Flexible Work Hours and Mode Change: Interpretation of Empirical Findings from San Francisco

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A series of surveys was conducted at four San Francisco Bay Area firms in 1979 to study the effect of flexible work hours on choice of mode for the work trip. Analysis of nearly 1200 individual responses showed consistent and statistically significant decreases in solo driving, even after mode changes that were estimated to be caused by 1979 gasoline shortfalls and skyrocketing energy prices were screened out. Individuals who changed to transit were found to be from generally lower-income households and thus susceptible to gasoline price increases; flextime further assisted their shift to transit by alleviating anxieties about being late for work due to unreliable transit service. These individuals frequently traveled during the off-peak hours, when seats were more readily available. Individuals who changed to ridesharing ranked congestion avoidance as high or higher than the ability to coordinate work schedules with fellow carpoolers (frequently a working spouse for employees at three downtown firms). Although there were diversions from ridesharing to transit, the net result was a statistically significant increase in ridesharing. The evidence from these four Bay Area firms strongly suggests that flextime is complementary to transit marketing and ridesharing promotions, although the net change in mode share is likely to be modest (less than 5 percent).

Since 1975, transportation professionals have placed increased emphasis on transportation system management (TSM)--the improvement of the existing transportation system through relatively low-cost incremental management techniques (1). Options under the TSM umbrella range from carpool matching to priority lanes, improved transit management, and alternative work schedules. Although some tactics, such as carpool matching, have been studied heavily for several years, others, such as alternative work schedules, have only recently appeared in the literature.

The goal of this paper is to contribute to the expanding literature on alternative work schedules. The major transportation aim of most alternative work schedule programs has been to spread peak-period work trips over a wider time period and thus reduce the intensity of congestion. Alternative schedules have been somewhat successful in spreading the work schedules of individuals; however, a deeper policy-related concern has emerged concerning the compatibility of alternative work schedules with campaigns to promote ridesharing and encourage transit use. A report on alternative work schedules by the Urban Consortium for Technological Initiatives states (2), "A serious and tricky problem with alternative work schedule strategies is the fact that they may have negative impacts on transit and carpooling, depending on how the strategies are designed and applied and upon the particular characteristics of each alternative."

The motivation of this paper was to study mode changes that have actually occurred at firms that have alternative work schedules, with the specific aim of providing guidance on how the design of the schedules affected the mode changes. It was decided that this could be done only if the research was able to study the magnitude of mode changes for large groups of employees while simultaneously attempting to understand the causes underlying individual mode changes. Table 1 summarizes a review of the existing literature concerning mode changes and motivations for change with alternative work schedules.

Four large areawide promotions were reported in the literature. The New York City study reported that insignificant mode changes occurred during a demonstration of flexible work hours at the Port Authority of New York and New Jersey (3) and did not report on mode changes that occurred during a larger demonstration of staggered work hours at numerous firms (4-6). The studies in Ottawa (7,8) and Toronto (9,10) report increases in transit ridership and carpooling, respectively; however, these studies were conducted during the 1973 energy crisis, so that alternative work schedules alone could not be isolated as a causal factor. In addition, the Ottawa study attempted to use actual traffic counts on streets and bus stops to determine the temporal spread in travel. Unfortunately, fluctuations in traffic volumes due to seasonal and monthly variations made it impossible to ascertain the contribution of work schedules to the changes in flow.

A work schedule promotion was also undertaken in Vancouver (11), but it was terminated after 6 months because of a lack of employer participation. None of the areawide promotions studied motivations for the reported mode changes.

All five of the studies at individual firms reported mode changes that occurred during alternative work schedule promotions. Studies of New Zealand government employees showed decreases in transit ridership and increases in solo driving (12). A study at the Department of Water Resources in Sacramento, California, reported increased use of transit and ridesharing with flexible work hours (13). Unfortunately, the flextime promotion occurred during transit service expansion and the end of the 1973 energy crisis. Studies of Transportation Systems Center (TSC) employees in Cambridge, Massachusetts (14), showed small increases in ridesharing and transit use. A study at the New York Department of Transportation in Albany reported similar findings, but the study was conducted during a vigorous ridesharing promotion campaign (15). A survey of state employees in Denver who had alternative work schedules indicated that only 71 percent retained the same mode after the experiment, but the study did not report the modes in which the changes occurred (16).

Only the Sacramento study was able to obtain an idea of motivations for mode change, but these were largely through survey margin comments and could not be extrapolated to the entire employee population.

In summary, the literature has reported mode changes with alternative work schedules; but the changes have generally been of small magnitude or have occurred during confounding events such as energy crises, ridesharing promotions, or transit service expansions. With the exception of the Sacramento study, little has been published concerning motivations of mode changers.

Rather than study mode changes that occur with all three types of alternative work schedules, this study concentrated on flexible work hours. Alternative work schedules can be divided into three basic types:

1. Four-day workweek--Rather than work five days per week, the employee works the same number of hours over a four-day period and either rotates different days off during different weeks or retains the same day off every week.
2. Staggered work hours--The employee works a

Table 1. Effect of alternative work schedules on work trip mode choice: summary of existing research.

