TRAVEL EFFECTS OF A SUBURBAN COMMUTER-CARSHARING SERVICE: A CARLINK CASE STUDY

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ABSTRACT

Since 1998, carsharing programs (or short-term auto rentals) in the U.S. have experienced exponential membership growth. As of July 2003, 15 carsharing organizations collectively claimed 25,727 members and 784 vehicles. Given this growing demand, decision makers and transit operators are increasingly interested in understanding the potential for carsharing services to increase transit use, reduce auto ownership, and lower vehicle miles traveled. However, to date, there is only limited evidence of potential program effects in the U.S. and Europe. This paper presents the travel effects of CarLink—a commuter carsharing model with explicit links to transit and employment in a suburban environment—in the context of participant demographic and attitudinal market profiles. A variety of research methods (including focus groups, interviews, questionnaires, and travel diaries) captured the following commute travel effects from the CarLink I and II programs:

- Increased commuter rail mode share by 23 percentage points in CarLink I and II;
- Reduced drive-alone mode share by 44 and 23 percentage points in CarLink I and II, respectively;
- Decreased average daily vehicle miles traveled by 23 miles in CarLink II and by 18 miles in CarLink I;
- Increased travel time but reduced stress;
- Reduced vehicle ownership by almost six percent in CarLink II; and
- Reduced parking demand at participating train stations and among member businesses.

The typical CarLink I and II member was more likely to be highly educated, in an upper income bracket, and professionally employed than average Bay Area residents. CarLink I and II members also displayed sensitivity to congestion, willingness to experiment, and environmental concern. The travel results of CarLink I and II are compared to those of neighborhood carsharing models in the U.S. and Europe to suggest the importance of CarLink's explicit transit and employment connections and the value of carsharing in a suburban location.

Key Words: Carsharing, CarLink, Station Cars, User Profile, and Travel Behavior

INTRODUCTION

Automobiles have profoundly influenced travel and land use in the U.S. by providing unprecedented flexibility, convenience, and speed. Despite the myriad benefits offered by private vehicles, there is a recognition of the negative social and environmental effects of car dependence (1, 2), for example, traffic-related deaths, congestion, air and water

pollution, and suburban sprawl. To date, implemented strategies to reduce auto use and dependency have largely focused on public transit. Carsharing programs (or short-term auto rentals) represent an intermediate strategy—situated between public transit and private vehicle ownership—for addressing several auto-related concerns. Furthermore, carsharing vehicles have the potential to enhance the existing transportation infrastructure, improving transit access and reducing parking demand at a lower cost than traditional capacity expansion projects.

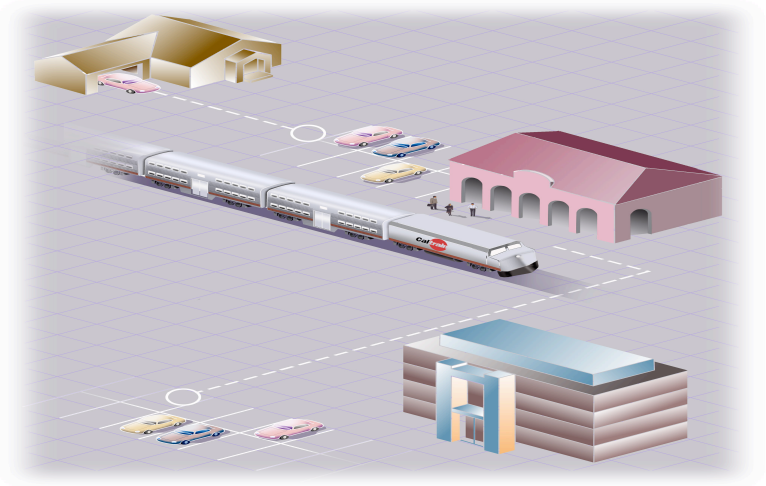
Carsharing was first conceived in Europe but has gained popularity in the U.S. over the past six years. Once subscribed to a carsharing organization, individuals can receive the benefits of private car use without the costs and responsibilities of ownership. Generally participants pay a fee each time they use a vehicle, which covers the cost of vehicle use, insurance, maintenance, and fuel. Participants in a carsharing organization incur variable costs of auto use, rather than the largely fixed costs of auto ownership. Thus, the carsharing service may encourage reduced auto ownership and use and increased transit use.

