Dynamics of Job and Housing Locations and The Work Trip: Evidence from Puget Sound Transportation Panel

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Residence and workplace locations are the defining elements for the work trip. However, until recently both have been treated in theoretical and empirical research as static determinants instead of being recognized for the numerous locational changes that occur every year. Many such changes can be viewed as adjustments to housing and commuting conditions. Panel surveys can provide data bases suitable for analyzing such adjustments. The Puget Sound Transportation Panel (PSTP) was used to draw household and worker samples for exploring the magnitude of locational changes and their effects on home-to-work travel behavior. Descriptive analysis indicated no strong evidence of bias as a result of panel attrition. Results showed high levels of residence and workplace location changes, connections to reductions in home-to-work distances for long work trips, and shifts in the usual travel mode to work, especially out of transit and carpooling and particularly for women workers. The PSTP data base is evaluated for its ability to support further dynamic demographic analysis.

Researchers in travel behavior have long been interested in residential and workplace locations as the defining elements in the home-to-work commuting distance and the choice of travel mode to work. Similarly, urban economists have sought to explain the spatial structure of metropolitan areas through the choices of residential (and work) locations with respect to the work trip. Both lines of inquiry have continually been frustrated by the theoretical complexities of multiple employment centers and chains of trip purposes and by empirical problems of limited data bases. However, both also suffer from the changes that individual workers are constantly making in their residential locations, their workplaces, and their travel modes. These changes are surprisingly numerous and may be viewed as adjustments to personal and travel conditions faced by the workers on a day-to-day basis.

The relationship between residential location choice and the work trip has long been recognized, analyzed, and modeled; it is the foundation for urban travel modeling. Much of the literature on household moves, however, has been concerned with the reasons for the move (*1*) or economic or public-sector choice variables (*2*). For travel analysis, the residential location was either a static given or a dependent variable to be predicted from travel conditions. Lerman (*3*), McFadden (*4*), and Anas (*5*) started modeling residential location as a joint dependent variable with travel choices. Anas (*6*) has developed dynamic models that incorporate location changes but has found data bases insufficient to make the models operational.

Workplace location and travel behavior have been extensively studied, but more from the perspective of transportation supply (transit service, parking costs) and public policy (demand management) than from a choice perspective (*7–9*). The following are the questions that have been raised: What characteristics of workplace locations are associated with what travel behavior by workers? What changes in those characteristics can induce changes in their behavior? The modeling of workplaces has mostly involved the selection of locations by firms, not by workers. Choice and changes of workplace locations by workers has only begun to surface in the urban economics literature (*10–13*).

There is also the normative issue of the balance between jobs and housing, which is under debate in land use and transportation planning circles. The issue involves using public policy to encourage or force additional housing in areas dominated by jobs, and vice versa, such that more opportunities would exist for shorter commutes and use of nonmotorized modes. It is policy based and begs the theoretical and empirical questions of individual choices of residences, workplaces, and modes. Giuliano (*14*) concluded a review of the jobs housing issue with the assessment that the policy bears only a tenuous relationship to the transportation problems it purports to address.

On the empirical side, most analysis of these questions has been conducted using cross-sectional data from such large-sample surveys as the Census Transportation Planning Package, the American Housing Survey, and the Nationwide Personal Transportation Survey. Much of the working wisdom on trends in work trip lengths, mode choices, and congestion levels derives from analysis of these data bases (*15,16*). These surveys, plus localized worker surveys on travel behavior, often in a before-and-after format, confirm the static or slowly changing travel characteristics that are typical results from repeated cross-sectional surveys (*17*).

Only recently has the perspective of worker changes emerged as a key element in travel behavior research. Zax and Kain (*13*) defined moves and quits as the equilibrating mechanisms for inefficient or suboptimal commutes. Gordon et al. (*18*) used worker changes as the fallback explanation for anomalies in commuting times in a large cross-sectional survey. Commuting is viewed as the critical link in spatial equilibrium for workers. The out-of-pocket costs and time spent in commuting to work absorb money and time that could be used for housing consumption, productive work, or leisure. Inefficient commutes—too long, too short, or by the wrong mode—impose excess costs on workers. Too short a commute is one for which the worker's housing consumption is suboptimal such that a longer commute could improve the worker's utility. Moves to more appropriate residences, changes to more convenient workplaces, and switches to more efficient modes are individual remedies for inefficient commutes.