Study Area	Magnitude of Mode Change Considered	Motivations for Mode Change Assessed
Citywide		
New York City	Partly[a]	No
Ottawa	Partly[b]	No
Toronto	Partly[b]	No
Vancouver	No	No
Individual firms		
Government employees, New Zealand	Yes	No
Department of Water Resources, Sacramento	Partly[b]	Partly[c]
State employees, Albany	Partly[b]	No
Transportation Systems Center, Cambridge	Yes	No
State employees, Denver	Yes	No

[a] Staggered work hours promotion did not consider mode change, but flexible work hours experiment did.
[b] Partly analyzed but confounding events occurred, which limited the strength of conclusions.
[c] Largely from survey margin comments.

five-day week, but start and end times are deliberately spread or staggered to distribute work schedules over a wider time period (note: employees generally do not choose their schedules, but are assigned to a schedule by management).

3. Flexible work hours--A work schedule system in which the employee chooses his or her schedule, with some constraints; he or she may be free to vary the schedule daily, vary the lunch hour, or bank hours from one day to the next or one pay period to the next, depending on the design of the program. All employees are generally required to be at work five days per week during designated core periods but may otherwise arrange their work schedules within the constraints imposed by the particular program.

Flextime is being actively promoted in several U.S. cities (17-19), enhancing its relevance for study in this research. Interestingly, after a five-year study of staggered work hours and a brief flextime experiment, the Port Authority of New York and New Jersey concluded (20), "The concept of flexible work hours appears to be superior to staggered work hours and the four-day week, particularly in the area of reduced transportation congestion and improved employee attitude."

The objective of this paper is to report empirical findings of mode changes observed at five San Francisco firms that have flextime, and to interpret the findings vis-à-vis ridesharing and transit use.

EXPERIMENTAL DESIGN

The development of the experimental design has been driven by the two major objectives of the study:

1. To assess the magnitude of mode changes that occur with flextime and
2. To assess the motivations that underlie the changes in mode.

The joint consideration of magnitudes and individual motivations leads to an experimental design that considers a survey of individual employees before and after flextime is instituted at the workplace. The mode of travel before and after flextime can be determined as well as motivations of changes in mode. The individual survey format also allows the collection of socioeconomic data to study the distribution of flextime benefits and possible effects of household structure, income, age, and automobile ownership. Individual surveys also avoid the difficulty of field measurement encountered by the Canadian researchers.

Based on the literature review and consideration of possible travel effects of flextime, a series of hypotheses was developed concerning flextime and mode change. The attempt was to be comprehensive, so that the survey could be designed to examine when particular hypotheses were accurate.

The hypothesis that created the biggest concern for transportation analysts and policymakers is that flextime makes the single-passenger automobile comparatively more attractive than carpool and transit, because flextime allows the automobile to be driven in the off-peak when congestion is less onerous. In areas where restricted parking supply is an incentive for carpool and transit use, flextime may encourage individuals to switch to automobiles and arrive early to capture the premium parking spaces. Flextime affords individuals more spare time to arrange for errands and personal business; some individuals may shift to driving alone to capitalize on this new freedom. There are, however, countervailing arguments that favor shifts from single-passenger automobiles to both carpool and transit.

One argument states that flextime will increase mass transit use because it allows travelers to ride during times when seats are more readily available and service is more reliable. Flextime also makes transit more attractive because it eliminates schedule buffering that may be due to a mismatch between fixed start times for work and arrival times available via transit. The problem is manifested by travelers who have to arrive at work 10 min early so that they are not 15 min late. Obviously, this problem becomes most acute when bus headways are large. Flextime can also allow travelers to deal better with the unreliability of transit schedules, because the workday starts when the worker arrives and he or she is thus freed from the worry of punitive action due to tardiness (13).

A similar argument can be made in support of flextime as a positive factor in carpool formation. Flextime allows greater freedom to adjust an individual's work schedule to the schedules of potential carpool mates. For two-worker households, an increasing socioeconomic phenomenon in the United States, there is a particular benefit in allowing greater freedom to match up with a spouse for the work trip. Carpools may be disrupted, however, because of incompatibilities in the work schedule that arise due to flextime privileges (13).

To the extent to which any one of these hypotheses is a reflection of an individual's changed perception of one mode, the remaining modes are comparatively worse off. Freedom to match up with carpool mates who were previously unavailable may therefore result in diversions from transit to shared ride as well as from driving alone.

Individuals' perceptions of these mode-change motivations were assessed in the survey by asking each individual who changed mode to indicate the importance of each of the motivations in his or her decision to change mode. Each motivation had a five-point scale that ranged from not important through very important. If, for example, someone changed from drive alone to transit, he or she might check very important for saving money on gasoline and being able to cope better with transit unreliability, and not important for all other motivations. The answers to these motivational questions contribute to a better understanding of the causes for the mode changes.

The hypotheses about flextime and mode change described in previous paragraphs led to the development of a questionnaire for individual employees.

The questionnaire was pretested (21,22), revised, and used in a final survey at a suburban firm as well as central business district (CBD) firms. The analyses of the data used statistical tests to determine the significance of magnitudes of mode change; studied motivations for mode change; and used socioeconomic data to study distributional benefits and possible life-style effects. Details of questionnaire design are contained elsewhere (22).

