Title

Using Longitudinal Methods for Analysis of a Short-Term Transportation Demonstration Project

Authors

Guiliano, Genevieve
Golob, Thomas F.

Publication Date

1990-08-01

Using Longitudinal Methods for Analysis of a Short-Term Transportation Demonstration Project

Genevieve Guiliano
Thomas F. Golob

August 1990
Reprint, No. 28

The University of California
Transportation Center

University of California
Berkeley, CA 94720

The University of California Transportation Center

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U.S. Department of Transportation, the California State Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, and Irvine; the Institute of Urban and Regional Development at Berkeley; the Graduate School of Architecture and Urban Planning at Los Angeles; and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in Center activities. Researchers at other universities within the region also have opportunities to collaborate on selected studies. Currently faculty at California State University, Long Beach, and at Arizona State University, Tempe, are active participants.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. For a list of publications in print, write to the address below.

University of California
Transportation Center

108 Naval Architecture Building
Berkeley, California 94720
Tel: 415/643-7378
FAX: 415/643-5456

Using Longitudinal Methods for Analysis of a Short-Term Transportation Demonstration Project

Genevieve Giuliano

School of Urban and Regional Planning
University of Southern California

Thomas F. Golob

Institute of Transportation Studies
University of California at Irvine

Reprint, No. 28

Transportation
17:1-28, 1990

The University of California Transportation Center
University of California at Berkeley

Transportation **17**: 1—28, 1990

Using longitudinal methods for analysis of a short-term transportation demonstration project

GENEVIEVE GIULIANO[1] & THOMAS F. GOLOB[2]

[1] *School of Urban and Regional Planning, University of Southern California, Los Angeles, CA 90089-0042, USA;*
[2] *Institute of Transportation Studies, University of California, Irvine, CA 92717, USA*

Accepted 12 March 1990

Key words: panels, flexible work hours, longitudinal data, Honolulu

Abstract. This paper documents an application of panel, or longitudinal data collection in the evaluation of a TSM (Transportation Systems Management) demonstration project. The project was a four-week demonstration of staggered work hours in downtown Honolulu during February—March 1988. The 4 wave panel survey elicited commuting experiences of approximately 2,000 downtown employees at two week intervals before and during the project. The sample involved both employees who participated in the project by shifting their work hours, and those who did not. The panel survey was augmented by floating-car observations of travel times on major routes into downtown Honolulu on the same four dates.

The purpose of the analysis was to determine whether employee commute times were affected, and if so, how these changes were distributed among various employee segments. Two methods were used. First, travel time changes were estimated using paired t-tests. Second, regression equations were used to estimate project time savings as a function of trip length, route, and location of residence. Results show that travel time savings due to the project were typically small, less than ten percent. Nonparticipants experienced greater savings than participants, and some segments of participants experienced longer travel times during the project. The panel method proved to be an effective way to measure project travel time impacts and shows that the method is appropriate in short time applications.

1. Introduction

Longitudinal, or panel, analysis has become the method of choice for many aspects of travel behavior research. Longitudinal methods have been advocated because of the dynamic nature of the travel choice process (Clarke, Dix & Goodwin 1982; Davies & Pickles 1985; Kitamura 1990).

Presented at the Annual Meeting of Transportation Research Board, January 7—11. 1990, Washington, D.C.

These dynamics include dependencies among travel choice sequences, lags and leads in responses to changing conditions, and interrelationships between perceptions, attitudes and choices. Under such conditions, longitudinal methods are required to properly specify relationships between travel choice factors and establish causality. Longitudinal methods have also been advocated because of their superior statistical efficiency and capacity to measure small changes compared to cross-sectional methods (Smart 1984; van de Pol 1984; Uncles 1988). Finally, longitudinal methods are particularly appropriate for analysis of attitudinal responses (Duncan, Justin & Morgan 1987).

The primary focus of longitudinal analysis has been on behavioral changes that can be effectively observed with panel survey waves one year apart, e.g., car ownership and mode choice, or life cycle characteristics and car use. The existence of several extensive panel surveys have made it possible to examine these "macrodynamic" processes (Clarke, Dix & Goodwin 1982). Some examples include the Dutch Mobility Panel (Golob, Schreurs & Smit 1985), the Michigan Panel Study of Income Dynamics (University of Michigan Survey Research Center 1972) and the Australian Automobile Panel (Hensher 1986). Long and intermediate term dynamics are particularly amenable to panel data; problems of sample consistency and retrospective data are minimized, while external temporal changes can generally be controlled.

Longitudinal methods have been used less frequently in short-term analysis, although their advantages with respect to measurement of small changes and of attitudinal responses are clear. This paper presents results of a panel study of responses to a short-term change in employee work schedules. The study provides a comprehensive evaluation of employee travel experiences, and thus demonstrates the advantages of using longitudinal methods for this type of research problem.

2. The research problem

The State of Hawaii conducted a one month staggered work hours demonstration Project to determine whether a large-scale shift in work hours among downtown workers could reduce traffic congestion. Evaluation of the Demonstration Project had several objectives:

- to determine the magnitude and pattern of traffic impacts, if any;
- to identify Project impacts on employees both at home and at work;
- to assess employee perceptions of the Demonstration Project; and

- to measure employee attitudes toward possible future permanent staggered work hours programs.

This paper focuses on the first objective.[1]

2.1. *Project description*

During the Demonstration Project, public sector employees were required to shift their work schedule from a daily start work time of 7:45 a.m. to 8:30 a.m. Operating hours of all state, city and county offices were changed from 7:45—4:30 to 8:30—5:15. Participation in the Project was mandatory for all public employees; nonparticipation required approval via a formal exemption process. Participation by private sector downtown employers was encouraged but not required. Employees at participating private companies were able to choose their Project work schedule.

The Demonstration Project was conducted from February 22 through March 19, 1988. These dates were chosen to coincide with the single longest period of relatively stable travel conditions (e.g., no major holidays, school vacations, etc), so that before/after comparisons could be made while minimizing possible seasonal effects.

2.2 *Research design*

A panel survey design was selected as the best method for measuring project impacts on traffic conditions. Daily traffic conditions tend to be highly variable, particularly on congested routes, even when traffic incidents and weather conditions are controlled. Thus identification of systematic effects is difficult at best. In addition, only a small proportion of the downtown workforce would be changing work hours, and of course downtown work trips make up only a portion of the traffic flow on any given route. It was therefore expected that Project impacts were likely to be quite small and to vary between routes. Given these conditions, measurement of project impacts required minimizing random sources of error and utilizing repeated measurements.

The panel design included a four wave employee survey supplemented by a corresponding four waves of traffic flow data. The employee survey included identical questions regarding travel experiences on each of the survey days. The traffic flow data provided a means to cross-validate the reported travel data. In view of the small changes that were likely to occur, devising a method to internally validate results was necessary.

3. The survey and data collection

The four-wave employee survey was administered at two week intervals, with two waves before the Project and two waves during the Project. Survey dates were February 3 and 17, and March 2 and 16. Survey dates were the same day of the week to minimize the effect of day to day differences in travel conditions. In addition to the questions on commuting experiences on each of the survey days, the first wave also elicited background information on demographic, socioeconomic and residential location characteristics. The last wave had questions regarding attitudes and perceptions of the project.

Respondents were selected on a uniform 20 percent, or 1 in 5 basis from both the public sector and private sector companies that had elected to participate in the project. Surveys were distributed and collected at the worksite. All four waves were distributed at one time, and instructions on when to complete each wave were written on each of the color coded questionnaires. Survey dates were prominently advertised, and employees were reminded to complete and return their surveys on each of the dates.