But to analyze or model such behavior empirically, there must be a data set on individuals' actions over a period of time. Such a data

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set is likely to be drawn from a panel survey, in which observations are made repeatedly from the same sample. Panel surveys have become more common in recent years in transportation planning and analysis. They have been developed for analyzing specific projects, in San Diego (*19*), Honolulu (*20*), and Sacramento (*21*), and for general-purpose data bases for transportation planning in the Netherlands (*22*) and the Puget Sound region of Washington State (*23*). Only with a panel survey can the adjustments over time in residence, workplace location, and modes be logged for the individuals actually making them. Travel panel surveys typically contain a trip diary for one or more days for each individual in a household unit at every survey wave. Changes are thus observed directly and unambiguously. And, as Kitamura (*24*) has emphasized, factors contributing to the travel behavior of a household or individual change almost continuously.

This paper is intended to demonstrate the use of panel data in analyzing the dynamics of locational adjustments to travel conditions. It is exploratory in approach, using primarily descriptive analysis to examine the issues of residential and workplace location changes and mode shifts and the ability of the Puget Sound Transportation Panel (PSTP) data to support such analysis. The paper also builds on preliminary research reported in Murakami and Watterson (*25*). Systematic attention is given to the potentials in the panel survey for biases because of the sample development and its attrition over time.

PUGET SOUND TRANSPORTATION PANEL

PSTP was initiated in 1989 by the Puget Sound Council of Governments, now the Puget Sound Regional Council (PSRC). PSTP is the first (and as-yet only) general-purpose travel panel survey in an urban area in the United States. It was designed to build on the conventional cross-sectional urban travel surveys that have been conducted in the Puget Sound and other metropolitan areas since the early 1960s by adapting elements of such ongoing travel panel surveys as the Dutch National Mobility Panel. PSTP surveys have included telephone interviews, household travel diaries, and attitude surveys.

PSTP survey data collection has taken place at least annually since the fall of 1989. Interviews and diaries were administered in the fall of 1989, 1990, 1992, and 1993. An attitudes-and-values survey, developed by transit marketing and university researchers, was administered to the panel in February 1990, October 1991, and October 1993. Additional contacts for address verifications and corrections, along with new panel member refreshment, also have been made periodically. A number of administrative details on PSTP are documented in Murakami and Ulberg (*26*). Once coded, cleaned, and checked, the panel data have been made available by PSRC for a variety of directed and independent research projects aimed at expanding the stock of information on travel behavior in the Puget Sound region. The result is an ever-increasing body of research using the PSTP data.

The analysis in this paper covers samples drawn from the 1989 and 1990 interviews and diaries, as well as from the 1991 survey. Three wave pairs are developed for this analysis: Wave1-Wave2 (1989–1990), Wave2-Wave3 (1990–1991), and Wave1-Wave3 (1989–1991). In each case, as many continuing households or continuously employed workers as possible were included in the samples for each wave pair. Thus, a household continuing for 1989 and 1990, but dropping out in 1991, could be used only for the Wave1-Wave2 sample. A 1990 replacement household continuing through 1991 could be included in the Wave2-Wave3 sample. Issues related to the validity of these samples are discussed in the next section.

The geographic dimensions of the residential and work location changes are represented by six subregions of the Puget Sound region. The largest county, King (located in the center of the region), is divided into three subregions—the central city of Seattle, plus two large suburban subregions of the county—each containing a population of about 500,000 in 1990. The other subregions are the other three counties in the Puget Sound region, ranging in population from almost 600,000 (Pierce, to the south) to 500,000 (Snohomish, to the north) to just under 200,000 (Kitsap, to the west, by ferry). All three are mainly suburban in composition, with the major exception of the central city of Tacoma in Pierce County (population, 175,000).

PSTP SAMPLES, BIAS, AND WEIGHTING

There are at least two issues in connection with developing samples from the PSTP data, especially ones that involve changes between panel waves. One stems from the stratification of the original PSTP panel by county of residence and by usual travel mode to work. The other involves attrition of panel members between waves and the sample bias this can produce.

Panel Stratification

The original 1989 PSTP was stratified by county and mode so that each county and each of the three major travel modes would contain a statistically valid sample size to permit longitudinal analysis by each stratified subsample. Thus, the original sample of 1,713 households significantly overrepresented households in Kitsap County (12.0 percent versus 6.4 actual, 1990) and Snohomish County (25.4 percent versus 15.6 actual).

For purposes of sample stratification, travel mode was defined on the following usual mode of choice:

1. Households without regular (four one-way trips per week) transit users or carpoolers;
2. Households with regular transit users; and
3. Households with regular (work trip) carpoolers.