DATA COLLECTION

After the questionnaire pretest, several firms in San Francisco were contacted concerning their potential participation in the study. No firms were adopting flextime at that time, so a strict before-and-after experiment was not possible. Instead, 10 firms that had flextime were contacted as potential participants; 5 agreed to participate. One, the California Department of Transportation (Caltrans) district office in San Francisco, had very strong ridesharing incentives. These incentives were not typical of those likely to occur at other firms that adopt flextime or typical of other major employers in San Francisco. For these reasons, the balance of this paper discusses findings at the four remaining firms: Lawrence Berkeley Laboratories (LBL) in Berkeley; and Chubb-Pacific Indemnity Insurance, Standard Oil of California, and Metropolitan Life Insurance in downtown San Francisco.

The four firms had nearly identical flextime programs. Flexible periods were typically 7-9:30 a.m. and 4-6:30 p.m. Employees were generally allowed to vary their start times within the morning band, so long as they worked five days per week and a full work day (e.g., 8 h) each day.

As an introduction to the data set used in the analysis, a brief description of flextime operations at each firm follows, including information regarding the number and proportion of survey respondents and the type and duration of the flextime program. Also, unique transportation characteristics related to the firm or its location are examined. Much of the transportation-related data is summarized in Table 2.

LBL

LBL employs approximately 3500 people, of whom 2800 have flextime privileges. Located in the hills above the city of Berkeley, the laboratory conducts high-technology, government-sponsored research on nuclear energy, as well as other research in the physical and life sciences. Because of the nature of the work, the composition of the work force is extraordinary for Bay Area firms that have flextime; a large number of the employees are research scientists and joint-appointed faculty members affiliated with the University of California. The rest of the work force consists largely of administrative, clerical, and technical support staff. Demographic data on the work force indicate the following significant features:

1. The age distribution is heavily skewed toward older employees, 36 percent are 46 years of age or older;
2. The occupational distribution is dominated by professionals (41 percent), consisting of scientists who conduct experiments and engineers who plan, operate, and maintain the physical plant;
3. Employment at LBL has increased dramatically in the past 5 years; this is reflected in the high percentage (51 percent) of employees who began employment at the laboratory in the 1970s; and
4. Seventy-one percent of the work force is male.

The automobile is used for 73 percent of the work trips; other mode shares are as shown in Table 3. The heavy automobile mode share is due to a number of factors. Parking is free and, although supplies of close-in parking have been diminishing, conversations with LBL employees indicate that spaces are still available. Because the laboratory is located in the Berkeley Hills, it is not served by direct public bus and rail transit, which necessitates that the laboratory run its own shuttle bus. The virtually mandatory transfer makes public transportation that much less attractive. Most LBL employees live within the cities of Berkeley or Oakland, which means a very short automobile trip and, concurrently, makes the schedule and transfer delays of transit even more onerous. The laboratory does participate in the university vanpool and carpool promotion, thus slightly better ridesharing incentives are offered here than at the other three firms.

Because of these unique travel characteristics, virtually all of the analyses in subsequent sections were conducted separately for LBL employees and the rest of the survey respondents.

Table 2. Summary of transportation supply information for four selected Bay Area firms.

Firm	Total Respondents	Response Rate (%)	Parking Availability	Parking Cost	Transit Availability	Carpool Incentives
LBL	689	25	Excellent	Free	Poor	Limited
Chubb-Pacific Indemnity Insurance	152	81	Good	High	Excellent	None
Standard Oil of California	89	45	Good	High	Excellent	None
Metropolitan Life Insurance Company	300	38	Good	High	Excellent	None

Table 3. Mode shares for four selected firms.

Firm	Automobile	Carpool	Bay Area Rapid Transit	Transit	Walk	Other
LBL	46.2	27.3	4.8	8.9	4.9	7.3
Chubb-Pacific Indemnity Insurance	3.3	20.4	21.1	47.4	2.6	4.6
Standard Oil of California	4.5	18.0	38.2	34.8	3.4	1.1
Metropolitan Life Insurance Company	2.0	20.0	24.0	45.0	1.3	7.7

Chubb-Pacific Indemnity Insurance

Chubb has approximately 187 employees who have flextime privileges, of whom 152 responded to the survey (81 percent response rate). The work force is largely clerical and administrative staff. The principal office tasks are to process insurance applications and claims. The flextime program has been in operation for approximately one year.

The transportation characteristics for Chubb are similar to those of the other San Francisco-based firms. Chubb offices are located in the Bank of America Building on California Street, which is well served by all mass transit in the Bay Area. No special parking provisions exist for carpoolers, and parking supplies are scarce and expensive ($3-$6/day). These factors account for the high transit mode shares illustrated in Table 3.

Standard Oil of California

Standard Oil, although a very large employer in San Francisco (approximately 3000 employees), has only about 200 people on flexible work hours. The employees are not located in one work unit but are spread across many divisions. The 89 employees who responded to the survey (45 percent response rate) all work in the Standard Oil Building on Bush Street in the financial district of San Francisco. Like Chubb-Pacific, it also is well served by all mass transit in the Bay Area. No special parking is provided for any employees. As in the case of Chubb-Pacific, the mode share for transit is very high (see Table 3).

Metropolitan Life Insurance

Metropolitan employs 1200 people at its downtown headquarters on Market Street. Approximately 800 of these employees have flextime privileges. The remainder (telephone operators, security personnel, and computer systems people) are excluded from flextime by the demands of their jobs.

