was applied to all trips made by that individual, the weighted number of trips will not equal the unweighted number if trip rates are not independent of the case weight (e.g., if more heavily weighted respondents tend to make fewer trips). The weighted sample sizes are: HBB = 109 people, 668 trips; HBT = 79 people, 414 trips; NHB = 811 people, 4,323 trips. The differences between the unweighted and weighted sample sizes imply that home-based workers of both types were overrepresented in the raw sample. All subsequent analysis is conducted on the weighted version of the sample.

Socioeconomic Characteristics of the Sample

Table 1 summarizes key socioeconomic characteristics for each of the three study groups. Because individual comparisons are of interest, pairwise *t*-tests were conducted for the (quasi-) continuous variables age, number of people in the household, number of people 5 years old or older, and number of vehicles; whereas chi-square tests were conducted for the categorical variables gender, dwelling unit type, industry, and income.

Taking each variable in turn, it can be seen that telecommuters are marginally ($p = 0.18$ and 0.07) older ($2\frac{1}{2}$ years, on average) than members of the other two groups, whose average age is nearly 40. The gender distribution was not significantly different across groups ($p = 0.17$). The relatively low proportion of women (36.7%) in the telecommuter group is counter to the stereotype that telecommuting appeals more heavily to working mothers trying to balance family and career, and contrasts with at least one empirical study finding equal proportions of men and women telecommuting (Mokhtarian et al. 1998). It is, however, consistent with the most recent Find/SVP annual nationwide survey of home-based work in the United States, which reports that approximately one-third of telecommuters are female (Gordon

TABLE 1 Socioeconomic Characteristics of the Sample

Variable	Indicator	Group (weighted size) ¹		
		HBB (109)	HBT (79)	NHB (811)
Age	Mean	39.7	42.2	39.7
Gender	% female	50.5	36.7	45.8
No. in household ^{BT, BN, TN}	Mean	2.5	3.3	2.9
No. ≥ 5 yrs. old ^{BT, BN}	Mean	2.4	2.8	2.7
No. of vehicles	Mean	2.1	2.4	2.3
Dwelling unit type	% single family house	77.1	77.2	74.3
Industry*	% retail trade	5.6	3.8	12.7
	% services	48.6	28.2	35.4
	% education	7.5	12.8	7.2
	% government	—	5.1	15.2
	% other	38.3	50.0	29.5
Annual household income	% < \$20 K	9.0	8.1	8.8
	% \$20–35 K	24.0	16.2	23.8
	% \$35–50 K	22.0	31.1	24.9
	% \$50–75 K	17.0	28.4	22.2
	% > \$75 K	28.0	16.2	20.3

¹ Sizes are smaller for some variables due to missing data.

Key: BT: HBB and HBT are significantly different ($\alpha = 0.05$); BN: HBB and NHB are significantly different; TN: HBT and NHB are significantly different; *: group type and industry are not independent (χ^2 test, $\alpha = 0.05$).

1997). Other researchers (e.g., Olson and Primps 1984; Bailyn 1989; Holcomb 1991) have identified two tiers of home-based workers: the predominantly female tier of clerical workers and the more heavily male tier of professional workers. It is quite possible that among telecommuters the latter tier is larger than the former.

The proportion of females among the HBB workers is 50.5%. By comparison (Deming 1994), in the 1991 Current Population Survey (CPS), women constituted 48.1% of those who worked at home for pay at least eight hours a week,³ and 59.1% of those working at home for pay at least 35 hours a week (9% of the total being telecommuters). The proportion of women (45.8%) in the NHB group is virtually identical to the proportion of women in the U.S. civilian labor force as a whole in 1991 (USDOC 1995, table 628).

On the other hand, in keeping with the stereotype, telecommuters do have significantly larger

households on average than the other two groups, and more children under age 5. Perhaps surprisingly, though, home-based business workers have the lowest number of people and young children in their households. Similarly, telecommuters have the most vehicles in their households, and HBB workers have the least (the difference being marginally significant at $p = 0.07$). Both types of home-based workers are slightly more likely to live in single-family houses than members of the NHB group, which is consistent with their needs for work space at home, but the difference is not significant.