Carpooler and nontransit, noncarpool (single-occupancy-vehicle) households were selected using telephone random-digit dialing, which is assumed to replicate reasonably well the proportions of occurrence within the sampled population. As for transit, although some transit-defined households were selected by this means, additional households necessary to overrepresent transit households in PSTP were recruited from transit surveys and on-bus fliers. These are choice-based procedures that present special problems for treatment of otherwise random survey samples.

The original PSTP sample households were defined for mode subsamples as 66.4 percent drive-alone, 22.3 percent transit, and 11.3 percent carpool, thus significantly overrepresenting transit-mode households. Of the 382 transit households in the original sample, 222 had been recruited by random-digit dialing, and 160 had been recruited by the various choice-based methods.

For analysis, the sample needs to represent the regional popula-

tion as closely as possible. To do so, the stratification bias in the original PSTP sample must be corrected with weights. Because the county stratification was based entirely on oversampling through random procedures, the correction weight for each county is the ratio of its actual proportion of households in the region to its PSTP proportion. The 1990 Census was the source of the actual household data. Thus, the King County household sample weight was 1.3849 to compensate for its underrepresentation, the weight applied to Kitsap was 0.5180, to Pierce it was 0.9957, and to Snohomish it was 0.6188.

For the travel-mode sample, the development of the weightings is somewhat more complicated. Pendyala et al. (*27*) have discussed the problem of choice-based samples in panel surveys and developed a system of weights for the PSTP sample to correct for the bias caused by overrepresentation of transit households. The procedure relates the proportions of total households randomly selected, transit households randomly selected, and total transit households in the original sample. The results as applied to the original 1989–1990 sample produced weights of 0.4073 for transit-mode households and 1.1080 for drive-alone and carpool household subsamples.

For households, the weightings changed the original sample means only slightly. Average household size, for example, was reduced from 2.60 to 2.55, whereas the average number of vehicles per household rose from 2.12 to 2.15. By distribution, the proportion of households with children remained at about 35 percent, and the proportion of households with 2+ adults 35–64 years with no children continued at around 28 percent. The weightings had little effect on the distribution of the sample by household income.

For employed workers, the weightings had a somewhat more dramatic effect. The sample means changed only slightly: the average person age rose from 40.0 to 40.8; the average household size dropped from 2.92 to 2.78; the average number of vehicles dropped from 2.48 to 2.44; and the average distance to work remained at about 11.0 mi. But the distribution of usual modes to work shifted to levels more representative of the overall population of the region—77.6 percent drive-alone, 6.3 percent transit, and 12.0 percent carpool, with the remainder in walk, bicycle, and other modes.

Between-Wave Samples

Because this analysis is concerned with samples of households and workers between wave pairs, the important question is the representativeness and consistency of the samples across time periods. Here the issue pertains to attrition of households from the original sample.

Panel attrition is a much-discussed and inevitable aspect of virtually all panel surveys (*28–30*). The risk is that the types of households that fail to continue from wave to wave will be sufficiently concentrated by relevant characteristics as to bias the presumably valid original sample. A related question (at least for panels that use replacement households to refresh the panel) is whether households selected to replace the lost households maintain the panel's representativeness of the population.

In this project, several samples were developed to analyze the amount, type, and impact of residential and workplace relocations in the Puget Sound region over time. Specifically, there were six different samples in this analysis: Wave1-Wave2 (1989–1990), Wave2-Wave3 (1990–1991), and Wave1-Wave3 (1989–1991), each for households and workers. For both 1990 and 1991, the households and workers consisted not only of households still considered part of the panel (those completing travel diaries and indicating willingness to continue), but also those dropping from the panel for whom some relevant information is available. Thus, the households in the Wave1-Wave2 sample include the 1,391 households that stayed in the panel, plus 218 households that dropped out in 1990 but whose 1990 residence locations and some other demographic information were recorded. Similarly, many original households and 1990 replacements dropped out in 1991 but can still be included in the Wave2-Wave3 sample. Any "splits" in households—household members who split to form their own households, through young person new household formation, divorce or separation, roommate splits and so on—are entirely omitted. Only the original household, if it continues as such, is retained for analysis.