There were 300 respondents to the questionnaire, for a 38 percent response rate. To test that the responses were representative of the entire firm, Metropolitan provided work start times from employee time sheets. A chi-square test failed to reject the hypothesis that the reported work schedules were drawn from the same population (with a significance probability, p = 0.45).

Transportation supply conditions at Metropolitan are similar to those at Chubb-Pacific and Standard Oil. Metropolitan offers no parking incentive and is equally well served by transit. Table 3 indicates the high mode share for transit.

Summary

The total flextime sample includes approximately 1200 individual responses. The transportation supply characteristics of the downtown firms are significantly different from those at LBL, and, therefore, the data analysis in the subsequent section is conducted for two groups: LBL employees and the employees at the three financial district firms.

DATA ANALYSIS

The experimental design illustrated in Figure 1 was used as a framework for the data analysis. The aim was to build on the information obtained during survey pretest. Separate analyses were conducted for the three San Francisco firms (hereafter referred to as CBD firms) and for LBL because of the different travel and socioeconomic characteristics of individuals at the firms.

Magnitudes of mode changes for each of the two groups of data are examined and tested statistically. Next, the individuals who changed modes were compared both with individuals who retained modes and with other mode changers for several socioeconomic variables. The aim was to identify profiles of the mode changers. The motivations for the mode change were then examined to see which, if any, of the hypotheses discussed were prevalent for our sample. As stated previously, the objectives of these analyses were the testing of the magnitudes of mode change and a study of motivations for mode change in order to provide guidance regarding the effect of flextime on mode change.

LBL

Mode changes reported at LBL are summarized in Table 4. Diagonal elments in the table represent individuals who retained specific modes (e.g., 76 used transit before and with flextime); off-diagonal elements represent individuals who changed from one mode before flextime to another mode with flextime (e.g., 20 individuals changed from driving alone to transit). The findings are similar to those observed during the survey pretest in that all types of mode shifts occurred. Note, however, that the overwhelming shift was from driving alone to both transit and ridesharing.

Statistical tests can be used to test the symmetry of Table 4. Mathematically, the null hypothesis is

$$p_{ij} = p_{ji} \quad i \neq j \tag{1}$$

where p_{ij} and p_{ji} are the off-diagonal row proportions in the tables. Stated in words, the test examines whether the proportional change from each mode is equal to the proportional change to that mode; for example, if the proportional change from bus to carpool is equal to the change from carpool to bus. The test statistic is given (23) as

$$\chi^2 = \sum_{i>j} [(X_{ij} - X_{ji})^2/(X_{ij} + X_{ji})] \tag{2}$$

where the X's are the numbers of observations in the off-diagonal cells. The test statistic is asymptotically χ^2-distributed with I(I-2)/2 degrees of freedom, where I is the number of cells in one dimension (in this case, 3).

As can be expected by inspecting the table, the null hypothesis was rejected at a very high level of confidence. This is not surprising since, for example, the mode change from drive alone to transit (20) is substantially more than the change from transit to drive alone (2). As mentioned previously, a gasoline supply and price crisis struck California in late May and early June of 1979. Fortunately, questions were added to the questionnaire to attempt to screen temporary transit and ridesharing arrangements that were stimulated by the energy problem alone. Ridesharers were screened to eliminate new carpools (less than two months' duration) in which saving money on gasoline was checked as a very important motivation. New transit users were screened by using the gasoline motivation alone; if it was the only very important motivation for using transit, then the user was considered temporary. These controls were selected before the analysis so that they could be used to obtain a conservative estimate of flextime mode changes that were independent of energy shortages. The lower half of the table shows small decreases in diversions from driving alone but still strongly rejected the hypothesis of symmetry.

Figure 1. Experimental design for study of mode changes with flextime.

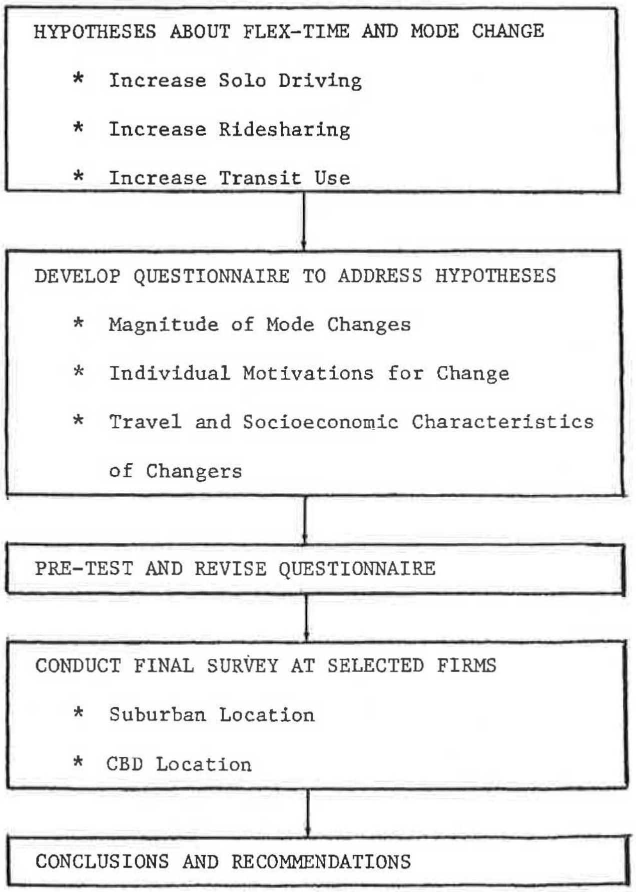

Table 4. Summary of mode changes with flextime for LBL.