In Europe, StattAuto of Berlin and Mobility CarSharing Switzerland are the two dominant carsharing organizations. The business-oriented Swiss organization boasts over 50,000 members. In the U.S., carsharing developed more recently; carsharing organizations have experienced exponential membership growth, from 1998 to the present. As of July 2003, 15 carsharing organizations collectively claimed 25,727 members and 784 vehicles (3).

In Europe and the U.S., the most common carsharing model is known as “neighborhood carsharing.” Under this model, the carsharing organization maintains a fleet of cars distributed among a network of neighborhood locations for convenient member access. This model is typically located in dense urban areas with strong transit networks. Ideally, members of such a system use transit for most of their trips and carshare only when traveling outside the transit network, when travel times do not coincide with transit schedules or for transporting heavy or bulky items.

The CarLink commuter carsharing model differs from more traditional neighborhood carsharing by providing a formal link to transit and employers in a suburban location. The primary target audience is daily commuters who use the cars frequently for short segments of their commute. The CarLink model includes three user groups: 1) Homebased Users, 2) Workbased Commuters, and 3) Workbased Day Users. Homebased Users drive the cars between their homes and the train station on mornings and evenings, using the train for the line-haul portion of their trip to work. Homebased Users also keep the cars on evenings and weekends for personal use. Workbased Commuters take the train to work in the morning, pick up a shared-use car at the station (left earlier by a Homebased User), and drive the car to work. Day Users can check-out the cars from their work site during the day for personal or work errands. Thus, each car is used by all three user groups throughout the day. See Figure 1, below, for an artist’s rendition of CarLink and how each user group interacts with the vehicles and transit.

FIGURE 1: The CarLink Model (Consisting of Three User Groups: Homebased Users, Workbased Commuters, and Workbased Day Users)



As demand for carsharing services grows, decision makers and transit operators increasingly need to understand the potential of these services to increase transit use and reduce auto ownership, vehicle miles traveled (VMT), and emissions. However, to date, there is only limited evidence on the potential travel effects of carsharing programs in the U.S. (4, 5, 6). Most of the research focuses on European experience with neighborhood carsharing. These studies indicate significant reductions in auto travel (30 to 70 percent) and auto ownership (10 to 60 percent) (7, 8, 9, 10). However, the methods employed in these studies were limited, and the results may not be generalizable to the U.S. (see literature review below). Only a few studies have been conducted on neighborhood carsharing in the U.S., and these studies suggest that travel benefits may be more modest than those found in Europe (e.g., 5, 6). Nevertheless, research evaluations of U.S. carsharing programs with an explicit transit link (also known as station cars) consistently suggest significant reductions in auto travel (11, 12, 13).

This paper presents the market and travel effects of CarLink I and II from the analysis of a range of before and after instruments (focus groups, interviews, travel diaries, and questionnaires). The results of CarLink I and II are pooled and compared here to: 1) expand the sample and thus the confidence in reported travel effects and 2) explore the relative importance of locational effects (e.g., congestion levels or quality of transit service) and program attributes (e.g., employer demand). The travel results of CarLink I and II are also compared to those of neighborhood carsharing models in the U.S. and Europe to suggest the importance of explicit transit and employment connections in the CarLink model and the value of carsharing in a suburban location.

This paper consists of five main sections. First, the authors present a review of carsharing travel effects in Europe and the U.S. Second, the authors describe the operational models

of CarLink I and II. Third, the methods employed in the study are documented. Fourth, study results are examined. Finally, the authors present key study conclusions.