Turning to industry of employment, HBB workers are more likely to be found in services (48.6%) and "other" (38.3%) industries than the other two groups. By comparison, the 1991 CPS classified as service industry 54.0% of the group working at home for pay at least eight hours a week (HBBs and HBTs). The service industry encompasses businesses as diverse as plumbing and management consulting. There are no government workers in this group, which is as expected and therefore engenders some confidence in the criterion used to define the group.

³ This group comprises both telecommuters and self-employed workers as a separate breakdown by gender was not provided, but telecommuters are only 16% of the total.

Fully half of all telecommuters are found in the "other" category, which is obviously quite broad, with services being the next largest industry at 28.2%. A higher proportion of telecommuters are in education (12.8%) than are conventional workers (7.2%), which is plausible in view of the flexibility enjoyed by many workers in that industry. It is also natural that relatively few telecommuters are in the retail trade industry (3.8%, compared to 12.7% for NHB workers). It may be surprising that proportionately fewer telecommuters are in government, in view of the numerous public-sector telecommuting programs in California, but a high proportion of NHB workers in government are likely to hold location-dependent jobs such as those of police, firefighters, garbage collectors, meter-readers, and building inspectors.

The distribution of NHB workers across industries is roughly consistent with that of the U.S. workforce as a whole. The 1991 CPS reports 16.5% and 35.1% of all workers in the retail trade and service industries, respectively, compared with 12.7% and 35.4% for the Caltrans sample taken the same year. Other industry categories were defined differently in the two studies, so that direct comparisons cannot be made.

Although all three groups share the same median annual household income category of \$35,000 to \$50,000, there are some interesting minor differences in distribution across the groups. Income is unimodally distributed for the HBT and NHB groups, but bi-modally distributed for the HBB workers. Almost half (46%) of the HBB group falls into the \$20,000 to \$50,000 range, but more than one-quarter of the group is in the single category of more than \$75,000. Sixty percent of the HBT group falls into the \$35,000 to \$75,000 range, but another 16% lie in the highest category of more than \$75,000. The NHB group has the most uniform distribution of the three.

COMPARISON OF TRAVEL INDICATORS

Table 2 presents selected mean trip rates (one-way, unlinked trips) for each of the three groups, and figures 3–5 illustrate trip shares by purpose, mode, and time of day for each group. Patterns are similar for rates and shares, but their contributions are

TABLE 2 Daily Mean Trip Rates by Group

Variable	Group		
	HBB 109 people 668 trips	HBT 79 people 414 trips	NHB 811 people 4,323 trips
Total person-trips	6.1	5.2	5.3
% trips using freeway ^{BN, TN}	21.2	23.7	39.1
Trips by purpose ^{1*}			
Work	—	—	1.3
Work-related	0.9	0.5	0.4
Social/recreation/ shop	1.3	1.4	0.9
School	0.0	0.1	0.1
Serve passenger	0.3	0.4	0.3
Change mode	0.2	—	0.1
Other	1.5	1.1	0.7
Return home	1.9	1.8	1.6
Trips by mode*			
Drive alone	3.5	2.7	3.3
Carpool	1.6	2.2	1.5
Transit/other	0.2	0.0	0.2
Bicycle/walk	0.8	0.3	0.3
Trips by time of day*			
Midnight to 3 a.m.	0.0	0.0	0.0
3 to 6 a.m.	0.0	0.1	0.2
6 to 9 a.m.	1.0	0.5	1.1
9 a.m. to noon	1.7	1.3	0.8
Noon to 3 p.m.	1.3	1.4	0.9
3 to 6 p.m.	1.0	1.4	1.4
6 to 9 p.m.	1.0	0.5	0.8
9 p.m. to midnight	0.1	0.1	0.2

¹ For the χ^2 test, the work and work-related categories were combined, and the school, change mode, and "other" categories were combined, to avoid small cell sizes.

Key: — means absolutely zero trips, whereas 0.0 means zero rounded off (i.e., fewer than 0.05); BN: HBB and NHB are significantly different ($\alpha = 0.05$); TN: HBT and NHB are significantly different; *: group type and the row variable are not independent (χ^2 test, $\alpha = 0.05$).

complementary rather than redundant. Because the per-capita trip totals are not identical across groups, in any given category shares could be similar between two groups while rates are different, or conversely. Table 3 presents mean travel time by purpose and mode for each group.