3.1 *Traffic flow data*

Traffic flow data were collected via floating car observations taken on each of the survey dates. Floating car observations are collected by making trips along an identical route, with one car commencing every 15 minutes, and recording actual times at a series of checkpoints along the route. Checkpoints were obvious points of reference (e.g., freeway overpasses), from 1/4 to 1 mile apart, chosen so as to be able to measure possible differences in conditions along the route. In most cases, a given starting time and route was driven by the same individual on each of the four dates, so this was a special type of panel data collection.

Floating car data were collected on three routes representing the major directional flows to and from the downtown area. The unique topography of Oahu creates three distinct, restricted corridors linking downtown with the island's residential areas. The Leeward Area in the northwest portion of the island is linked to downtown by a corridor squeezed between Pearl Harbor and the central mountains (Koolau Range); the East Honolulu Area is linked to downtown via a corridor between these mountains and the sea. Finally, the Windward Area is on the opposite side of the mountains from downtown, being accessed by only two trans-mountain routes. Route 1 starts in the Leeward area suburbs, Route 2 starts in the East Honolulu area, and Route 3 starts in the Windward area (Table 1).

Table 1. Floating car routes.

Route	Description	Residential area	Starting point	Ending point	Length in miles	Peak period
1. Mililani	Mililani via Kamehameha Hwy H-1 Freeway, Moanalua Freeway	Leeward	Kamehameha Hwy. at Kuahelani Ave.	Vineyard Blvd. off-ramp	15.1	5:15—8:15 a.m.
2. Hawaii Kai	Hawaii Kai via Kalanianaole Hwy., H-1 Fwy.	East Honolulu	Kalanianaole Hwy. at Keahole St.	Ward Ave. overpass	9.3	6:00—9:00 a.m.
3. Kailua	Kailua via Pali Hwy.	Windward	Kalanianaole Hwy. at Castle Hospital	Off-ramp to Punchbowl and H-1 Fwy.	9.1	5:30—8:30 a.m.

Floating car data were collected only for the AM peak, and the peak period was selected based on the traffic flow pattern for each route.

3.2. *Panel survey response and attrition*

Attrition is a well-known potential problem in panel surveys. Attrition may affect the representativeness of the final sample, and can introduce bias if drop out is correlated with factors related to the issues under analysis (Hausman & Wise 1979; Kitamura & Bovy 1987). Attrition may be due to loss of contact with the respondent, respondent fatigue, or other factors. In this case the first possibility was minimized by distributing all survey waves at the same time and by the short time span of the survey.

A total of 2,297 survey packets were distributed, each packet consisting of a cover letter and four surveys to be filled out and returned on the four survey dates. The response rates for the four waves are shown in Fig. 1: 2,021 or 88.0 percent of the sampled employees responded to the first wave, and this dropped in successive waves to 85.4 percent, 83.3 percent, and 76.8 percent. The corresponding incremental drop-out or attrition rate is also graphed in Fig. 1. The attrition rate for the first three waves shows the expected diminishing marginal rate experienced in other surveys (e.g., Meurs et al. 1990), but the attrition rate of wave four does not. The relatively high attrition between waves three and four is apparently due to the added burden of attitudinal questions that were included

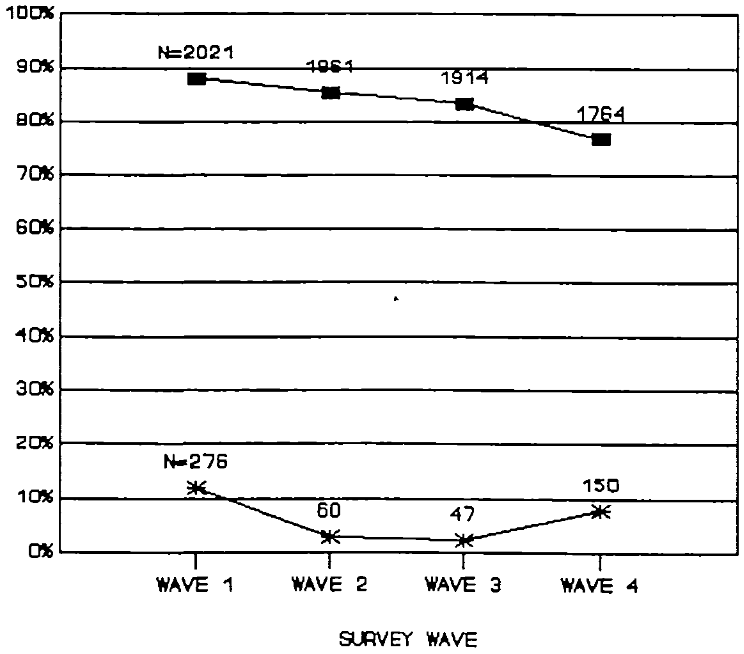

Fig. 1. Employee panel survey response and incremental drop-out rates.

only on this last wave. Some respondents might have chosen not to respond to these questions because of perceived or actual employer pressure, even though all responses were confidential. Thus, although there is evidence that attitudes, preferences, and feelings can be asked in panel surveys without undue sample attrition and panel conditioning effects (e.g., Lyon 1984; Morgan 1982), it is possible that such questions were problematic in the staggered work hours demonstration project panel. The overall response rate was unexpectedly high and the aggregate attrition rates, even considering the accelerated last-wave attrition, were acceptable.

In order to detect potential sample attrition bias problems in the analyses of time savings, logit models were estimated in which the dependent variable measured whether or not a respondent dropped out of the panel. The independent variables were measures of personal and household characteristics, including employment sector dummy variables and a dummy variable for project participation. Separate models were run for drop out after each of the first three panel waves and for drop out after any of these waves. The only variables that were statistically significant at the $p = 0.05$ level were the employment sector dummy variables. Controlling for employment sector (state, city-county, and private), there were no significant relationships between the probability of panel drop out and socioeconomic and demographic characteristics, or between attrition and whether or not a respondent participated in the demonstration project. The differential response rates by sector were controlled for in the analysis either by conducting statistical tests separately for each employee segment or by applying appropriate weighing factors. Separate analysis is also dictated for the private and public sectors because of differences in their respective sample universe.

4. Analysis of the panel data

The Honolulu panel data are different from most other panel data collected for travel demand analysis purposes because of the short duration between survey waves and the focus on the commute to and from work. Other panels tend to have waves with annual or biannual intervals and are concerned with broader issues of mobility and travel demand. Consequently, many of the methods used in the analyses of such other panels (reviewed in, for example, Hensher & Wrigley 1986, and Kitamura 1989) are inappropriate or present unnecessary complications in the present case. Dynamic demand issues such as lagged effects, asymmetrical change, temporal stability, and path dependency (Kitamura 1987, 1989) are less important here than in other panel data. But there are still issues such as panel conditioning, initial conditions, and autocorrelated errors that must be taken into account in analyzing the data.

Travel time impacts were analyzed in two stages. The initial stage of the analysis involved estimation of mean travel time changes from before to during the Demonstration Project for various groups of commuters. The groups included participants and nonparticipants in the Demonstration Project, government versus private sector employees, and commuters using different travel corridors to and from the downtown Honolulu area. It is desirable to have a control group of commuters not affected by the Project, but this was not possible since all commuters into downtown Honolulu were potentially affected by changes in traffic flow due to the Project. These first stage estimates were generated using paired t-tests; e.g., pairwise comparisons of trips made by the same commuter. This is a particularly efficient statistical test for two reasons. First, the high positive correlation between before-and-during-Project trip times reduces the variance of the trip time differences. Second, the test controls for individual-specific sources of variation such as driving behavior, route, parking location, etc. The panel data thus provide the potential for detecting changes smaller than those that can be detected using independent before-and-after survey data.