CARSHARING IMPACTS IN EUROPE AND THE UNITED STATES

To date, a number of U.S. carsharing studies have quantified various social and environmental impacts. While a variety of measures have been tracked (e.g., VMT, auto ownership, modal shift), study methods are largely inconsistent. A majority of the information regarding travel impacts comes from European experience (7, 8, 9, 10). Most European studies document impressive VMT reductions, with annual vehicle mileage declining from 30 to 70 percent as a result of carsharing. Vehicle ownership impacts are also notable, ranging from 10 to 60 percent of members selling a vehicle after joining a carsharing program. Although some VMT reductions result from foregone trips, a significant amount of this change is attributed to modal shifts (i.e., members substituting private car use with public transit and non-motorized options).

While European carsharing results are encouraging, the methods employed also vary among studies. First, several rely on data collected only after an individual used carsharing, requiring members to reflect back on prior modal use (versus documenting mode split prior to membership). Not surprisingly, the accuracy of these data is unknown. Second, control groups are seldom used to provide a comparison of behavioral changes for members and non-members over the same time period, controlling for outside factors (e.g., economic downturn). Third, many studies document the behavior of those who are among the first to adopt carsharing (or early adopters). Thus, results may not reflect travel patterns after an individual has fully adjusted to carsharing, as well as evolving market impacts (e.g., new target segments and attrition). Contextually, there are also numerous issues. For example, in Europe, public transit networks are denser, fuel prices are substantially higher, and car ownership rates are lower than those in the U.S. Thus, the degree to which European results can be generalized to the U.S. is questionable.

Several systematic studies have been conducted on U.S. carsharing research demonstrations and just a few on existing programs. These include Purdue University's Mobility Enterprise shared-car experiment of the early 1980s (14) and an evaluation of the Short Term Auto Rental Service in San Francisco (15) around the same time. More recent studies include the San Francisco Bay Area Station Car Program (11); CarLink, a commuter-based carsharing system deployed in the San Francisco Bay Area (12, 13); and Intellishare's campus car study (16). Among operating programs, two-year evaluations of CarSharing Portland and City CarShare have been completed (5, 6).

Evaluation of station car programs (i.e., carsharing with an explicit transit link) conducted thus far have universally supported the proposition that increased transit connectivity can dramatically reduce VMT among program participants. This is not surprising because many of these programs specifically recruit individuals who would otherwise drive to work rather than commute via public transit. CarLink I, a carsharing field test with a central station-car component, yielded a net average commute VMT reduction of approximately 18.5 miles per day. CarLink I also resulted in 20 *new* daily

Bay Area Rapid Transit (BART) District trips among CarLink I commuters (20 participants). Several participants stated that if CarLink I became a permanent service, they would sell one of their personal cars, which could greatly reduce their transportation costs (12). Findings from the San Francisco Bay Area station car demonstration also revealed substantial reductions in commute-related VMT. These findings indicate that personal vehicle mileage declined from 45 percent of total VMT to three percent, with drivers substituting a combination of rail and electric vehicles (11).

Vehicle travel effects are less clear in the case of neighborhood carsharing, largely due to limited samples, length of time studied, modest behavioral changes, or a combination of factors. A study of CarSharing Portland membership behavior after two years of operation indicates that aggregate VMT decreased among members by 7.6 percent. This reduction was largely driven by members who had given up an owned or leased car after joining the carsharing organization. Among this group, VMT was decreased by 25 percent. For members without household vehicle access, VMT increased by 19 percent (5). A similar outcome was observed in a two-year evaluation of City CarShare in San Francisco, which revealed a two percent VMT reduction among members (6). Although modest, it is important to note that this particular measure may underestimate carsharing VMT impacts. Among a comparable group of non-members (a control group), VMT increased by 49 percent over the same period, suggesting that carsharing may have reduced total VMT beyond the modest two percent reduction reported. The authors hypothesize that the influence of carsharing membership on vehicle ownership is likely reflected in reduced VMT among households that either sold or forfeited a car purchase.

Few studies of neighborhood carsharing in the U.S. evaluate the modal shift effects of carsharing, and some study results have been contradictory. For example, CarSharing Portland's two-year study indicates a slight increase in transit use and walking/cycling, while the City CarShare year-two study reports a decline in walking, cycling, and transit usage. In the case of City CarShare, carsharing appears to have largely displaced these travel modes among members (5, 6).