The sample enhancement is possible because this analysis needed relatively little information from the travel diaries, which are the defining element for the panel stayers and dropouts. Most of the data for this analysis came from the telephone interviews or follow-ups. The enhancement was not very successful for households in 1991 because no telephone interviews were conducted for demographic data and little follow-up was undertaken. There was more success for workers in 1991 because there were questions on the attitudes-and-values survey that year that completed some employment data.

Nevertheless, there was attrition between each of the wave pairs used for analysis in this project. The question is whether there is serious and relevant bias in this attrition. For an analysis of residential movers and workplace changers, those that drop out of the panel are more likely to have moved than those that stay in the sample—moving is one of the primary reasons for dropping out. But the sample enhancement picks up on a good many of these moves, even out of the region, thus minimizing the number of dropouts. The amount of moving will still be understated. But the important question is how different the lost movers are from the retained movers. Does the between-wave sample still resemble the original sample in its characteristics? Table 1 presents such comparisons for households and workers.

The comparative household and worker demographic characteristics are not substantially divergent across the samples. Even if they were, Hensher (*28*) has argued that nonrandomness in such variables that are exogenous to the analysis at hand are not an important panel attrition bias. The important variables are the endogenous ones—in this case those pertaining to travel behavior. The travel characteristics presented in the tables—work trip length and work-travel mode—do not vary widely across samples. There is some loss of carpool workers, mostly offset by gains in drive-alone workers, but these are relatively small.

Overall, this brief analysis does not find a great deal of evidence that attrition bias is a major problem in the samples developed for this analysis of household movers and workplace changers. There is slightly more such evidence for the Wave2-Wave3 sample than for the Wave1-Wave2. But there is not a prima-facie case for correction of attrition bias, even if there were good data on which to base the correction.

The Wave3 survey in 1991 was not accompanied by the high level of effort in following up and verifying panel household moves and some characteristics connected with these changes. The results for Wave2-Wave3 and Wave1-Wave3 for household residential moves, which are presented in the next section, are significantly degraded by the sample deterioration for 1991.

TABLE 1 Comparison of Household and Worker Characteristics Across Samples: Weighted Observations

Variable	Original	Wave 1-2	Wave 2-3
HOUSEHOLDS:	1713	1609	1722
Average Household Size	2.55	2.54	2.54
Average No. Adults in Household	1.90	1.91	1.89
Average No. Children in Household	0.65	0.64	0.65
Average No. Household Vehicles	2.15	2.17	2.14
Percent by Household Type			
1. Any child <6 yr.	17.7	17.2	17.3
2. All children 6-17 yr.	17.6	17.6	17.2
3. One adult, <35 yr.	4.7	3.8	4.3
4. One adult, 35-64 yr.	9.2	9.0	10.4
5. One adult, 65+ yr.	4.6	4.6	3.8
6. Two+ adults, <35 yr.	6.8	6.2	8.1
7. Two+ adults, 35-64 yr.	27.7	28.9	28.2
8. Two+ adults, 65+ yr.	11.8	12.6	10.6
Percent by Income Level			
1. <$7,500	1.7	1.4	2.1
2. $7,500-$15,000	7.5	7.2	5.9
3. $15,000-$25,000	14.2	13.6	14.4
4. $25,000-$30,000	10.6	10.4	8.4
5. $30,000-$35,000	14.4	14.5	11.0
6. $35,000-$50,000	26.5	27.1	25.6
7. $50,000-$70,000	13.1	13.7	19.6
8. $70,000+	7.5	7.6	11.8
9. Don't Know/Refused	4.7	4.6	1.3
WORKERS:	2034	1878	1487
Average Person Age	40.79	41.01	42.53
Average Household Size	2.78	2.79	2.72
Average No. Household Vehicles	2.44	2.45	2.38
Average Distance to Work (in miles)	10.84	10.96	11.02
Percent by Usual Work-Travel Mode			
1. Drive-Alone	77.6	78.2	79.9
2. Transit	6.3	6.4	6.8
3. Carpool	12.0	11.8	10.1
4. Walk	1.8	1.7	1.4
5. Other	1.6	1.5	1.5
6. Don't Know/Refused	0.8	0.4	0.3

RESULTS OF ANALYSIS

Despite the limitations imposed by the 1991 Wave3 survey, samples were developed for all three wave pairs—Wave1-Wave2, Wave2-Wave3, and Wave1-Wave3—and analysis was conducted. The analysis was intended from the start to be exploratory and descriptive, seeking to develop the best possible samples, to probe what preliminary findings could be drawn from the sample data, and to assess what types of analysis the panel data could support.