. The second stage of the analysis involved an explanation of Project influences on travel times in terms of employee segments and trip characteristics. The objective in this stage is to estimate the parameters in an equation appropriate for regression, analysis of variance, or log-linear modeling:

$$T_D - T_B = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \ldots + \beta_p\chi_p + \varepsilon, \tag{1}$$

where T_D and T_B are trip times during and before the Demonstration Project, respectively, $\chi_i(i = 1, 2, \ldots, p)$ are explanatory variables, $\beta_j(j = 0, 1, \ldots, p)$ are parameters to be estimated, and ε is the residual or error term. Ordinary least squares estimates of the parameters of Equation (1) will be biased because both T_D and T_B are separate, highly correlated functions of many of the same χ_i variables, and one of the χ_i is likely to be T_B itself; that is, the difference in travel times is expected to be a function of before-Project travel time. Fortunately, panel data provide a means of dealing with the biases inherent in such an equation.

The explanatory variables in Equation (1) can be partitioned into before-Project travel time, all other variables, and the first-order interactions between travel time and the other variables. For expository purposes, it can be assumed that there is only one explanatory variable in addition to travel time. In general, such a variable would be static, or temporarily invariant over the course of the panel survey (for example, a dummy variable capturing residential location or employment sector). Equation (1) can then be rewritten for travel time differences based on comparisons between the first during-Project panel wave (wave 3) and both of the pre-Project waves (waves 1 and 2):

$$T_3 - T_1 = \beta_{01} + \beta_{11}T_1 + \beta_{21}\chi + \beta_{31}T_1\chi + \varepsilon_1 \tag{2}$$

and

$$T_3 - T_2 = \beta_{02} + \beta_{12}T_2 + \beta_{22}\chi + \beta_{32}T_2\chi + \varepsilon_2 \tag{3}$$

where T_i denotes travel time in wave i, χ is the static explanatory variable, and the β_{ij} are parameters to be estimated. Equations (2) and (3) can be rewritten as

$$T_3 = \beta_{01} + (\beta_{11} + 1)\,T_1 + \beta_{21}\chi + \beta_{31}T_1\chi + \varepsilon_1 \tag{4}$$

and

$$T_3 = \beta_{02} + (\beta_{12} + 1)\,T_2 + \beta_{22}\chi + \beta_{32}T_2\chi + \varepsilon_2 \tag{5}$$

These equations express a special type of autoregressive process; clearly each residual term will be related to the terms on the right-hand side of each equation that involve travel time, because the unexplained portions of T_3 and T_1 or T_3 and T_2 will be related. It is logical to assume that these residual terms, representing effects of the Project and any other special traffic conditions on the date of the wave 3 survey that are *not* explained by the explanatory variables, are highly correlated:

$$\varepsilon_2 = \phi\varepsilon_1 + \nu, \tag{6}$$

with $1 < \phi < 0$, and ν normally distributed and independent of ε_1.

Correlation (6) can be used to transform Equations (4) and (5) to eliminate the dependencies between T_1 and ε_1 and T_2 and ε_2. Subtracting ϕ times Equation (4) from Equation (5) yields

$$\begin{aligned} T_3 - \phi T_3 = {} & \beta_{02} - \phi\beta_{01} + (\beta_{12} + 1)\,T_2 - \phi(\beta_{11} + 1)\,T_1 \\ & + (\beta_{22} - \phi\beta_{21})\,\chi + \beta_{32}T_2\chi - \phi\beta_{31}T_1\chi + \varepsilon_2 - \phi\varepsilon_1 \end{aligned} \tag{7}$$

Rearranging Equation (7) yields:

$$T_3 = \frac{\beta_{02} - \phi\beta_{01}}{(1-\phi)} + \frac{(\beta_{12}+1)}{(1-\phi)} T_2 - \frac{\phi(\beta_{11}+1)}{(1-\phi)} T_1 + \frac{(\beta_{22} - \phi\beta_{21})}{(1-\phi)} \chi$$

$$+ \frac{\beta_{32}}{(1-\phi)} T_2\chi - \frac{\phi\beta_{31}}{(1-\phi)} T_1\chi + \frac{1}{(1-\phi)} \nu \qquad (8)$$

Ordinary least squares estimates of Equation (8) will generally be unbiased if the relationship between travel times is first-order autoregressive because χ is static, thus precluding lagged effects. If it is assumed that the main effects of χ on changes in travel times are stable, the regression coefficient of χ in Equation (8) is identically $\beta_{22} = \beta_{21}$. If the interaction effects are stable, $\beta_{32} = \beta_{31} > 0$, in which case the serial correlation coefficient ϕ can be estimated from the negative ratio of the regression coefficients of χ T_1 and χT_2. If there is more than one static explanatory variable with stable interaction effects, then the serial correlation coefficient ϕ is overidentified and a comparison of estimates provides an insight into the validity of the model assumptions (Kessler & Greenberg 1981).

5. Results

Panel survey data on reported departure and arrival times for each commute trip made it possible to conduct four before/after combinations (wave 1 to wave 3, 2 to 3, 1 to 4, and 2 to 4) for each individual commuter. The travel time analysis reported here is limited to auto commuters, representing approximately 80 percent of all employees.[2] Since the intent of the Project was to redistribute peak period traffic, it was expected that changes in travel time experiences by each individual would depend upon whether the individual participated in the project and shifted to the new 8:30—5:15 schedule. as well as on his/her prior schedule. It was also suspected that project effects could differ by geographic area, in view of differences in peak traffic patterns. level of congestion, and share of downtown trips in the traffic stream. Reported travel times were therefore analyzed for different employee segments and different geographic areas.

Respondents were divided into four main categories:

1. Participants — shifted to the 8:30 to 5:15 schedule.
2. Nonparticipants — did not change work hours.

3. "Early changers" — shifted to a work schedule at least one half hour earlier than usual.
4. "Late changers" — shifted to a work schedule at least one half hour later than usual.

Table 2 gives the number of commuters in each category by sector. Participants were further divided into those who previously started work at 7:30 or later (defined as "prescribed changers"), and those who previously started work before 7:30 a.m. ("radical changers"). Table 2 shows that a substantial proportion of public sector employees (almost 40 percent) applied for and received exemption from project participation.

Because of the differences in travel conditions between travel corridors, residential locations, reported by respondents on the basis of zip code areas, were clustered into six areas for purposes of analysis. The areas were selected on the basis of homogeneous travel characteristics of the residents and are defined in detail in Giuliano and Golob (1989: 39—40). Briefly, these areas are: East Honolulu (east of Diamond Head), Windward, Leeward (west of Pearl Harbor), Near (or East) Leeward, West Central (West downtown Honolulu) and East Central (East downtown Honolulu).

Table 2. Work hour changes by sector.

Group	Public		Private	
	Number	%	Number	%
1. Participants	610	49.6	74	8.4
2. Non participants	489	39.7	552	62.7
3. Early changers	10	.8	97	11.0
4. Late changers	72	5.9	23	2.6
Varying hours	49	4.0	134	15.2

5.1. *Single-point estimates of changes*

Results of paired t-test analyses of changes in work-bound travel times for segments of Project participants are shown in Table 3. Travel time means, standard deviations and differences are given in minutes. The statistics are for car travelers (drivers and passengers) who reported no stops from home to work in either period being compared (consequently the different sample size for each comparison). The changes experiences by the segments of participants were consistent across all four pre-Project to Project

Table 3. Paired comparisons of pre-project and project work-bound travel times: participant segments.