Neighborhood carsharing appears to have a relatively strong effect on vehicle ownership. Most U.S. carsharing studies demonstrate that shared-use vehicles have a mitigating influence on vehicle ownership, motivating members to either sell a vehicle or avoid a vehicle purchase. For instance, CarSharing Portland's two-year study reported that 23 percent of members sold a personal vehicle, and 25 percent were able to avoid purchasing one (5).

The next section presents an overview of the CarLink I field test and CarLink II pilot program.

OVERVIEW OF CARLINK I AND II

The CarLink I field test was launched on January 20, 1999, and ended on November 15, 1999. Fifty-four individuals enrolled in the program and shared 12 natural gas powered Honda Civics. The participants were from San Francisco, Oakland, and East Bay

communities. The cars were based in premium parking spaces at the Dublin-Pleasanton BART station. The CarLink I model accommodated traditional and reverse commute travel patterns as well as day-time travel needs of employees at the Lawrence Livermore National Lab (LLNL).

The CarLink I field test combined short-term rental vehicles with communication and reservation technologies (i.e., smart technologies) to facilitate shared-use vehicle access. The ten-month demonstration project was implemented and researched by two teams at the Institute of Transportation Studies at the University of California, Davis. Project partners included the California Department of Transportation (Caltrans), American Honda Motor Company, the BART District, California Partners for Advanced Transit and Highways (PATH), and LLNL. INVERS (a Germany-based smart carsharing technology company) and Teletrac provided the advanced carsharing and vehicle tracking technologies.

The CarLink I model included three separate user structures: a Homebased User lease; transit links for Homebased Users and Workbased Commuters; and shared vehicle access at the LLNL employment site through Day Use. During the field test, each user group paid a distinct fee according to the duration of car use. All user fees included fuel, insurance, and maintenance costs. Roadside assistance and an emergency taxi service were also provided. In addition to vehicle support services, CarLink I implementation staff supported the program by cleaning and occasionally refueling the vehicles, as well as maintaining e-mail and phone contact with users.

Using questionnaires, household interviews, and focus groups, researchers explored CarLink I attitudes and use over time. Although the CarLink I participant sample was small (i.e., 54 enrolled), the results yield valuable lessons. CarLink I findings include operational understanding, participant profiles, behavioral findings, preliminary economic analysis, and directions for future research (13).

The CarLink II pilot program was launched on July 1, 2001, and ended on June 30, 2002, and included 107 members. CarLink II continued the investigation of commuter carsharing as developed in the CarLink I field test. There were five key differences between the CarLink I field test and CarLink II. First, CarLink II was a pilot program that included a transition to an ongoing carsharing organization once the initial pilot stage was completed. Researchers found that many CarLink I users would have remained in the program, sold a household vehicle or forgone a purchase, and increased transit and/or alternative mode use (e.g., carpooling and vanpooling), had the field test been continued (13). Thus, project partners considered a more sustainable program approach to be critical in CarLink II. Second, the size of the CarLink fleet increased from 12 to 19 vehicles, consisting entirely of 2001 Ultra Low Emission Vehicle (ULEV) Honda Civics. CarLink II's larger size enabled researchers to gain a deeper understanding of the model's niche potential with greater statistical significance. A third difference was the program's focus on providing commuter feeder and day use services to *many* companies in the region rather than a single employer. Fourth, the participation of multiple employers and employees required the development of integrated carsharing technologies, which

coordinated vehicle tracking, data collection, and reservations. Smart key fobs facilitated instant vehicle access and eliminated the need for multiple "key boxes" at transit stations and work locations. The potential of these technologies to enhance service capabilities and reduce program costs was central to the CarLink II program. Finally, CarLink II was located in the Palo Alto region, south of San Francisco, and its chief transit partner was Caltrain (i.e., a commuter rail system that runs for approximately 75 miles between Gilroy and San Francisco). The notable congestion and growth of the South Bay also rendered it a prime location for exploring commercial viability. The key differences between CarLink I and CarLink II are also summarized in Table 1, below.