Mode Used Before Flextime	Mode Used with Flextime: Transit	Drive Alone	Shared Ride	Total
Before Screening for Energy Shortage				
Transit	76	2	5	83
Drive alone	20	312	23	355
Shared ride	2	5	160	167
Total	98	319	188	605
After Screening for Energy Shortage				
Transit	76	2	1	79
Drive alone	16	312	21	349
Shared ride	2	4	160	166
Total	94	318	182	594

Note: Table entries are the number of respondents who report use of specific modes before and with flextime.

This test for symmetry can be considered a first cut at examining the magnitude of mode changes with flextime. A relevant policy questions is, "Has there been a significant increase (or decrease) in an individual mode share?" This question can be analyzed statistically by collapsing the 3x3 tables shown in Table 4 into a set of three 2x2 tables as shown below.

Mode Before Flextime	Mode with Flextime: Transit	Other	Total
Transit	76	7	83
Other	22	500	522
Total	98	507	605

Mode Before Flextime	Mode with Flextime: Drive Alone	Other	Total
Drive alone	312	43	355
Other	7	243	250
Total	319	286	605

Mode Before Flextime	Mode with Flextime: Carpool	Other	Total
Carpool	160	7	167
Other	28	410	438
Total	188	417	605

The same test for symmetry can be conducted on each 2x2 table; however, the interpretation of the test is slightly different. The hypothesis $P_{ij} = P_{ji}$ essentially tests whether the mode share before flextime is equal to the mode share after flextime. The results of these tests both with and without energy controls are shown in Table 5. Notice that even with energy controls there is a statistically significant reduction in solo driving and significant increases in transit use and ridesharing.

The next step is to compare the socioeconomic and travel characteristics of the mode changers with those who retained existing modes. It was hoped that profiles of likely mode changers could thus be identified. A wide range of variables was used in the comparison, including household location, automobile ownership per worker and per licensed driver, occupation, marital status and family structure (children, working spouse), household income, and age. In addition, for carpools only, comparisons were conducted regarding carpool composition, for number of riders, length of time in the carpool, and composition vis-à-vis spouse, children, other household members, non-household-members employed at same firm, and non-household-members employed at different firms.

Very few (7) LBL employees shifted to driving alone, so there are insufficient data to perform statistical analyses. Of practical significance is that the magnitude of the change is very small. It appears that the motivations of congestion avoidance, capturing parking places, and the freedom to run errands with a car contribute to mode changes to solo driving but for very few employees.

The diversions from solo driving to transit and ridesharing were much more prevalent. The diversions from solo driving occurred more frequently for clerical and administrative personnel than for professionals and managers. The changes also occurred more often in lower-income households, a largely corroborative finding. These income pressures are not directly reflected in levels of automobile ownership, however, as more than 73 percent of the changers to transit and carpool had automobile ownership levels (per licensed driver and per household worker) equal to or greater than one. The interpretation is that the vast majority of changers to higher-occupancy modes had an automobile available for a solo commute to work. The motivations for the changes illustrated in Table 6 support this income-centered view of mode change, but also show that flextime travel opportunities were crucial to the mode change decisions.

The income-related pressures are revealed as responses to the gasoline-price motivation (Table 6). More than 83 percent (15) of the changers from drive alone to transit stated that the saving of money on gasoline was a very important motivation for their change in mode. Nearly as great a number (12) stated that flextime enabled them to use transit in spite of unreliable service. The ability to ride when seats are available and mesh with transit schedules also contributed to the mode changes.

Table 5. Results of hypothesis tests for mode share changes for LBL employees.

	No Energy Controls		With Energy Controls	
Mode	χ^{2a}	Significance Probability	χ^{2a}	Significance Probability
Transit	7.76	<0.005	10.71	<0.005
Drive alone	27.94	<0.005	24.85	<0.005
Shared ride	12.60	<0.005	9.72	<0.005

[a]Reject H_0 with $\alpha = 0.05$.

Table 6. Summary of mode change motivations for LBL.

	Changes from Drive Alone to Transit				Changes from Drive Alone to Ridesharing			
Motivation	NA	NI	SI	VI	NA	NI	SI	VI
1. Arrive early to find parking	8	4	4	2	3	4	6	7
2. Use car for errands	9	5	3	1	3	10	2	6
3. Avoid rush-hour traffic	9	4	2	3	1	1	5	15
4. Adjust work schedule to share a ride with a family member	8	5	2	2	7	4	4	6
5. Adjust work schedules to join or form a carpool	13	2	0	2	4	4	6	7
6. Able to use transit even if it is unreliable	1	0	5	12	10	6	2	3
7. Able to use transit when seats are available	1	5	6	6	11	6	1	2
8. Easier to meet transit schedules	1	4	5	8	11	6	0	3
9. Able to save money on gasoline and leave car at home	1	0	3	15	4	2	6	6

Notes: NA = not applicable, NI = not at all or not too important, SI = somewhat important, and VI = very important.