Comparison				Pre-Project		Project				
Pre-Project	Project	Segment	N	Mean	Std. Dev.	Mean	Std. Dev.	Correlation	Mean Diff.	t-value
Wave 1	Wave 3	Prescribed changers	85	34.8	19.9	31.0	14.8	0.86	−3.75	−3.34*
		Radical changers	54	30.2	12.4	41.0	17.3	0.76	+10.81	7.07*
Wave 2	Wave 3	Prescribed changers	101	36.3	20.3	33.1	16.8	0.82	−3.27	−2.81*
		Radical changers	58	29.8	15.3	39.2	17.1	0.74	+9.34	6.03*
Wave 1	Wave 4	Prescribed changers	70	33.1	20.2	30.5	15.9	0.80	−2.60	−1.81
		Radical changes	42	26.2	11.9	35.4	14.9	0.75	+9.14	6.00*
Wave 2	Wave 4	Prescribed changers	80	33.6	20.0	30.9	16.4	0.85	−2.83	−2.39*
		Radical changers	47	25.7	12.5	34.7	15.0	0.69	+9.00	5.56*

* Mean difference significant at $p = 0.05$ level.

comparisons and were statistically signficant at the $p = 0.05$ level in all but one case. The prescribed changers experienced approximately a 9 percent improvement in work-bound travel time, but radical changers experienced a substantial deterioration in travel times of approximately 34 percent. This was the penalty for moving from early starting times, an unintended consequence of the Demonstration Project. There were no further segmentations of these two groups with significantly different travel time changes. This is partly a consequence of small sample sizes and is a principal motivation for the multivariate regression analyses described in Section 4, the results of which are documented in the next section.

Results for the home-bound trips of car commuters are shown in Table 4. (The t-test results in this and following tables are consistent for the four pre-Project to Project comparisons; thus only the wave 2 to wave 3 comparisons, which are less subject to panel conditioning effects (Golob 1989) is shown to simplify the presentation.) There was no significant change experienced by prescribed changers on their home-bound trips, but radical changers experienced a significant increase in their travel time. This increase averages about 14 percent for the four pre-Project to Project comparisons.

Nonparticipants' experiences were different from those of the Project participants. Typical comparison results for work-bound trips for nonparticipants divided into two segments, government (State of Hawaii, and City and County of Honolulu) and private-sector employees are shown in Table 5. Government sector nonparticipants experienced an increase in work-bound travel time, which averaged about 4 percent for the four pre-Project to Project comparisons, while private-sector nonparticipants experienced a decrease in travel time, which averaged about 5 percent. As the private-sector nonparticipants represent a larger universe than the government-sector nonparticipants, this indicates a net gain for the total universe of nonparticipants. However, these detected changes are not statistically signficant at the $p = 0.05$ level. There were no significant, or even marginally insignificant, changes in nonparticipants home-bound trips.

Travel time results for government-sector nonparticipants were further disaggregated by mode and residential location to determine whether travel time changes were significant for specific subgroups. Results are given in Table 6. The deteriorations in work-bound travel times are concentrated among car passengers rather than car drivers, indicating potential problems with passenger drop-offs due to localized congestion in the vicinity of government facilities. Furthermore, Windward area residents experienced the greatest increase in travel time, followed by residents of the East Honolulu area. Leeward area residents experienced a

Table 4. Paired comparisons of pre-project and project home-bound travel times: participant segments.

Comparison				Pre-Project		Project				
Pre-Project	Project	Segment	N	Mean	Std. Dev.	Mean	Std. Dev.	Correlation	Mean Diff.	t-value
Wave 2	Wave 3	Prescribed changers	47	29.8	13.7	30.1	14.1	0.66	+0.34	0.84
		Radical changers	25	28.1	9.7	32.9	12.1	0.61	+4.76	2.41*

* Mean difference significant at $p = 0.05$ level.

Table 5. Paired comparisons of pre-project and project work-bound travel times: nonparticipant segments.

Comparison				Pre-Project		Project				
Pre-Project	Project	Segment	N	Mean	Std. Dev.	Mean	Std. Dev.	Correlation	Mean Diff.	t-value
Wave 2	Wave 3	Government employees	131	31.4	15.5	32.6	15.9	0.85	+1.2	1.61
		Private-sector employees	134	34.8	17.0	33.6	17.2	0.87	−1.6	−1.58

* Mean difference significant at $P = 0.05$ level.

Table 6. Paired comparisons of pre-project and project work-bound travel times: nonparticipant government sector segments.

Comparison				Pre-Project		Project				
Pre-Project	Project	Segment	N	Mean	Std. Dev.	Mean	Std. Dev.	Correlation	Mean Diff.	t-value
Wave 2	Wave 3	All Government Employees	131	31.4	15.5	32.6	15.9	0.85	+1.20	1.61
		car drivers	92	31.6	15.4	32.3	15.6	0.84	+0.59	0.65
		car passengers	39	30.8	15.9	33.4	16.7	0.88	+2.67	2.05*
		East Honolulu	34	26.9	12.0	29.1	8.4	0.42	+2.21	1.13
		Windward	27	41.2	14.5	45.0	17.5	0.86	+3.78	2.22*
		Leeward	21	30.4	12.2	28.5	11.3	0.87	−1.90	−1.46
		Other areas	47	29.4	17.7	29.6	17.6	0.94	+0.13	0.14

* Mean difference significant at $P = 0.05$ level.

(statistically nonsignificant) decrease in travel times. All nonparticipants were also segmented by arrival time interval for travel time comparisons. Results are shown in Table 7. Nonparticipants who maintained their 7:30-7:59 a.m. arrival time experienced travel time savings in the range of 6 to 12 percent. Estimated average time savings for this interval, based on a weighted averaging of all paired comparisons, is 3.3 minutes or 9% for an average trip of 36 minutes. Travel time changes for most other time intervals are insignificant, although some comparisons suggest travel time losses in the earlier and latest arrival intervals. These results are quite consistent with a spreading out of the peak — the intent of the Demonstration Project. Travel time savings are concentrated the "peak of the peak" interval.

The single-point estimates of paired comparisons provide a first approximation of travel time impacts. However, sample size limited possible sample breakdowns. In addition, it is generally not possible to detect interaction effects among the segmentation variables relying on paired

Table 7. Mean work-bound travel time differences for nonparticipants by consistent arrival time. (Differences in terms of project period minus pre-project period.)

Arrival	Wave 1 vs. Wave 3	Wave 2 vs. Wave 3	Wave 2 vs. Wave 4	Wave 2 vs. Wave 4
6:00 – 6:29 a.m.	(NS)	+2.2. Min. (9.2%)	(NS)	(NS)
6:30 – 6:59 a.m.	(NS)	−2.6 Min. (8.5%)	(NS)	−3.6 Min. (−10.7%)
7:00 – 7:14 a.m.	(NS)	(NS)	(NS)	(NS)
7:15 – 7:29 a.m.	(NS)	(NS)	(NS)	(NS)
7:30 – 7:44 a.m.	−3.3 Min. (−8.2%)	−5.0 Min. (−11.3%)	−2.7 Min. (−6.6%)	−5.6 Min. (−12.3%)
7:45 – 7:59 a.m.	(NS)	−2.2 Min. (−8.8%)	−4.2 Min. (−12.2%)	−2.7 Min. (8.7%)
8:00 – 8:14 a.m.	(NS)	−9.3 Min. (−24.7%)	−3.3 Min. (−8.1%)	(NS)
8:15 – 8:29 a.m.	(NS)	(NS)	(NS)	(NS)
8:30 – 9:30 a.m.	+4.5 Min. (+17.1%)	(NS)	+3.4 Min. (11.3%)	(NS)

NS = Difference not statistically significant.

t-tests alone. A regression analysis of travel time impacts was therefore conducted.