The household residential moves and the worker workplace changes are separate analyses, each with three wave pair samples. In each case, the basic comparisons are between location changers and nonchangers. The focus is on explaining the changes through relationships in the data, and on relating the changes to travel and travel behavior. Conclusions are restricted by the data limitations and the analytic methods. But still there are some clear directions emerging from the data.

Change in Residential Location

Overall, approximately 13 percent of the original PSTP households changed their residence location between the first two waves of the PSTP (not counting changes by household members who "split" from main households). This is likely to be an understatement of the total residential mobility during the period because among the 104 households that left the panel and were not able to be followed there was probably a higher rate of moving than within the sample. On the other hand, the rate of residential location change in the Wave2-Wave3 sample was markedly lower, and within the 2-year Wave1-

Wave3 sample the moving was not correspondingly as high. The known data deficiencies at Wave3 suggest a greater reliance on the Wave1-Wave2 findings than for the other samples.

The rates of household residential moves by county and subregion were near the regional rate for all wave pairs. In each pair, the move rates for the central city of Seattle were the highest, and those for East/North King County suburban areas were the lowest. By mode sample, the household move rates tended to be highest for the transit-rider sample, but there was no consistent pattern.

Within these geographic and mode samples, demographic characteristics were clearly the dominant factors in household move rates. Households that changed their residential location did not differ much from nonmovers in average household size, but the movers in all three wave samples clearly were young adult households—single adults, adult couples, or families with preschool children. Households with below-median incomes were more likely to move their residence than those with above-median incomes. Although the housing tenure of households was not collected, many more renter households have below-median than above-median income. Renters have been shown to relocate more frequently than owners (*1*). There was little correlation between household moves and the number of employed persons, licensed drivers, or motor vehicles in the household. Households that moved, however, were far more likely than nonmovers to have experienced a change in the household size during the period, especially to a smaller size.

As for the geographical patterns of the household moves, the strongest tendency was for movers to stay within the same subregion, as might be expected from literature on residential search. But there were large variations among the subregions—85 percent of the Kitsap County moves and 75 percent of the Pierce County moves stayed within those counties, whereas only 40 percent of Eastside King County and 50 to 60 percent of the Seattle and South King County suburban movers remained in those subregions. Seattle, South King County, and, surprisingly, suburban Snohomish County were net losers in the residential relocations. Not included were moves from outside the region into the various subregions. But almost 12 percent of the moves from within the region were to locations outside the region (Wave1-Wave2 only). A full 25 percent of the mover households from Eastside King County moved to locations outside the region.

A question of considerable interest is whether household residential moves are used to reduce the home-to-work commuting distance. To examine this, the individual worker work trip distances were summed for the household for both ends of the wave pairs, and the differences were taken. The distribution of these changes is shown in Table 2, along with the mean of all the changes. Trip distances, calculated directly from networks, were used in this analysis.

On the basis of the between-wave changes in home-work distances for households, there is a clear and consistent pattern in all

TABLE 2 Home-Work Distance Changes for Movers by Prior Wave Distance

Original Distance	Less Distance	More Distance	Same Distance	Total	Average Change
WAVE 1-2					
0-5 miles	41.1	30.8	27.8	100.0	1.3 mi.
5-10	54.6	36.5	8.9	100.0	0.9 mi.
10-15	50.6	38.2	11.1	100.0	-1.3 mi.
15-20	66.2	18.4	15.3	100.0	-3.0 mi.
20-30	57.5	23.5	19.0	100.0	-6.6 mi.
30-50	78.6	16.1	5.3	100.0	-13.5 mi.
50+	68.7	17.4	14.1	100.0	-34.9 mi.
Total	54.3	29.5	16.2	100.0	-3.7 mi.
WAVE 2-3					
0-5 miles	41.0	43.7	15.3	100.0	3.8 mi.
5-10	51.9	35.5	12.6	100.0	-0.6 mi.
10-15	78.5	16.4	5.1	100.0	-7.0 mi.
15-20	85.8	14.2	0.0	100.0	-9.8 mi.
20-30	71.3	19.6	9.1	100.0	-9.8 mi.
30-50	95.7	4.3	0.0	100.0	-28.4 mi.
50+	100.0	0.0	0.0	100.0	-52.4 mi.
Total	67.5	24.5	8.0	100.0	-8.2 mi.
WAVE 1-3					
0-5 miles	29.4	46.4	24.2	100.0	3.2 mi.
5-10	57.1	34.7	8.2	100.0	1.7 mi.
10-15	75.6	12.6	11.8	100.0	-3.9 mi.
15-20	80.1	19.9	0.0	100.0	-9.9 mi.
20-30	86.2	4.4	9.5	100.0	-14.5 mi.
30-50	95.0	5.0	0.0	100.0	-22.9 mi.
50+	87.8	12.2	0.0	100.0	-58.4 mi.
Total	66.5	23.4	10.2	100.0	-7.6 mi.