The interpretation is that income-related pressures caused individuals to consider alternative modes, and flextime's freedom from tardiness helped individuals lessen concerns for transit unreliability, allowing them to use public transit for their work trips. The reliability question is particularly important at LBL since more than half of the mode changes were to Bay Area Rapid Transit (BART), which experiences frequent service disruptions, breakdowns, and strikes. Individuals do not appear to be as strongly motivated by the ability to find seats or to buffer schedules as the hypotheses suggest.

Interestingly, mode changers from drive alone to ridesharing reflect a rather different set of concerns. Table 6 indicates that the most important motivation was the ability to avoid rush-hour traffic. Although gasoline prices were not inconsequential (very important for six respondents), the ability to adjust schedules to form a carpool and the ability to arrive early and find a parking space were of nearly equal importance. The use of a car for errands was also important for eight of the respondents.

The importance of the rush-hour avoidance motivation is reflected in the behavior of the new carpoolers. Nearly 62 percent of the new carpoolers saved time in their commute, compared with their travel time when driving alone. They were able to save time by traveling in the off-peak hours (near 7:00 or 9:30 a.m. for the morning commute). Because many of these new carpools have only two occupants, the driver toured to pick up only one passenger, and was able to decrease the total commuting time by traveling when streets and highways were uncongested.

Individuals who shifted to carpools did not have income levels significantly different from those of other carpoolers, but they tended to be newer employees (employed less than 9 years) and were more likely to form two-occupant carpools (with a signficance probability, p = 0.14). Interestingly, the two-occupant carpools were formed with coworkers nearly 70 percent of the time. LBL's relatively isolated location has resulted in a lower number of carpools composed of spouses than the hypotheses would suggest.

Comparisons of the income levels of changers to carpool and transit revealed that the new transit riders had significantly lower household incomes than the new carpoolers. The transit riders had a mean income of $22 000; carpoolers had a mean income of $27 000. More significantly, 84 percent of the new carpoolers had incomes above $20 000; 47 percent of the transit riders had incomes below $20 000. These findings corroborate the survey responses discussed previously: The new transit riders respond more strongly to income pressures, and the ridesharers are availing themselves of a new travel mode facilitated by flextime.

The other motivations listed in Table 6 are of only marginal significance and importance. For example, motivations 6-8 (transit related) were very important for the few individuals who indicated that they occasionally take transit when not sharing a ride. Similarly, two or three of the changers from drive-alone to transit rate factors 1-3 very important because they use the automobile for access to transit (primarily BART).

The other mode changes that were shown in Table 4 occurred for so few employees that analyses of socioeconomic characteristics and motivations could not be conducted.

Only a few of the hypotheses concerning flextime and mode change appear to be prevalent at LBL. Employees have shifted in significant numbers from solo driving to both ridesharing and transit, despite the prevalence of free parking and relatively poor transit service. Changers to transit seem to be strongly driven by increases in gasoline price but are able to use transit without the fear and stress of being late because of service unreliability. Hypotheses concerning schedule buffering and finding a seat during off-peak hours are supported by the findings, but they do not appear to be as strong a motivation as coping with service unreliability.

CBD

Mode-change findings for the three CBD firms are shown in Table 7. The pattern of mode change in these firms is substantially more complex than at LBL. The decrease in solo driving was substantial and significant (19); only one individual shifted to driving alone. There were, however, substantial diversions between transit and shared ride--26 individuals shifted from transit to shared ride and 21 from shared ride to transit. These numbers do not change substantially, even after the gasoline-crisis mode changers are screened.

Table 8 shows the results of hypothesis tests for significant mode changes. Before controls for energy are applied, there is a strongly significant reduction in driving alone and marginal increases in ridesharing and transit use. After the controls for energy shortages, there was only a small decrease in the number of individuals who changed from drive-alone to both transit and shared ride; nearly all of the mode changes were tested as being independent of the energy crisis. There was enough of a decrease in transit riders to make the increase in transit use statistically insignificant; however, the increase in ridesharing was of marginal statistical significance.

The CBD employees were analyzed for mode changes relating to transit and shared ride only because there were so few solo drivers that statistical comparisons were not possible. Concerning shifts to and from transit, trip distance was significant. Interestingly, individuals who had long-distance trips were more likely to shift both to and from transit. For all the mode changes that occurred between ridesharing and transit, trip distance was very significant: The individuals who changed from both ridesharing and transit had significantly longer trip lengths than did those who retained each mode. Commuting is certainly most onerous for these long-distance commuters, so it is not surprising that they are highly represented among the mode changers. The individuals who did change may have been dissatisfied with their previous choices but, until flextime, had no alternative available.

Shifts from transit (which occurred exclusively to shared ride, except for one individual) occurred more frequently for married individuals who have working spouses and in households where incomes are higher (once again, highly corroborative). Comparison of automobile ownership levels indicates that these shifters did not have statistically different levels of automobile ownership from that of individuals who remain transit riders.