Total Trips

Perhaps not surprisingly, HBB workers have the highest average number of daily person trips, at

TABLE 3 Daily Mean Travel Time by Group

Variable	Group		
	HBB 109 people 668 trips	HBT 79 people 414 trips	NHB 811 people 4,323 trips
Total person travel time (hours) ^{BN}	1.43	1.50	1.77
Hours by purpose ^{1*}			
Work	—	—	0.46
Work-related	0.25	0.15	0.15
Social/recreation/ shop	0.30	0.35	0.23
School	0.00	0.05	0.03
Serve passenger	0.04	0.11	0.08
Change mode	0.02	—	0.04
Other	0.39	0.28	0.21
Return home	0.43	0.56	0.56
Hours by mode*			
Drive alone	0.82	0.62	1.14
Carpool	0.41	0.77	0.47
Transit/other	0.03	0.01	0.09
Bicycle/walk	0.17	0.10	0.06

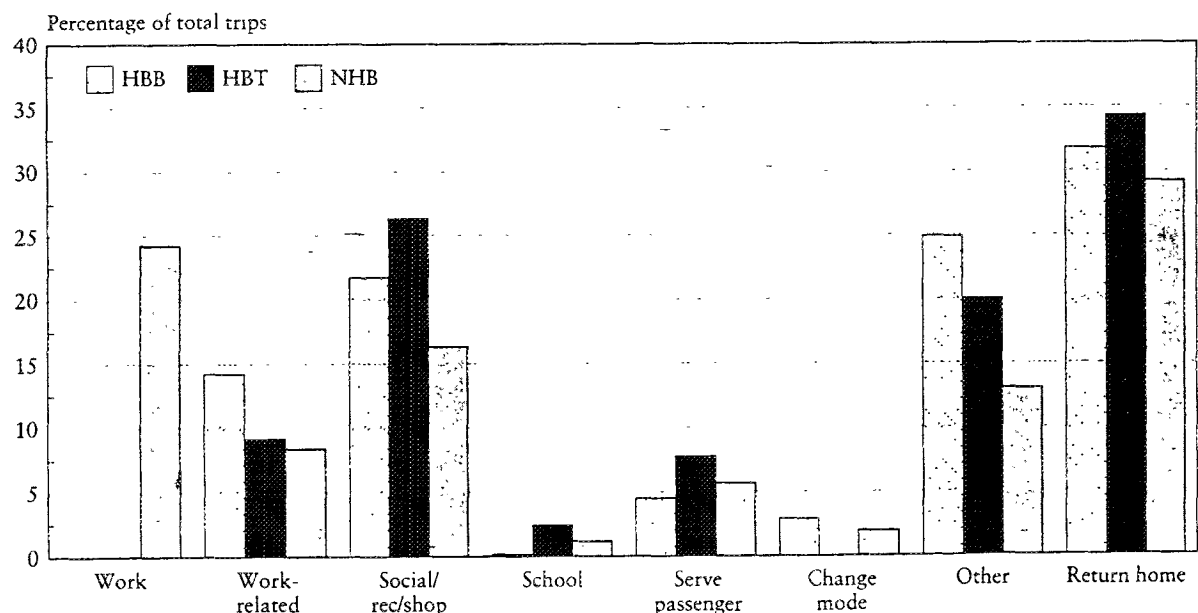
¹ For the χ^2 test, the work and work-related categories were combined, and the school, change mode, and "other" categories were combined, to avoid small cell sizes.

Key: — means absolutely zero travel time, whereas 0.00 means zero rounded off (i.e., fewer than 0.005 hours); BN: HBB and NHB are significantly different ($\alpha = 0.05$); *: group type and the row variable are not independent (χ^2 test, $\alpha = 0.05$).

6.1. Since the variance for this group is relatively higher than for the other two groups, however, the HBB-HBT difference is not significant, and the HBB-NHB difference is only significant at $p = 0.09$. It could be expected that HBB workers would make more work-related trips than the other two groups, and this is confirmed by table 2. However, the table and figure 3 illustrate that HBB workers also have higher trip rates and shares for other trip purposes as well, including social/recreation/shop, return home, and "other."