5.2. *Regression models of changes*

The t-test results suggest that individual project travel time impacts were determined by project participation, extent of work schedule change, employment sector, residential location, and transport mode. A series of regression models in the form of equation (8) was specified to further test the effects of these variables. Models are estimated for each of two travel times, work-bound and home-bound, and for each of the two basic employee segments, Demonstration Project participants and nonparticipants.

Results for work-bound travel of Project participants are listed in Table 8. Regression equations were estimated using ordinary least squares, and coefficients were calculated as described in Section 4. Work-bound travel time during the Project period was found to be a function of three static variables:

1. Whether or not the participant changed his or her hours radically from an early starting time to the Project hours (as opposed to the prescribed 45 minute change).
2. Whether or not the project was a resident of the East Honolulu area.
3. Interaction between the first radical-changers variable and whether or not the participant was a resident of the windward area.

The coefficients of each of these three static variables are positive, indicating greater travel times for these groups than predicted on the basis of pre-project travel times alone (potential travel time "losses" rather than "savings" due to the project). In addition, there is a significant positive

Table 8. Regression results: participants' work-bound travel time.

Explanatory variable	Co-efficient	t-Value
Time-Wave 2	0.419	5.15
Time-Wave 1	0.450	5.54
Radical changers dummy	3.904	3.01
Area: East Honolulu dummy	2.583	2.05
Radical changers dummy × Windward area dummy	5.242	1.80
Constant	3.269	2.67
$R^2 = 0.80$ N = 157		

constant, indicating a fixed added amount of Project travel time for participants. This added travel time is likely due to an increase in localized congestion at worksites since the project also resulted in a greater concentration of work arrival and departure times.

Regression results thus indicate that travel time savings depend on trip length; e.g., whether the fixed time loss is offset by the linehaul travel savings. Equation (8) can be used to estimate travel time savings due to the Demonstration Project as a function of the explanatory variables by subtracting pre-Project time from the right-hand side and dividing the difference by pre-Project time. This prediction applied to the results of Table 8 leads to the graph of Fig. 2, showing predicted travel time savings for the participant segments of prescribed changers and radical changers. Prescribed changers with pre-Project work-bound travel of under 30 minutes experienced travel time losses, due to the localized congestion penalty and insufficient line-haul travel time; those with trips of over 30 minutes saved time. Approximately 55 percent of prescribed-change car travelers had trips of over 30 minutes, and would thus be estimated to experience time savings. However, the crossover point for radical-changers is estimated to be 65 minutes. Thus, almost all radical changers are estimated to experience travel time losses, since only about 5 percent of this segment had pre-project travel times in excess of 65 minutes.

Graphed in Fig. 3 are the estimated travel time savings for two groups of prescribed-change participants: residents of the East Honolulu area,

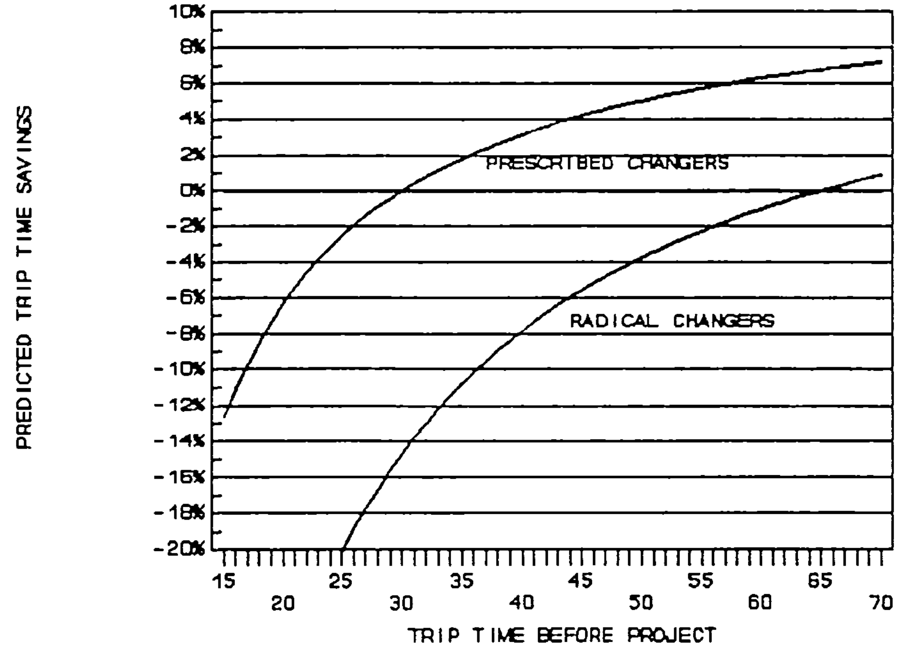

Fig. 2. Predicted mean change: work-bound trip times of participants by degree of change.

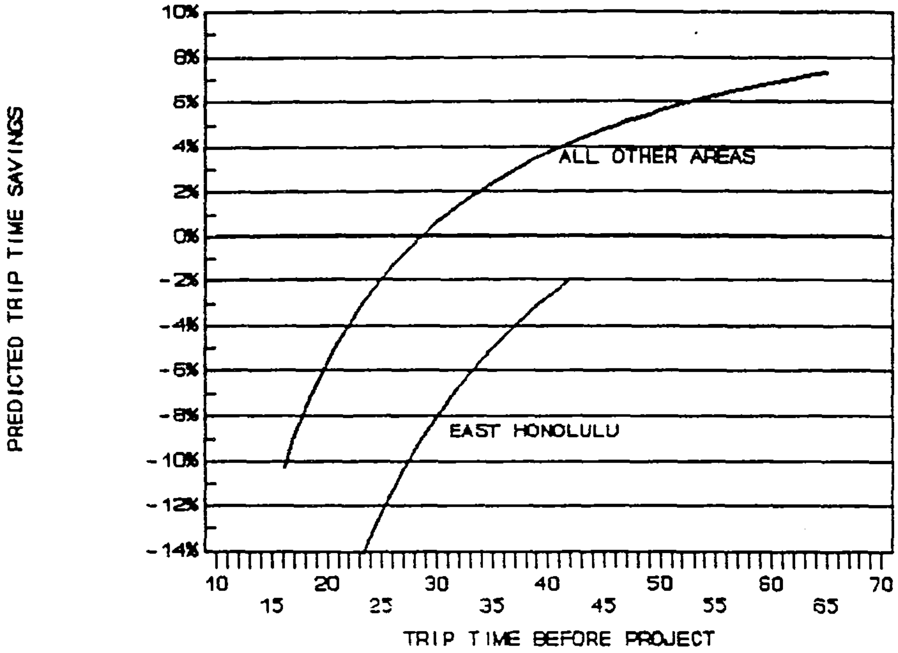

Fig. 3. Predicted change: work-bound trip times of prescribed-change participants by area.

and residents of other areas (the windward, leeward, near-leeward and central areas).[3] East Honolulu prescribed participants fared badly, which depresses the aggregate curve of Fig. 2.