Analysis of motivations for mode change (see Table 9) helps to explain the causes for the mode changes. Responses to motivations 4 and 5 indicate that flextime was important in allowing individuals to share rides with family members and adjust work schedules to form a carpool. These results are consistent with the hypotheses that argue for increases in ridesharing. Surprisingly, the most important motivation for these new ridesharers is the ability to avoid the rush hours. In fact, 89 percent of the new ridesharers reported decreased commute times compared with those for their old transit mode, and 79 percent were able to save time by arranging shared rides to arrive at work before 8:00 a.m. (the most congested portion of the peak period). Of the 79 percent who reported time savings, nearly half had work arrival times before 7:00 a.m.; another 35 percent arrived between 7:00 and 8:00 a.m.

The other motivations in Table 9 indicate that former transit patrons still rate the ability to find seats on transit fairly highly (12 of 26 rate it as somewhat or very important). Survey comments indicate that these individuals occasionally use transit and also value the ability to use it if necessary. The great importance of saving money on gasoline is explained by the fact that individuals are comparing their money savings if they drove alone rather than carpooled. Interestingly, the capturing of parking spaces and use of car for errands are relatively unimportant. Remember that these switchers from transit to carpool have long trip lengths; therefore, the concern for congestion avoidance is rational. Commuting corridors in San Francisco are frequently congested for two hours or more during the morning and evening peak periods. These individuals have shifted from crowded, slow-moving transit to ridesharing arrangements that allow travel in the prepeak period with concomitant savings in travel time.

Analysis of individuals who changed from ridesharing to transit yield rather complementary findings. Individuals who switched to transit were frequently single or the sole wage earner. Once again, analysis of automobile ownership levels failed to detect differences, compared with levels for ridesharers who remained in their carpools. As at LBL, however, there appears to be an income effect: Mode changers from shared ride to transit had significantly lower average incomes than did those who retained the ridesharing mode. Further, mode changers from transit to shared ride had a mean income of

Table 7. Summary of mode changes for CBD.

Mode Used Before Flextime	Mode Used with Flextime: Transit	Drive Alone	Shared Ride	Total
Without Energy Controls				
Transit	344	1	26	371
Drive alone	14	14	5	33
Shared ride	21	0	77	98
Total	379	15	108	502
With Energy Controls				
Transit	344	1	26	371
Drive alone	12	14	2	28
Shared ride	20	0	77	97
Total	376	15	105	496

Note: Table entries are the number of respondents who report use of specific modes before and with flextime.

Table 8. Results of hypothesis tests for mode share changes for CBD employees.

	Without Controls for Energy		With Controls for Energy	
Mode	χ^2	Significance Probability	χ^2	Significance Probability
Transit	1.035	>0.25	0.42	>0.50
Drive alone	19.78[a]	<0.005	13.44[a]	<0.005
Carpool	1.935	>0.1	1.34	>0.25

[a]Reject H_0 with $\alpha = 0.05$.

Table 9. Summary of mode change motivations for CBD.

	Changes from Transit to Ridesharing				Changes from Drive Alone to Ridesharing				Changes from Drive Alone to Transit				Changes from Ridesharing to Transit			
Motivation	NA	NI	SI	VI	NA	NI	SI	VI	NA	NI	SI	VI	NA	NI	SI	VI
1. Arrive early to find parking	12	7	3	3	2	0	1	2	6	2	1	5	15	3	0	2
2. Use car for errands	9	8	6	3	2	0	0	3	4	3	2	4	7	4	4	2
3. Avoid rush-hour traffic	7	0	7	12	0	0	1	4	6	2	0	6	12	2	3	3
4. Adjust work schedule to share a ride with a family member	9	1	5	11	3	0	0	1	9	3	1	1	14	3	1	2
5. Adjust work schedules to join or form a carpool	7	4	3	11	1	0	1	3	8	4	2	0	15	3	1	0
6. Able to use transit even if it is unreliable	13	2	7	4	1	0	1	2	1	3	3	7	1	3	5	9
7. Able to use transit when seats are available	13	1	5	7	1	0	0	3	1	1	4	8	2	2	4	12
8. Easier to meet transit schedules	13	3	6	4	1	0	1	2	1	1	5	7	0	3	7	10
9. Able to save money on gasoline and leave car at home	14	1	3	7	1	0	0	3	2	2	1	9	5	0	3	13

Notes: NA = not applicable, NI = not at all or not too important, SI = somewhat important, and VI = very important.

$26 000; however, changers from shared ride to transit had a mean income of $21 000; 62 percent of the new transit patrons had incomes below $20 000, but only 31 percent of the new ridesharers had household incomes less than $20 000. Responses to motivations for mode change in Table 9 support these findings: Saving money on gasoline is the motivation checked as very important by most people. Notice, however, that all the other transit-related motivations are nearly as important. Transit that arrived in the San Francisco CBD was usually very crowded during peak periods; some operations had frequent reliability and schedule-adherence problems as well. It is therefore not surprising that these service-related motivations are ranked high by new transit patrons. Responses to the importance of carpool and automobile-related motivations reflect the use of these modes for access to transit. Table 9 indicates that the pattern of motivations for individuals who change from drive-alone to transit is nearly identical to the results for changes from ridesharing to transit.

In summary, the costs of long-distance commuting appear to bear heavily on the lower-income households that used to drive or ride in an automobile to work. These individuals are able to switch to transit because of the additional latitude that flextime provides to avoid service unreliability, lack of seats, and mismatched schedules, by permitting them to arrive at work in the prepeak period. Ridesharers also travel in the prepeak hours, but do so to avoid rush-hour congestion, and arrive at work (and home) earlier in the day.