TABLE 1: Key Differences Between CarLink I and CarLink II

CHARACTERISTICS	CARLINK I	CARLINK II
Community Access	• Limited primarily to employees of a National Laboratory and 10 households • 54 users	• Increased network of users, with several businesses • 107 users
Timeframe	• 10-month field test	• 12-month pilot project, before transitioning to third-party operator (Flexcar)
Vehicles	• 12 Honda Civics fueled with compressed natural gas	• 19 internal combustion engine Honda vehicles
Technology	• Smart key manager • Manual key boxes • On-board vehicle computers • Vehicle tracking units • Manual reservation system (facilitated through web page)	• Smart key fob remote access system (i.e., no key boxes) • On-board vehicle computers • Global Positioning System (GPS) vehicle tracking units • In-vehicle navigation system • Computerized reservation system for Day Use
Transit Partner	• Bay Area Rapid Transit (BART) District	• Caltrain
Location	• Dublin-Pleasanton and Livermore (east of San Francisco)	• Palo Alto and Silicon Valley (south of San Francisco)

As in the CarLink I field test, three distinct categories of users shared the CarLink II vehicles:

- **Homebased Users,** who had access to the vehicles on evenings and weekends, paid $300 per month. These members lived in or near Palo Alto and drove a CarLink vehicle to the Caltrain California Avenue station each weekday morning, before taking a train to work and then home again at night.
- **Workbased Commuters** were employees of Stanford Research Park businesses, who used the CarLink vehicles that Homebased Users parked at Caltrain in the morning, to

commute to and from the California Avenue station and work sites. Employers paid approximately $50 per month per vehicle for employee access to vehicles. Employers were encouraged to promote carpooling among Workbased Commuters. This aspect of the program was very successful.

- **Workbased Day Users** were employed by business subscribers of the Stanford Research Park (i.e., the same companies that employed the Workbased Commuters) and used the vehicles for personal and business trips throughout the day. Day Use was provided as a subscription package to employers for $300 per vehicle per month. Employers paid a total of $350 per month per car for the Day Use and Workbased Commuter components.

Again, all user fees included maintenance, insurance, and fuel costs. Roadside assistance and emergency taxi services were also provided. The CarLink implementation staff also supported the program by cleaning the vehicles, as well as maintaining e-mail and phone contact with users.

During site selection, the CarLink II team worked with the Stanford Research Park to recruit employer participants. Stanford Research Park has over 700 acres and 10 million square feet of developed facilities, 162 buildings, 150 companies, and 23,000 employees. As its name suggests, the Stanford Research Park primarily houses research companies, whose type and size varies widely. Companies include high-tech law firms, software companies, pharmaceutical research companies, and several “dot coms.”

The companies most interested and suited to CarLink II participation included those with regular work schedules (in contrast to “dot coms”) and ranged in size between 100 to 600 employees. CarLink II included six employers, located throughout or nearby the Stanford Research Park.

The following section provides an overview of the CarLink II research methodology and data collection methodology.

RESEARCH AND DATA COLLECTION METHODOLOGY

The CarLink II evaluation built upon the research of the CarLink I longitudinal survey and field test (13, 17). As in the CarLink I field test, the CarLink II research investigates the perceptions and attitudes of carsharing participants through focus groups, questionnaires, and household interviews, as well as examining changes in travel patterns by comparing travel diaries and automatically collected vehicle data.

Focus groups were the first research instrument employed; two were conducted several months prior to the CarLink II launch to investigate carsharing perceptions and gather feedback on final design details (e.g., costs and recruitment techniques). These focus groups were used to collect rich qualitative data from participant and moderator interactions. They also allowed researchers to monitor the level of emotion or enthusiasm for a subject; these data proved invaluable to the CarLink system design. The focus groups consisted of individuals living in the Palo Alto area (i.e., potential Homebased

Users), who were recruited at Caltrain stations and through "cold call" telephone solicitation. Focus groups and interviews were also conducted with program participants mid-way and at the end of the evaluation period.