The final graph for participants work-bound trips is for radical changers (Fig. 4). Here, due to the interaction between the windward area

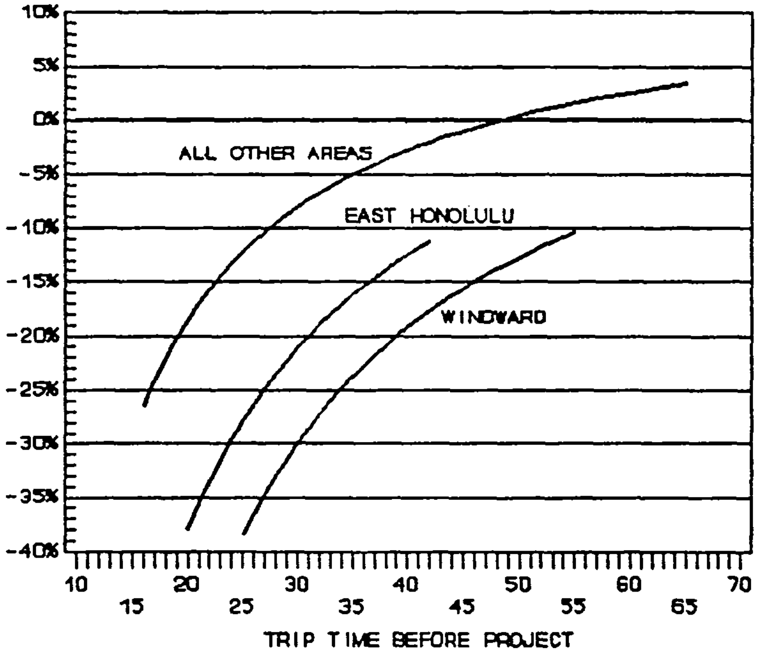

Fig. 4. Predicted change: work-bound trip times of radical-change participants by area.

and this segment, three residential areas are distinguished: East Honolulu, Windward and all others. Project participants from the Windward area who switched from early starting times to the prescribed Project times fared quite badly compared to similar participants from all other areas with the exception of East Honolulu.

Regarding participants' home-bound travel times, there were no significant explanatory variables for Project travel time (wave 3 of the panel) except the two pre-Project travel times of waves 1 and 2 of the panel. Also, the constant was insignificantly different from zero, and the coefficients indicated a one-to-one relationship between pre-Project and Project home-bound travel of Project participants.

For nonparticipants there were significant relationships between pre-Project and Project work-bound travel. As shown in Table 9, there was one static dummy variable, private-sector versus public-sector employees, and three interaction terms between residential areas and travel time; the residential areas are East Honolulu, Windward, and Leeward.[4] The negative sign on the private sector dummy variable indicates greater travel time savings for private sector nonparticipants. Estimates of travel time savings as a function of trip distance suggest that about 73 percent of a private sector nonparticipant car travelers saved time as a result of the demonstration project, while only 20 percent of government nonparticipants were estimated to have positive time savings. It seems reasonable that private sector employees would fare better overall, since their participation was voluntary. That is, private sector employees were able to choose the commute schedule most convenient for them.

The travel time savings estimated from the Table 9 results for private-sector employees living in different residential areas is provided in Fig. 5.

Table 9. Regression results: nonparticipants' work-bound travel time.

Explanatory variable	Coefficient	t-Value
Time-Wave 2	0.172	1.08
Time-Wave 1	0.703	4.45
Private sector dummy	−1.676	−1.99
Area: East Honolulu dummy × Time-Wave 2	0.241	1.69
Area: East Honolulu dummy × Time-Wave 1	−0.153	−0.69
Area: Windward dummy × Time-Wave 2	0.391	1.77
Area: Windward dummy × Time-Wave 1	−0.349	−1.55
Area: Leeward dummy × Time-Wave 2	0.379	1.85
Area: Leeward dummy × Time-Wave 1	−0.345	−1.71
Constant	3.738	3.19
$R^2 = 0.86$ $N = 189$		

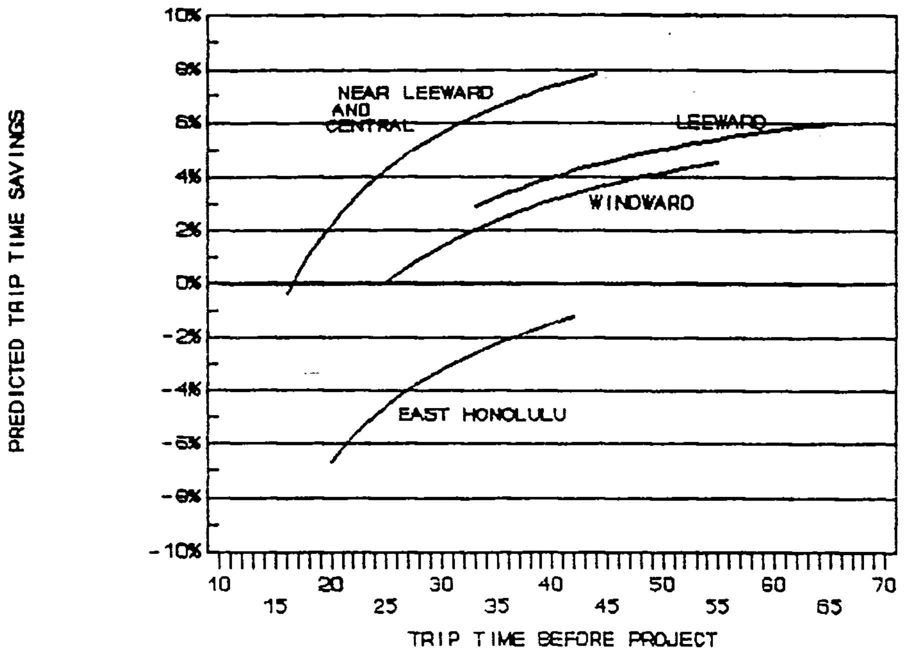

Fig. 5. Predicted change: work-bound trip times of private sector nonparticipants by area.

Significant coefficients were found for the dummy variables corresponding to three of the six residential areas. Only commuters from the East Honolulu area experienced time losses, while those from all other areas are estimated to have had positive time savings for essentially all trip lengths.

The second graph of estimated nonparticipants' work-bound time savings is for government sector employees by residential area (Fig. 6). As in the case of private-sector employees, residents of the East Honolulu area fared the worst, followed by Windward area and Leeward area residents. Residents of the Central and Near Leeward areas did better than East Honolulu, Windward, and Leeward residents with the same travel time, but the shorter trips from the Near Leeward and Central areas lead to travel time losses for the bulk of these commuters. Overall, these results suggest significant inbound traffic problems in the East Honolulu corridor during the demonstration project. No specific cause for these problems could be identified either from the data or by agency sponsors and participants familiar with the local area.

For each of the three (of six) residential areas included in the regression of Table 9, the pair of regression coefficients representing the interaction of the variable with wave one and wave two travel times provides an estimate of the serial correlation coefficient ϕ of Equation (6). If the interaction effects are stable over time, ϕ is estimated by the negative of the ratio of Time-Wave 1 coefficient over the Time-Wave 2 coefficient

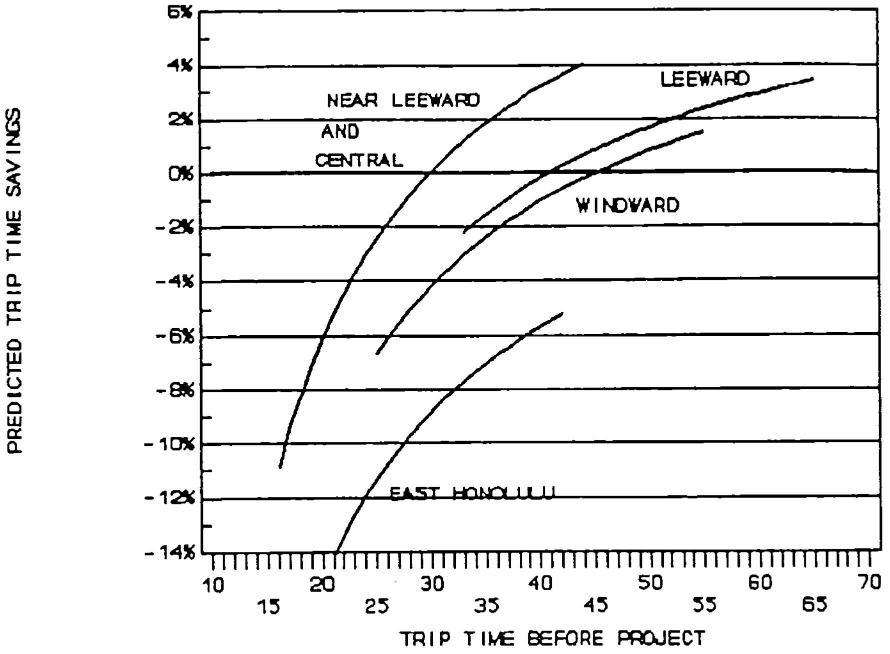

Fig. 6. Predicted change: work-bound trip times of govt. sector nonparticipants by area.