SUMMARY

Only some of the hypotheses discussed appear to have motivated mode changes at the firms studied. Individuals at the CBD firms were most easily able to share rides with spouses, but at the more isolated site (LBL) this was not a major phenomenon. Neither group of individuals showed a significantly increased incidence of ridesharing with individuals at other firms. Surprisingly, at both sites these new ridesharers were attracted by the ability to avoid congestion as much as (if not more than) by the flexibility to form new carpool arrangements.

New transit riders were strongly motivated by income constraints and increased gasoline prices, but flextime allowed them to deal with unreliable transit service (particularly on BART), and to travel during times when seats were available on transit vehicles. The hypothesis of schedule buffering did not receive much support for either group of employees.

In many ways, the most satisfying finding was the significant decrease in solo driving for both the LBL and CBD groups as well as for the survey pretest. For the individuals in this study, the freedoms available to avoid the rush hour, find parking spaces, and arrange work schedules to use a car for errands were not sufficient inducements to increase solo driving in large numbers. In fact, many new ridesharers were able to avail themselves of these opportunities while traveling with a spouse or coworker.

Flextime did not favor any one mode over all others. Clearly, each of the individuals who changed modes had improved commuting time as a result. Society as a whole can be said to benefit by the decreased numbers of solo drivers. To answer the question originally posed as the motivation for this research: Yes--flextime is compatible with ridesharing and transit promotions, according to the responses to our study. Note, however, that only one of the many variants of flextime was studied. It is hoped that the findings help allay fears of transportation professionals regarding flextime and mode change.

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Assessment of Flextime Potential to Relieve Highway Facility Congestion

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Travel surveys of flextime workers at three firms in downtown San Francisco are used to assess the potential impact of flextime for relief of congestion on a freeway facility. The changes in work schedules for the survey respondents are extrapolated to reflect the effects of a large, areawide flextime promotional campaign. The freeway-corridor model FREQ was used to investigate two simulation scenarios. The first scenario resulted in few vehicles (less than 4 percent) changing their times of travel but yielded substantial improvements in facility traffic flow. The second scenario resulted in a much larger number of vehicles changing their time of travel, and actually revealed a worsening of traffic-flow conditions on the Bay Bridge. Interpretation of the simulation results vis-à-vis the survey responses of individuals at the three firms indicates that these worsened traffic conditions are unlikely to occur for extended periods of time or on facilities that have different operating characteristics. It is clear that very few vehicles need to change their time of travel to have facility impacts, and that the numbers of vehicles needed are within the reach of modestly successful flextime promotion campaigns. Interpretation of the simulation findings generally supports the promotion of flextime programs by transportation professionals to provide clear travel benefits to program participants, and possible travel benefits to users of a freeway facility who do not have flexitime privileges.

Since the inception of the transportation system management (TSM) regulations in 1975 (1), alternative work schedules have been included in the list of tactics to be considered in the attempt to better manage the existing transportation system. Proponents of these tactics hope that the removal of a few individuals from the peak will result in decreased congestion for travelers who remain peak-period commuters.

Several areawide demonstrations have already illustrated the effects of two alternative work-schedule policies--staggered work hours and flextime. A major promotion of staggered work hours in New York City (2-4) reported decreased peaking at several subway stations in the study area (e.g., passenger counts at the three busiest subway stations decreased by 6 percent in the peak 10 min). Even more dramatic decreases in peak flows under flextime and staggered work hours were reported in Toronto (5). Before the demonstration, peak passenger flows occurred between 8:00 and 8:30 a.m.; after six months of the demonstration program, the peak shifted to between 7:45 and 8:00 a.m. and flattened considerably. Many people traveled before 7:45 a.m. and considerably fewer traveled during the former peak.

These studies provide evidence of reduced peaking for subway lines; however, the situation for bus and highway systems is less clear. Results of a work-schedule promotion in Ottawa (6) indicate that traffic flows at screenlines and parking facilities changed during the promotion, but the effect of changes in the work schedule could not be separated from seasonal flow variations and the influence of the 1973 energy crisis.

Several recent studies have reported changes in the quality of the commute for individuals who have flextime. Findings from Albany, New York (7); Cambridge, Massachusetts (8); and San Francisco, California (9), indicate that individuals who have flextime were able to save up to 15 min in travel time by commuting during the off-peak period.

Two studies used analytic models to examine impacts of alternative work schedules. Tannir and Hartgen (10) used transportation planning models to assess areawide impacts of a hypothetical four-day workweek at the New York State Department of Transportation in Albany, New York, and found 4-9 percent reductions in vehicle kilometers of travel near the work site, but negligible impacts areawide. Jones and others (11) used a freeway-corridor simulation model (FREQ) to study corridor impacts of flextime promotions in San Francisco. The analysis assumed that time shifts would occur to eliminate congestion during the peak period. The results of eliminating congestion were a 16 percent decrease in travel time; 1.4 percent decrease in fuel consumption; and 6-7 percent decreases in hydrocarbon and carbon-monoxide vehicle emissions for the evening peak only.

These findings suggest that areawide impacts are likely to be negligible, but that impacts at the corridor level (particularly for heavily traveled freeway corridors) are possible. Stronger conclu-