Note: Values are sums of home-work distances within households (in percentages).

three samples. Above the range of 10 or 15 mi total work trip distance, the residential moves are serving to reduce the trip length and by rather substantial amounts at the high end. However, 60 percent or more of the household moves occur with households having a total work trip distance of less than 15 mi.

Change in Workplace Location

Although a change in residence location affects all members of a household, changes in work location must be examined for particular workers within the household. As with households, the samples of workers were constructed with the maximum number of persons reporting "employment outside the home" in both ends of each wave pair, for whom geographic and demographic information was collected. For example, of the 2,034 persons reporting being employed in Wave1, a total of 1,878 qualified for the continuing sample of Wave1-Wave2.

A change in workplace location was determined using information from both the travel diaries and self-reporting in interviews and survey instruments (especially in Wave3). By these measures, 20.7 percent of the continuing workers changed work locations between Wave1 and Wave2, 19.1 percent changed between Wave2 and Wave3, and 35.7 percent changed in the 2-year period between Wave1 and Wave3.

Workers from the carpool sample had a consistently lower rate of work-location change, whereas those from the transit sample had a somewhat higher level of change. However, the age of the worker was the primary demographic characteristic that distinguished workplace changers from nonchangers. Workers in younger ages were much more likely to change locations between the waves, although there was a substantial amount of change even among the older workers. In the Wave1-Wave2 sample, for example, 36.2 percent of the workers 15 to 24 years old changed workplace, whereas 26.7 percent of the workers 25 to 34 years old changed, and 15.7 percent of the workers 45 to 54 years old changed. The disparities were even greater over the 2-year Wave1-Wave3 period.

The overall rate of workplace change tended to be close to the regional rate in most subregions, with the notable exceptions of consistently low rates of change for workers in Kitsap County and high rates in Eastside King County. Most of the work location changes took place within the same subregion, although with considerable variation among subregions. For example, in the Wave1-Wave3 period, 86 percent of the Pierce County changers stayed in the county, whereas only 54 percent of the Seattle changers stayed in Seattle, and 55 percent of the Eastside King County changers stayed in that subregion. This pattern suggests that at least in King County potential labor market areas are perceived to encompass more than one defined subregion, whereas in Pierce and Kitsap Counties the county defines the labor market area.

There were significant net shifts of workers among subregions. For Seattle in the Wave1-Wave3 sample, there were 100 Wave1 workers changing location, with 54 remaining in the city, less 46 relocating out of the city, plus 28 relocating into the city, for a net loss of 17 or 17 percent. For Eastside King County, there were 45 Wave1 workers changing location, with 25 remaining in the subregion, less 20 relocating out, plus 36 relocating into the subregion (mostly from Seattle), for a net gain of 16 or 35 percent. Pierce County was also a major net gainer of workers, gaining 22 percent, mostly from South King County.

As with the household residential location changes, there were consistent effects in the work location changes of decreasing the workers' home-to-work trip distance, at least for those with distances greater than 10 to 15 mi. Table 3 shows the distribution of these trip distance changes by prior home-to-work distance, along with the average amount of the changes.

Even though the data from the Wave2-Wave3 pair are not as smooth, the work trip distance changes provide consistent evidence of workers using workplace location changes to reduce their commute distances, especially those with longer work trip lengths. It should be noted, however, that the majority—over 60 percent—of the workers changing locations started with work trip distances under 15 mi. But clearly those with the longer distances were using such changes to shorten the work trip.

A final aspect of workplace location changes is changes in travel mode to work. In the PSTP, the mode to work was reported in two different ways: (*a*) identification of the "usual mode" to work for each household member in the telephone interview or questionnaire, and (*b*) a record in the trip diaries of the actual mode taken by each household member on the 2 assigned days for each wave (Wave1 and Wave2 only). The identified usual mode is the basis for the results presented next. Table 4 contains transitions in travel mode between waves for workers changing job locations.