(Equation (8)). For the Table 9 regression, the estimates of ϕ are 0.63 for the East Honolulu area, 0.89 for the Windward area and 0.91 for the Leeward area: the mean for the overestimated serial correlation coefficient being 0.81.

Regression models were also estimated for nonparticipants homebound travel. Results showed that two interaction terms between residential area and travel time were significant, namely the East Honolulu and Leeward areas (Table 10). The positive constant again indicates a travel time loss for all nonparticipants, while the interaction terms suggest offsetting travel time savings for East Honolulu and Leeward residents.

Table 10. Regression results: nonparticipants' home-bound travel time.

Explanatory variable	Coefficient	t-Value
Time-Wave 2	0.470	4.32
Time-Wave 1	0.445	4.13
Area: East Honolulu dummy × Time-Wave 2	−0.328	−2.68
Area: East Honolulu dummy × Time-Wave 1	0.219	1.84
Area: Leeward dummy × Time-Wave 2	−0.163	−2.45
Area: Leeward dummy × Time-Wave 1	0.144	1.76
Constant	3.738	3.19
$R^2 = 0.86$ $N = 94$		

Once again, predicted changes in travel time as a function of pre-project trip time are calculated from Equation (8). For all but the shortest trips, homebound trip travel time savings are positive for all nonparticipants. When the sample is disaggregated by geographic location, it is evident that time savings are concentrated among East Honolulu residents, with lesser savings to Leeward residents (Fig. 7). Nonparticipants from all other areas are predicted to experience travel time losses for trips of up to 43 minutes.

The estimates of the serial correlation coefficient ϕ (Equation 8) from the regression results for nonparticipants home-bound travel time (Table 10) are: 0.67 for the East Honolulu Area-travel time interactions, and 0.88 for the Leeward Area-travel time interactions. The mean of these estimates, 0.78, is comparable to the mean of the estimates from the regression for nonparticipants work-bound travel time (0.81). These high positive values are consistent with the repetitive nature of the dependent variables and the short interval between panel waves. Such a strong autocorrelation justifies the need for multiple before and after observations so that the compensatory mechanism of Equations (1) through (8) can be used to develop unbiased estimates of travel time savings or loss as a function of travel time.

Estimation of the regression models has made it possible to test for interactive effects on travel time savings, and to estimate the proportion of individuals who experienced savings or losses. These results give a more

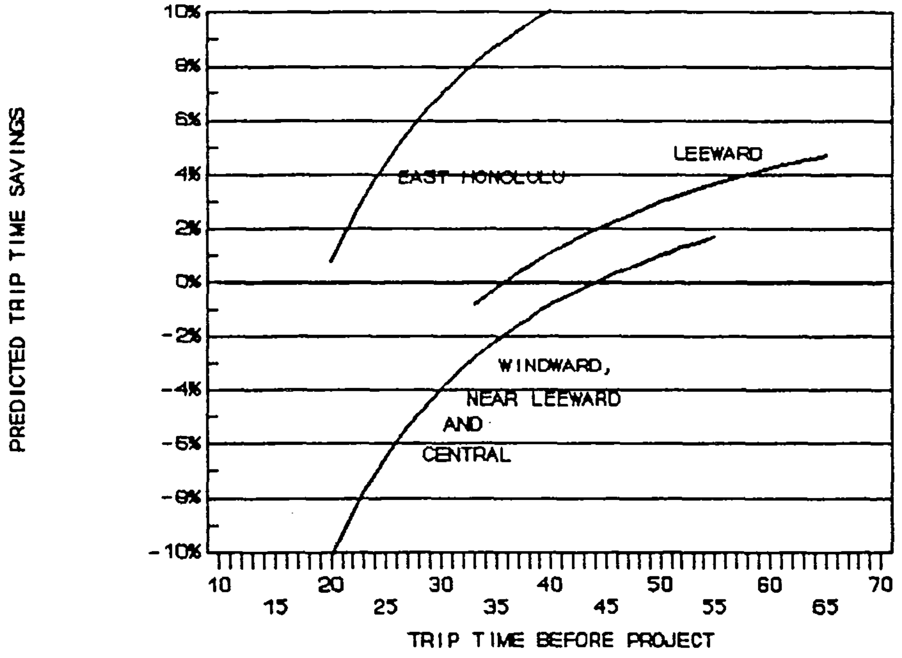

Fig. 7. Predicted change: home-bound trip times of all nonparticipants by area.

detailed picture of project impacts than is possible with paired t-tests. The results indicate that the project had very mixed impacts, but overall, nonparticipants were likely to have fared better than participants. Specific geographic areas, notably East Honolulu, were associated with travel time losses for several groups. Finally, participants who shifted from very early schedules suffered some of the greatest travel time losses.

5.3 *A comparison with floating car results*

Floating car data provide a second measure of project impacts and a basis of comparison for the reported travel time results. Results should be consistent between the analyses of the floating car and panel data.

Travel time savings were calculated by comparing the various combinations on pre-project/project travel times provided by the four waves of floating-car observations over each departure time interval. Detailed results are provided in Giuliano & Golob (1989, 1990). Floating car results are summarized in Table 11. Analysis of Route 1 data showed possible time savings attributable to the Project of 2 to 7 minutes for the 5:30 to 7:15 a.m. time interval. No systematic time differences were observed for departure intervals after 7:15 a.m.

Comparisons of average travel times before and during the Project on Route 2 (Hawaii Kai) yielded estimates of travel time savings over the range of 6:45 a.m. to 7:30 a.m. of comparable relative magnitude to that of Route 1, about 9 to 12 percent. However, because Route 2 is much shorter than that of Route 1, the time savings estimate is smaller in absolute terms, 3 to 4 minutes. For later travel times, possible savings decline until the 8:00 a.m. to 8:15 a.m. interval, where they became negative: additional travel time of about 2 minutes is attributable to the Project in this time interval.

Estimates of Project impacts on Route 3 (Kailua) are similar to those of Route 2. Possible time savings are generally positive between 6:00 a.m. and 7:45 a.m., and negative thereafter. Possible savings range from 7 to 18 percent; possible losses range from 0 to 10 percent. In the two cases for which data were available (Routes 2 and 3), time savings in earlier

Table 11. Travel time savings due to project by route.

Route	Departure times	Minutes	Percent
1-Mililani	5:30—7:15 a.m.	2 to 7	5 to 13
2-Hawaii Kai	6:45 to 7:30 a.m.	3 to 4	9 to 12
	7:45 to 8:15 a.m.	0 to −2	0 to −9
3-Kailua	6:00 to 7:45 a.m.	0 to 6	0 to 18
	7:45 to 8:15 a.m.	0 to −2	0 to −10

time intervals were found to be offset by travel time losses in later time intervals. However, in each case, the magnitude of the loss is not as great as the magnitude of the savings. These results suggest a spreading out of the peak, with travel time savings in the peak of the peak intervals, and travel time losses on the shoulders of the peak.