Telecommuters have the lowest trip rate of the three groups, which is in keeping with conventional wisdom and which has been empirically demonstrated in the small-scale studies cited earlier (both when telecommuters have been compared with nontelecommuters and when their own travel has been compared on telecommuting and non-telecommuting days). However, it is noteworthy that the rate for conventional workers is just 0.1 trips per person per day higher than that for telecommuters, a difference that is not statistically significant ($p = 0.78$). Previous studies (Pendyala et al. 1991; Henderson et al. 1996) have found differences of 1.7–2.0 trips a day between telecommuters (on their telecommuting days) and nontelecommuters. One reason for this contrasting result may be that at least one previous study

FIGURE 3 Distribution of Trips by Purpose



(Koenig et al. 1996) found a small number of commute trips being made by telecommuters on telecommuting days, whereas in this study people making work trips were eliminated from the HBT sample to prevent the likely misclassification of a conventional worker as a telecommuter. However, the average number of 0.1 daily vehicle commute trips by telecommuters seen in that earlier study would compensate for at best a small part of the difference.

Differences in travel patterns may be indirectly inferred from the proportion of trips that involve freeway use. Nearly two-fifths of NHB trips used the freeway, compared with 21% to 24% for the other two groups. If freeway use can be taken as a proxy for distance, then this result suggests that NHB workers travel significantly farther than do the HBB workers and telecommuters on their telecommuting days, which again is in line with expectations and with findings of previous telecommuting studies.

Trips by Purpose

Examining the trip purpose distribution more closely, for the two home-based groups (by design), neither of them have any "work trips" (i.e., trips for which "work" was the stated purpose at the destination). The NHB group has 1.3 work trips per day, one of which is the commute trip and the remainder being trips back to the workplace in the middle of the day. Although HBB workers have the highest number of work-related trips (0.9), the NHB group makes nearly twice as many work and work-related trips combined as the HBB group, and more than three times as many as the HBTs. HBTs, however, make slightly more work-related trips (0.5) than the NHB workers (0.4).

Telecommuters have the highest social/recreation/shop trip rate of the three groups, potentially a reaction to the more isolated nature of their workday. This is consistent with Balepur et al. (1998), who found somewhat higher proportions of shopping and social/recreational trips by telecommuters on telecommuting days than on their nontelecommuting days and by nontelecommuters. It is also consistent with Gould et al. (1998), who found that home-based workers

spent more time shopping and traveling to shopping than did office workers. HBB workers make the most "return home" trips, followed closely by the telecommuter group. This suggests that less trip chaining takes place for these two types of workers.

Trips by Mode

Turning to the distribution of trips by mode, table 2 and figure 4 show that home-based business workers and NHB workers have similar rates and shares of drive-alone, carpool, and transit/other trips, although trip rates are slightly higher in the HBB group for drive alone and carpool. Most of the difference in total daily trips between the HBB and NHB groups lies in the higher number of bicycle/walk trips by the home-based business workers. Cross-tabulation of mode and purpose (not shown) indicates that these nonvehicular trips by the HBB group are predominantly for social/recreation/shop (0.34), other (0.21), and return home (0.17) purposes.

Telecommuters have a different mode split from the other two groups. They make fewer drive-alone trips, more carpool trips, and a negligible number of transit/other trips. These results are likely derived from the larger household sizes for this group observed in table 1, with differences in share also deriving from the lack of a commute trip. Interestingly, the bicycle/walk trip rate for telecommuters is equivalent to that for NHB workers, not to the higher rate for HBB workers as