The second research instrument consisted of a before-and-after questionnaire series. A questionnaire was administered when participants joined CarLink II and at the conclusion of the data collection period or when they left the program. The initial survey instruments addressed each household's pre-CarLink travel patterns as well as basic demographic questions about household characteristics. Researchers compared these responses to participant travel diaries. In addition, respondents also answered a series of psychographic questions related to their opinions and attitudes about transportation and other items (e.g., environment, advanced technologies, and willingness to try new things).

The third research instrument was a three-day travel diary (i.e., two consecutive weekdays and a weekend day). To evaluate the travel effects of CarLink II (e.g., transit and auto travel, auto ownership, and parking space needs), researchers needed to know how members traveled before and during the program. Before joining CarLink II, all participants were required to complete a travel diary. Subsequently, researchers compared the pre-CarLink travel data to CarLink vehicle usage data collected automatically, as well as travel diaries completed as part of the CarLink II final evaluation.

The response rates for the before-and-after questionnaires and diaries by gender and user groups are presented in Table 2, below. The total response rate for the CarLink II questionnaires and diaries was 59.8 percent. Some surveys were returned two to six months after the end of the program and after Flexcar—the third party operator—took over the program. Participants were contacted by telephone to remind them to complete the surveys. Overall response rates for females were seven percent higher than for males.

TABLE 2: CarLink II Response Rates by Gender and User Group

USER GROUP	MALE	FEMALE	AVERAGE
Homebased Users (N=9)	62.5%	50.0%	56.3%
Workbased Commuters (N=21)	64.3%	85.7%	75.0%
Workbased Day Users (N=34)	50.0%	57.1%	54.0%
Total Average (N=64)	56.0%	63.2%	59.8%

The distribution of program members and survey respondents by user group are presented in Table 3, below. The distribution of Homebased Users is close to equal. However, it appears that Workbased Commuter respondents are somewhat under-represented and Workbased Day User respondents are somewhat over-represented relative to total user group proportions.

TABLE 3: Distribution of CarLink II Participants and Survey Respondents[a] by User Group

USER GROUP	PARTICIPANTS (N=107)	RESPONDENTS (N=64)
Homebased Users	15.0%	14.1%
Workbased Commuters	26.2%	32.8%
Workbased Day Users	58.9%	53.1%

[a] Note that all participants completed the initial surveys, but respondents completed both the initial and final surveys.

The CarLink in-vehicle technology provided the fourth study instrument, collecting car usage data automatically. These data could be viewed in real-time (i.e., the fleet manager could monitor vehicles at any time) and were archived to provide usage histories. Data include:

- User ID,
- Start and end times,
- Start and end locations, and
- Fuel level (to an eighth of a tank).

CarLink researchers used these data to calculate total vehicle miles traveled, trip number, fuel used, time of use, and other statistics.

EARLY ADOPTER MARKET PROFILE

In this section, demographic and attitudinal market profiles of CarLink II early adopters are created from data gathered through participant questionnaires described above. The profiles assist in understanding the generalizability of the project and its potential impacts to other locations. For example, commuter carsharing programs may be more or less effective in metropolitan regions depending on land-use patterns, transit systems, and population demographic and attitudinal characteristics. The market profiles for CarLink II are compared to CarLink I whenever possible to help explore any variation in travel effects. The demographic profiles are also compared to U.S. Census data (2000) for the Bay Area to illustrate the similarity between CarLink I and II early adopters and the general Bay Area population.