The results are also consistent with the reported travel times. Participants who shifted from the prescribed schedule were likely to experience a small time change because relative differences in traffic conditions were small. Nonparticipants traveling during the usual highest peak intervals were likely to experience time savings, as other commuters shifted out of their regular departure time interval. Nonparticipants traveling during later time intervals, on the other hand, were likely to experience slight travel time losses as more commuters (participants) shifted into these later time intervals. Finally, losses of the radical change participants resulted from shifting to the more congested later peak period.

6. Conclusions

This paper has presented results from a panel study of travel behavior impacts of a short-term change in employee work schedules. The change was occasioned by a government-sponsored demonstration project aimed at testing whether shifting work schedules of downtown employees would spread out peak traffic and thereby reduce peak period traffic congestion.

The panel approach proved to be effective. Repeated measurements of employee work trip experiences reported in the panel survey made it possible to estimate project impacts for various employee segments, despite their small magnitude in many cases. Analyses revealed that travel time savings resulting from the project were highly variable. Savings (or losses) were found to depend on whether or not the employee changed his/her work schedule, and if so, by how much; as well as on employment sector and location of residence. Repeated measurements made it possible to conduct several different pre-project to project comparisons, and thus minimize sampling variance. Furthermore, the floating car data, collected in comparable panel form, provided an additional means for validating the analysis.

The results of this research also suggest that longitudinal methods may have an additional advantage in short-term applications. First, short-term panels can have lower attrition rates than those experienced in longer-term panel surveys. Loss of contact with the respondent is minimized because of the short duration of the survey, while respondent fatigue, etc. should be independent of the survey's temporal duration. However, the circumstances of this research were particularly favorable to a high response rate: the surveys were collected and distributed at the work site; there was a very high level of interest in the survey (several employees who were not selected requested to be included in the survey); and survey dates were well publicized. Thus the response rate reported here may not be indicative of short-term panels in general.

Short-term panels also minimize the influence of external dynamic factors, such as changes in employment conditions, growth in traffic congestion, etc. The short survey duration makes it possible to focus on project-related changes without having to control for many of these external factors.

The results of this analysis also have clear policy implications. Although the goal of the Project was achieved and peak period traffic was redistributed, this redistribution differentially impacted employees. The Project had particularly negative effects for participants who shifted from a very early work schedule. They suffered substantial travel time losses in addition to the inconvenience and disruption generated by a large shift in the work schedule. In contrast, some groups of nonparticipants enjoyed significant travel time savings. These effects were reflected in the perceptual and attitudinal data collected on the last survey wave. Project participants were more likely to perceive worse travel conditions and to report worse conditions in performing household, social and work activities than nonparticipants (Giuliano & Golob 1989, 1990). Not surprisingly, participants had significantly more negative attitudes toward the demonstration project itself.

These results suggest that the while transportation system management strategies such as staggered work hours can have positive overall effects on traffic conditions, they are likely to generate a complex mix of effects on the individuals involved. The survey methods employed in this research made it possible to identify such effects.

Acknowledgements

This research was supported by the State of Hawaii and Oahu Metropolitan Planning Organization. Re-analysis of the data was supported by a U.S. Department of Transportation University Centers Grant. Views expressed, as well as any errors or omissions, are those of the authors.

Notes

1. For a summary of demonstration project results, see Giuliano and Golob 1990.

2. A turnover analysis (Golob, van Wissen and Meurs 1986) of mode choice (car driver, car passenger, bus, and other) revealed that there was no significant change of mode from the pre-Project to Project periods.
3. In this graph, and all others parameterized by residential area, the range of the curve for each residential area is established by the 15 percentile and 85 percentile bounds of pre-Project travel time by car travelers from that area.
4. Note that the form of equation requires that the interaction terms involving travel time be included for both pre-Project times, regardless of t-values; the true coefficient of effect on time difference is the difference of the two time interaction terms for each static variable.

References

Clarke M, Dix M & Goodwin P (1982) Some issues of dynamics in forecasting travel behavior-a discussion paper. Transportation 11: 153—172

Davies R & Pickles AR (1985) Longitudinal vs. cross-sectional methods for behavioural research: A first round knockout. Environment & Planning A 17: 1315—1329

Duncan G, Juster F & Morgan J (1987) The role of panel studies in research on economic behavior. Transportation Research 21A 4/5: 249—263

Giuliano G & Golob TF (1989) Evaluation of the 1988 staggered work hours demonstration project in Honolulu. Final Report. Prepared for the State of Hawaii and Oahu Metropolitan Planning Organization. Irvine, CA. Institute of Transportation Studies, University of Dalifornia

Giuliano G & Golob TF (1990) Staggered work hours for traffic management: a case study. Presented at Annual Meeting of Transportation Research Board, January 7, 1990, Washington, D.C. Transportation Research Record (in press)

Golob J, Schreurs L & Smit J (1985) The design and policy applications of a panel for studying changes in mobility over time. In: Behavioral Research for Transport Policy (pp 81—96). Utrecht: VNU Science Press

Golob TF (1989) The dynamics of household travel time expenditures and car ownership decisions. Presented at International Conference on Dynamic Travel Behavior Analysis, Kyoto University, July 18—19, 1989, Kyoto, Japan

Golob TF, van Wissen L & Meurs H (1986) A dynamic analysis of travel demand. Transportation Research, 20A: 401—414

Hausman J & Wise D (1979) Attrition bias in experimental and panel data: the Gary Income Maintenance Experiment. Econometrica 47: 153—161

Hensher D (1986) Dimensions of automobile demand: an overview of an Australian research project. Environment and Planning A 18: 1339—1374

Hensher D & Wrigley N (1986) Statistical modeling of discrete choices in discrete time with panel data. In: Behavioural Research for Transport Policy (pp 97—118). Utrecht: VNU Science Press

Kessler RC & Greenberg DF (1981) Linear Panel Analysis. New York: Academic Press

Kitamura R (1990) A panel analysis of changes in car ownership and mode use. Transportation (in press)

Kitamura R & Bovy P (1987) Analysis of attrition biases and trip reporting errors for panel data: Transportation Research 21A 4/5: 287—302

Kitamura R (1989) Panel analysis in transportation planning: overview. Presented at International Conference on Dynamic Travel Behavior Analysis, Kyoto University, July 18—19, 1989, Kyoto, Japan

Lyon P (1984) Time-dependent structural equations modeling: A methodology for analyzing the dynamic attitude-behavior relationship. Transportation Science 18: 395—414

Meurs H, van Wissen L & Visser J (1990) Measurement bias in panel data. Transportation (in press)

Morgon JN (1982) Effects of inflation on attitudes, status, and behavior. In: Hill DH, Hill MS & Morgon JN (eds) Five Thousand American Families-Patterns of Economic Progress (pp 60—92). Ann Arbor, MI: Institute for Social Research, University of Michigan

Smart H (1984) The dynamics of change-applications of the panel technique to transportation surveys in type and wear. Traffic Engineering and Control December: 595—598

Uncles M (1988) Longitudinal data analysis: methods and applications. London papers in Regional Science 18. London: Pion Ltd.

University of Michigan Survey Research Center (1972) A panel study of income dynamics: study design, procedures, available data. Ann Arbor, MI: Institute for Social Research, University of Michigan

Van de Pol F (1984) Better measurement with a panel design? Working paper No 13458-84-M1. Voorburg, The Netherlands: Netherlands Central Bureau of Statistics, Department for Statistical Methods