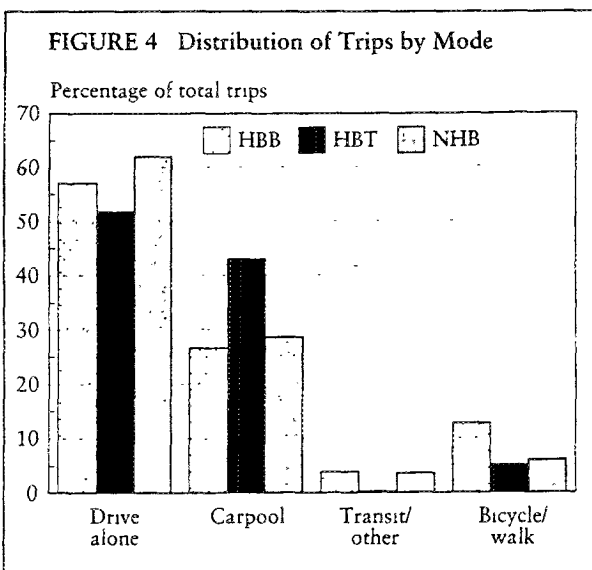
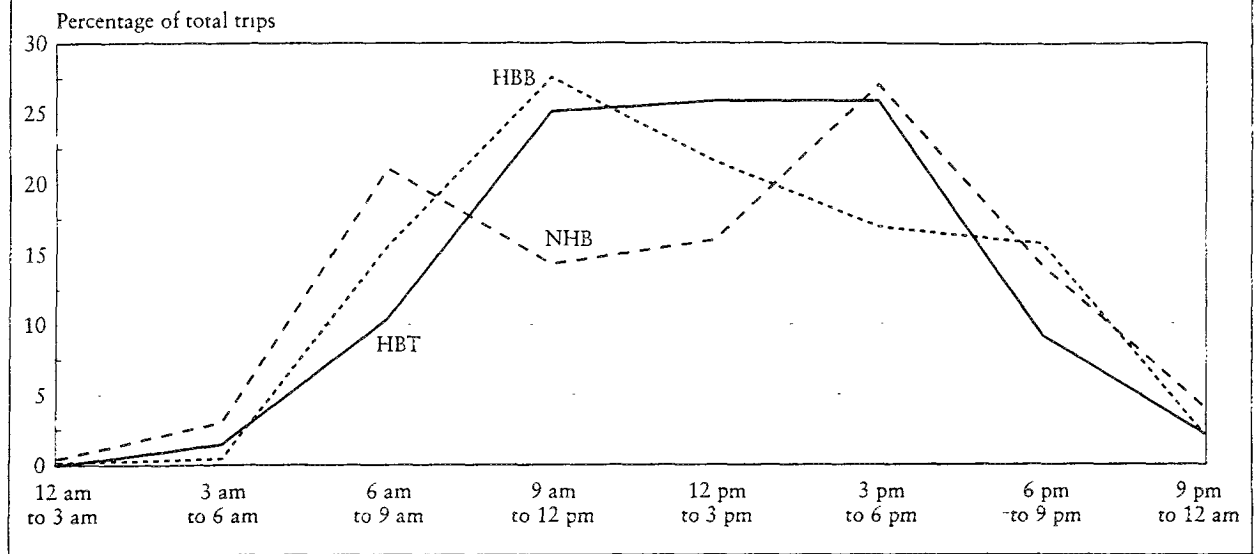


FIGURE 5 Distribution of Trip Start Times by Time of Day



might have been expected. Also, the small number of transit trips on telecommuting days is similar to the results of previous studies in the United States (particularly Mokhtarian et al. 1997) and the Netherlands (Hamer et al. 1992), but those studies have found higher rather than lower shares of drive alone trips by telecommuters on telecommuting days (e.g., Pendyala et al. 1991; Henderson et al. 1996; Mokhtarian et al. 1997).

Importantly, unlike the case for total trips, the difference in daily drive-alone trip rates between HBT (2.7) and NHB workers (3.3) is comparable to those found in other studies. Koenig et al. (1996) reported nearly identical rates of 2.73 drive-alone trips by telecommuters on telecommuting days and 3.29 drive-alone trips by non-telecommuters. The Roads and Traffic Authority (RTA 1995) of New South Wales reported daily averages of 2.37 car trips (including carpool) by telecommuters on telecommuting days and 3.14 car trips for the nontelecommuting control group. The results of Henderson et al. (1996) are not as close (2.58 and 4.33 drive-alone trips per day, respectively), but are still generally similar. It has been argued elsewhere (e.g. Koenig et al. 1996) that it is the reduction in drive-alone trips due to telecommuting that is most important, since those are the only trips that materially affect congestion and air quality.