Among workers changing work locations, there was a high degree of shifting their usual travel mode to work, especially out of transit and carpooling, with most of these going to driving alone. But there were correspondingly large shifts by workplace changers into transit and carpooling, so that the net shifts for such workers were about nil. These shifts suggest workplace changes to locations with good transit service and perhaps closer to the workplaces of spouses or other friends.

The surprising result of the PSTP mode transition data was the degree of instability in carpooling, for both those who changed job locations and those who did not. Even for the nonchangers, the carpool retention rate ranged from 40 to just over 50 percent in the three wave pairs. And, among the workplace changers, for the Wave1-Wave3 period there seemed to be deterioration in the gains made by carpooling over the 2-year period. For transit users in Wave1 who switched to driving alone by Wave3, over 60 percent had changed job locations, probably out of places with good transit service. But for carpoolers in Wave1 who had switched to driving alone (well over half of the Wave1 carpoolers), only 30 percent had changed job locations; all the others just shifted mode with the same workplace.

Gender Characteristics

In light of literature that suggests differences in travel behavior between men and women workers, the worker sample was further disaggregated by worker sex. A total of 45.7 percent of the continuing workers between Wave1 and Wave 2 were women. Change of workplace rates for both men and women were comparable: 20.4 percent for men and 21.2 percent for women. The only significant sample difference was a greater predominance of driving alone to work for men and more transit to work for women.

As for workplace changers, women were markedly younger than men. Almost 48 percent of the women who changed were under 35 years, versus 33 percent of the men. In life cycle stage, there were similar relative proportions in each stage, except that single women

TABLE 3 Home-Work Distance Changes for Workers by Prior Wave Distance

Original Distance	Less Distance	More Distance	Same Distance	Total	Average Change
WAVE 1-2					
0-5 miles	8.1	79.6	12.3	100.0	6.3 mi.
5-10	38.4	48.3	13.3	100.0	2.3 mi.
10-15	56.6	42.4	1.0	100.0	2.2 mi.
15-20	66.5	29.0	4.5	100.0	-3.7 mi.
20-25	73.7	16.9	9.4	100.0	-4.7 mi.
25-30	72.0	28.0	0.0	100.0	-7.2 mi.
30+	86.6	13.4	0.0	100.0	-20.8 mi.
Total	40.6	50.2	9.2	100.0	1.0 mi
WAVE 2-3					
0-5 miles	27.3	61.5	11.1	100.0	4.2 mi.
5-10	38.5	56.2	5.3	100.0	2.5 mi.
10-15	65.9	33.6	0.5	100.0	-0.9 mi.
15-20	57.1	40.4	2.5	100.0	0.7 mi.
20-25	53.8	39.5	6.8	100.0	-2.6 mi.
25-30	43.2	37.4	19.4	100.0	-2.5 mi.
30+	63.5	28.7	7.8	100.0	-11.1 mi.
Total	45.8	47.6	6.6	100.0	0.6 mi.
WAVE 1-3					
0-5 miles	25.9	64.3	9.8	100.0	5.2 mi.
5-10	42.9	52.1	5.0	100.0	1.8 mi.
10-15	59.5	40.1	0.4	100.0	-1.6 mi.
15-20	64.1	33.8	2.1	100.0	-2.5 mi.
20-25	80.0	15.5	4.5	100.0	-9.5 mi.
25-30	79.1	12.4	8.5	100.0	-11.6 mi.
30+	84.2	15.8	0.0	100.0	-17.8 mi.
Total	49.8	45.1	5.1	100.0	-0.8 mi.

Note: Values are in percentages.

under 35 years were far more likely than comparable men to change workplaces during the year. Women workplace changers were more likely to stay within the same subregion and more likely to suburbanize. All women workers were more likely than men to live and work in the same subregion. This characteristic was reinforced by the workplace location changes.

Women workers in general lived closer to work than men. Except for the workplace changers, a full 73 percent lived less than 10 mi from work (before the change), compared with 52 percent of the men who changed. Only 15 percent of the women had work trip distances greater than 15 mi, whereas 33 percent of the men who changed did. But the average changes in work trip distance were similar for both groups.

As for work trip mode, the mode shifts for women who changed workplaces were dramatic—and devastating for transit and carpool use in work trips. Only 40 percent of the transit users and 35 percent of the carpoolers remained in those modes to work after their workplace changes. Transit mode share dropped from 9.5 percent to 6.5 percent. For men who changed workplaces, the transit mode share increased by 65 percent. Enough women who changed shifted into carpools to keep the same overall share, but for men who changed so many previously solo drivers shifted to carpools that the mode share doubled from 7 to 14 percent over the year.