Trips by Time of Day

Table 2 and figure 5 show the trip rates and shares, respectively, classified by the time of day the trip started. The temporal distributions are quite different for the three groups. The NHB group exhibits the traditional bi-modal distribution, with a morning peak and a larger afternoon peak. The HBB distribution is unimodal, with a peak in the 9 a.m. to noon interval and with sizable but successively declining shares later in the day. The relatively low trip rate in the 3 p.m. to 6 p.m. interval is particularly interesting, suggesting that this group is more successful at avoiding the afternoon peak (for whatever reasons) than the other two groups. The HBT distribution is almost exactly symmetric about the noon to 3 p.m. interval and is flat rather than peaked. That is, trips are uniformly distributed across the nine hours from 9 a.m. to 6 p.m., with 77% of the total for HBT falling in that range. By comparison, 66% of HBB trips and 57% of NHB trips fall within the same nine hours. The finding that telecommuters travel less during peak periods than nontelecommuters is consistent with Pendyala et al. (1991).

Travel Time

Table 3 shows that HBB workers have the lowest average daily travel time, although they have the highest trip rate of the three groups (see table 2). Because they also travel more in the offpeak, when

average speeds are higher, this partially confounds any conclusion about distance traveled. However, the other surrogate indicator of distance, proportion of trips using the freeway, is also lowest for the HBB group, which suggests that they do in fact travel the shortest distance.

As expected, NHB workers travel the longest, an average of about 16 minutes (difference significant at $p = 0.09$) and 20 minutes ($p = 0.02$) longer than HBT and HBB workers, respectively. Their one-way commute trip is about half an hour, and probably because of the trip home from work, they spend the most time returning home of the three groups. NHB workers spend less time than the others in travel for social/recreation/shop and "other" activities. Consistent with the results for number of trips, telecommuters spend more time than the other workers in travel for social/recreation/shop purposes, and they also spend the most time on serve passenger trips (again related to their larger household sizes).

As for travel time by mode, the HBB and NHB workers have roughly comparable times and shares for the drive alone, carpool, and transit/other modes. Contrary to the case for trips but consistent with the comparison for overall travel time, NHB workers spend more time in each mode. As with number of trips, HBB workers spend the most time bicycling/walking of the three groups. Telecommuters have a different distribution from the other two groups, with the shortest drive-alone time and the longest carpool time. Although telecommuters and NHB workers make equal numbers of bicycle/walk trips, telecommuters spend a few minutes longer on such trips than the other group. This is a natural result in view of the time telecommuters save by not making the commute and the potential desire to compensate for a lower level of physical exercise during the workday itself, relative to the NHB group.

Telecommuters spend 46% less time driving alone than NHB workers. This compares consistently with previous studies that found that telecommuters on their telecommuting days had 42% (Henderson et al. 1996) and 67% (Koenig et al. 1996) fewer vehicle-miles traveled than a non-telecommuting control group, where only drive-alone trips were counted in the VMT totals.

HBB Worker Differences by Industry

Because so little is known about the travel behavior of HBB workers, it is useful to examine that group in more detail. In particular, because the group is so heterogeneous, it is instructive to analyze differences in trip rates and trip purpose distributions across industry. It should, however, be cautioned that sample sizes within industry groups are small (unweighted sizes of 15, 67, 7, and 42 for the four industry groups respectively; weighted sizes as shown in table 4), and hence this analysis can only be suggestive rather than conclusive.

Table 4 presents the comparison, which shows clear differences across industries. Overall trip rates are much higher for workers in the retail trade (7.5) and service industries (7.2) than for education (5.4) and "other" (4.9). There are substantial differences in freeway use among the groups. The retail trade group uses a freeway 36% of the time, four times as often as the education group. Despite having overall trip rates similar to the retail trade group, the services group uses the freeway for only 19% of its trips. The "other" group uses the freeway almost three times as much (25%) as the education group (9%; difference significant at $p = 0.09$), despite making fewer trips altogether.

The breakdown of trip rates by purpose sheds further light on the differences in overall trip rates. HBB workers in retail trade make more than twice as many work-related trips on average (2.6 per day) as those in the other three groups. Many of these may be deliveries or sales calls, which would be consistent with the high level of freeway use by this group. Workers in the "other" industry category, on the other hand, make very few work-related trips: on average, fewer than one in three of these workers makes such a trip on a given day. Although this group includes a wide variety of industries (financial/insurance/real estate, transportation/utilities/communications, manufacturing, wholesale trade, agriculture, forestry, fisheries, mining, and construction), it may be dominated by largely location-dependent work such as agriculture. It is notable that this group has the highest social/recreation/shop trip rate of the four, suggesting that there may be some tradeoff between mobility at work and mobility for leisure.

TABLE 4 Home-Based Business Workers' Travel by Industry

Variable	Industry			
	Retail trade 6 people 43 trips	Services 52 people 372 trips	Education 8 people 44 trips	Other 41 people 197 trips
Total person-trips ^{SO}	7.5	7.2	5.4	4.9
% trips using freeway ^{RE}	36.0	19.4	9.0	25.3
Trips by purpose ^{1*}				
Work	—	—	—	—
Work-related	2.6	1.1	1.2	0.3
Social/recreation/shop	1.2	1.3	0.5	1.6
School	0.1	0.0	0.0	—
Serve passenger	0.3	0.3	0.8	0.2
Change mode	—	—	—	0.5
Other	1.3	2.0	1.1	1.0
Return home	1.5	2.6	1.8	1.3

¹ For the χ^2 test, the work and work-related categories were combined, and the school, change mode, and "other" categories were combined, to avoid small cell sizes.

Key: — means absolutely zero trips, whereas 0.0 means zero rounded off (i.e., fewer than 0.05); SO: Services and Other are significantly different ($\alpha = 0.05$); RE: Retail trade and Education are significantly different; *: group type and purpose are not independent (χ^2 test, $\alpha = 0.05$).

The services group has much higher trip rates for "other" and return home purposes than the other three groups. The high return home trip rate suggests that this group engages in trip chaining to a lesser degree than the others. A final point of note in the table is the relatively high number of serve passenger trips for workers in the education industry (again, however, these are based on a small sample). These could be in-home childcare providers taking their charges on a field trip, or perhaps school bus drivers. In either case, those trips would more accurately have been classified as work-related, but the distinction is rather weak. Some of those trips could be teachers taking their own family members to various activities. This group has the lowest social/recreation/shop trip rate of all (rates for the other groups are two and a half to three times as high), again suggesting some kind of tradeoff among activities.

CONCLUSIONS

Current urban travel demand forecasting practice does not use work location (in-home or out-of-home) or employment type (self-employed or salaried) as explanatory variables. In view of the results found here, and the growing importance of

home-based and mobile work to an information economy, current modeling practice could perhaps be improved with further attention to the association of these indicators with significant differences in travel behavior. The research presented here is the first known U.S. study of HBB travel, and the first representative-sample study of HBT travel on their telecommuting days. Some interesting findings emerge.

HBB workers have the highest average daily unlinked trip rate of the three groups, at 6.1 trips per day. However, much of the difference between HBB and NHB trip rates (5.3 per day) lies in a higher frequency of bicycle/walk trips in the former group. As expected, HBTs have the lowest total trip rate (5.2 per day), but in marked contrast to other studies, the rate is statistically equivalent to the rate for NHB workers. On the other hand, the difference in *drive-alone* trip rates between HBTs and NHB workers is comparable to previous results, with HBTs making an average of 0.6 (18%) fewer drive-alone trips per day. The lower drive-alone mode *share* for HBTs compared to NHB workers, however, poses another contrast to previous findings. Consistent with earlier studies, transit use by HBTs on telecommuting days is negligible.

Taking both freeway use and travel time as indicators of trip distance suggests that the NHB group travels farthest, which is as expected. It could be noted, however, that based on previous studies, telecommuters are likely to travel farther on their nontelecommuting days than the other two groups, due to having above-average commute lengths. There are substantial variations in freeway use across industry within the HBB group.