SUMMARY AND CONCLUSIONS

Summary of Findings

Although this project was exploratory and descriptive in its approach and the data from the 1991 Wave3 do not support extensive analysis, there still are some clear and consistent results from the tabulations. There was a high rate of both residential and workplace change among the panel members. Almost 14 percent of the households moved their residences during the best 1-year period (Wave1-Wave2); the other wave periods have apparent data deficiencies. This figure may be lower than the true rate because of moving households lost to the panel. Continuing workers changed work locations at a rate of about 20 percent each year. These changes were dominated by young adult households and younger workers, although there were a considerable number of changes by others as well. Women who changed tended to be younger than men. The youthful bias also correlates with relatively low incomes, renter tenure, and transit ridership.

Geographically, there were some variations in rates of change across the six subregional areas: residential moves tended to be low in Pierce County and Eastside King County and high in Seattle, whereas workplace changes were very low in Kitsap County and

TABLE 4 Mode-to-Work Transitions by Wave Pair: Workers Changing Workplaces

WAVE 1-2	*Wave 2 Mode*				
Wave 1 Mode	Drive Alone	Transit	Carpool	Walk/ Other	Total
Drive-Alone	224	10	19	3	256
Transit	8	10	2	1	21
Carpool	10	0	13	0	23
Walk/Other	2	0	2	4	8
Total	244	20	36	8	308

WAVE 2-3	*Wave 3 Mode*				
Wave 2 Mode	Drive Alone	Transit	Carpool	Walk/ Other	Total
Drive-Alone	176	7	15	8	206
Transit	3	9	2	1	15
Carpool	13	1	9	1	24
Walk/Other	5	0	0	3	8
Total	197	17	26	13	253

WAVE 1-3	*Wave 3 Mode*				
Wave 1 Mode	Drive Alone	Transit	Carpool	Walk/ Other	Total
Drive-Alone	273	7	9	11	301
Transit	12	10	3	3	28
Carpool	21	4	7	0	31
Walk/Other	4	2	0	1	7
Total	310	23	19	15	367

high in Eastside King County. Residential moves tended to be within the same subregion, but with an outward bias away from Seattle to suburban King County and toward Pierce County. Workplace changes in King County were less likely to be in the same subregion, again with an outward direction from Seattle. Kitsap and Pierce County changes were mostly within the same county.

Both residential and workplace changes were strongly connected with reductions in home-to-work distances for those households and workers with prior distances greater than 15 mi, and the greater the distance, the larger the average reduction in distance after the change. Workplace changes brought about shifts in the workers' usual travel mode to work, especially out of transit and carpooling. But there also were significant shifts by workplace changers into transit and carpooling, suggesting changes to locations with better transit service and perhaps closer to workplaces of spouses or other friends. Carpooling in general appears to be unstable, for both those who change job locations and those who do not.

When disaggregated by worker gender, however, more dramatic shifts appear. Women who change workplaces tend to start from relatively short work trip lengths, and the change leads to substantial shifts out of transit and carpool modes. Although transit mode share of women changers dropped by a third, the men who changed increased their transit and carpool use by large amounts.

A Final Word

Despite the negative comments on the quality of the 1991 PSTP data base and its implications for the ability of the PSTP to support dynamic demographic analysis of travel behavior, the results from this work indicate bright prospects for such analysis. First of all, the findings support the hypothesis that there is a great deal of change occurring in demographics and travel behavior, such as residential and workplace mobility and mode shifts. Second, the demographic changes seem to bear significantly on the observed changes in travel behavior by urban residents. Third, such changes suggest a dynamic process of adjustment on the part of households and workers to their needs. Finally, the panel data base seems ideally suited to empirical research on emerging theory of individual adjustments to inefficient commutes.

This work has also pointed up some important deficiencies in the PSTP data bases and some limitations in the amount and type of research that they can support. This will always be the case with real-world panel surveys and the data they produce. But the PSTP is the first general-purpose travel panel survey in the United States, and the more its data are used, the more will be known for better panel survey design and administration. There is great potential through such surveys for major breakthroughs in research and expanding knowledge of the way urban areas and their residents behave. Change is the foundation of life, and the panel design is well suited to analysis of that change.

ACKNOWLEDGMENTS

Much of this research was conducted under a contract with the Puget Sound Regional Council. PSTP data base and technical support for this research were provided by the Regional Council.

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Publication of this paper sponsored by Committee on Traveler Behavior and Values.