Although HBB workers have the highest work-related trip rate, the NHB group makes nearly twice as many work and work-related trips combined as does the HBB group, and more than three times as many as HBTs. The temporal distribution of HBB trips is unimodal, in contrast to the traditional bimodal distribution for NHB trips and a flat distribution (from 9 a.m. to 6 p.m.) for HBTs. HBB workers have the fewest trips in the afternoon interval of 3 p.m. to 6 p.m., whereas telecommuters have the fewest trips during the morning peak of 6 a.m. to 9 a.m. and between 6 p.m. and 9 p.m.

The HBB group is quite heterogeneous, with distinct differences across industry in overall trip rates and rates by purpose. The retail subgroup makes the most work-related trips, the services subgroup makes the most return home and "other" trips, the education subgroup makes the most serve passenger and fewest social/recreation/shop trips, and the "other industries" subgroup makes the most social/recreation/shop and fewest work-related trips. The sample sizes are small for these subgroups, however.

The approximate nature of the identification of the three groups in this study means that these results should be viewed with some caution. The representative-sample, general-purpose data set used in this study offers two key points of comparison with earlier studies of telecommuting based on self-selected, special-purpose samples: number of trips and travel distance. Here, it is found that telecommuters on their telecommuting days make essentially the same number of total trips as conventional workers, compared with telecommuting-day decreases of up to two full trips per day in previous studies. On the other hand, the lower drive-alone trip rates for telecommuters compared with conventional workers have been found to be similar to those in other studies. Further, to the

extent that travel time approximates travel distance, the finding here that telecommuters drive alone for 46% less time than conventional workers is similar to previous findings for vehicle-miles traveled.

This initial study offers a useful foundation upon which to build, but a number of research questions remain. On the same data set, it would be of interest to explore differences by metropolitan and nonmetropolitan areas; however, sample sizes for the HBB and HBT groups will be dangerously small. It may be possible to combine the statewide database with supplemental data collected at the regional level to obtain larger sample sizes for those two groups in particular. Along the same lines, it would be valuable to explore differences by gender and household type (e.g., with and without children), although the same caveat about sample sizes applies. Also, this study focused on travel behavior at the individual level for maximum comparability with earlier telecommuting studies, but as regional travel demand forecasting is typically done with the household as the unit of analysis, it would be of interest to take the same perspective with this sample. In that case, however, it would be important to distinguish households having various mixtures of workers among the three study groups.

Future similar data-collection efforts would be far more valuable if information on occupation and trip lengths were obtained. The former measure is an important basis for segmenting travel patterns within each group, and the latter measure is essential to conducting a meaningful comparison of emissions across the three groups. Replicating and extending this study on the Nationwide Personal Transportation Survey (NPTS) data would be of particular interest; although the NPTS sample does not contain occupation data, it does report trip lengths.

Further, collecting data across a multi-day period would permit a direct comparison of travel on home-based work days versus other days (both within the two home-based groups and across all three groups), possibly with an analysis of the transference of travel between the two types of days. Any such data-collection effort should obtain information on the frequency of occurrence of

home-based versus non-home-based work days, to be able to properly assess the aggregate effects of home-based work. In a study of center-based telecommuting, for example (Balepur et al. 1998), it was found that although telecommuters traveled 65% fewer vehicle-miles on a telecommuting day than on a conventional commuting day, when travel on each day type was weighted by the frequency of occurrence of each type of day, the overall reduction in weekday vehicle travel for telecommuters was only 17% of their non-telecommuting baseline. It is important to be able to put the former number in the context of the latter, to avoid overstating the potential of home-based work to reduce travel.

Finally, it is important to realize that inferences about causality are not justified with the data used here. We are able to identify differences among groups, but not to assert with confidence whether status as a home-based or conventional worker was a cause or consequence of these differences. There is, of course, some value in identifying patterns of association. However, causal inferences could be made more confidently with panel data (or, at the simplest, before-and-after data such as that often collected for the telecommuting studies done previously) that tracks individuals through changes in work location status over time. Changes in travel patterns observed subsequent to changes in work status are more likely to be effects rather than causes, although even there, third-party correlation and other effects cannot technically be ruled out. It would be of particular interest to identify, classify, monitor trends in, and study the travel patterns of mobile workers, whether home-based or non-home-based.

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