Demographic Profiles

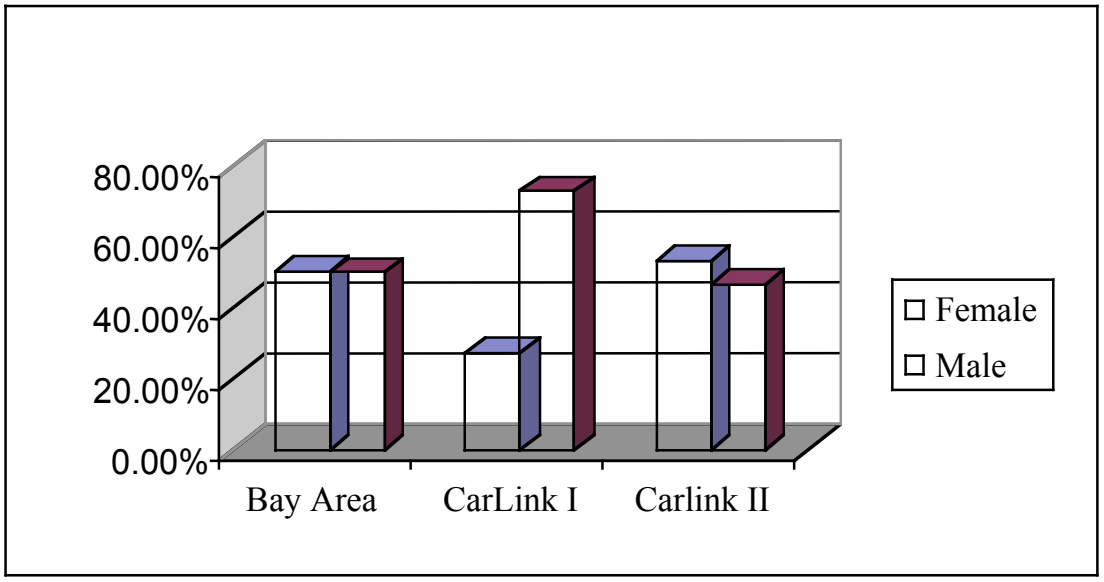
Demographic variables examined include gender, age, education, income, occupation, and vehicle ownership.

Gender

Men and women were equally represented in CarLink II, which is consistent with the distribution of men and women in the Bay Area. However, in CarLink I, male participants were disproportionately represented. Figure 2, below, presents a comparison of the gender distribution of the CarLink I and II participants and the Bay Area population. Studies of European carsharing have also found that men tend to participate

in carsharing more frequently than women (17). The difference in gender distribution between CarLink I and CarLink II may be explained by the demographic or attitudinal characteristics of employees at the respective worksites. The worksite in CarLink I (LLNL) may employ more men than women or female employees may possess less early adopters attributes than male employees.

FIGURE 2: Gender of CarLink Members Relative to Bay Area Residents (2000 Census)



Age

CarLink II participants tended to be younger than the general Bay Area population and CarLink I participants. The comparison to the Bay Area population excludes those under 20 and over 64 because of CarLink's membership age restrictions. The location of CarLink II in the Silicon Valley, which tends to have a relatively young employee base, may explain the lower relative age of participants in CarLink II. Similarly, the LLNL worksite in CarLink I may explain the higher relative age of participants (i.e., employment may require more advanced degrees). Table 4, below, presents a comparison of the age distribution of the CarLink I and II participants and the Bay Area population.

TABLE 4: Age of CarLink Members Relative to Bay Area Residents (2000 Census)

AGE [A]	**20-44**	**45-64**
Bay Area	64%	36.0%
AGE	**20-40**	**41-64**
CarLink I (N=54)	40.9%	59.1%
CarLink II (N=107)	79.3%	20.5%

[a] Note that age categories differed from Census to CarLink Data and were collapsed for best consistency.

Education, Income, and Occupation

Participants in both CarLink I and II possessed higher levels of education than the general Bay Area population. Fifty-seven percent of CarLink I and 48 percent of CarLink II participants had completed a bachelors degree or higher. This compares to 14.1 percent of Bay Area citizens over the age of 25 with a bachelors degree or higher.

The household income levels of CarLink participants were also relatively high. Thirty percent of CarLink I members had household incomes ranging from $80,000 to $99,999, while 16 percent had a household income greater than $100,000. CarLink II members had fewer participants in the $80,000-$99,999 range (19 percent), but more participants earning over $100,000 (47 percent). In CarLink II, the greatest portion of all user groups was in the $100,000 plus income category. However, Homebased Users tended to have a relatively large percentage of members in lower income groups, and the reverse was true for Workbased Commuters. Workbased Day Users tended to have a more even distribution across the income categories than the other user groups.

With higher education and income levels, CarLink members were primarily employed in the professional/technical category (68.2 percent in CarLink I and 64.7 percent in CarLink II). This is high relative to Bay Area residents (see Table 5 below). The distribution of occupation types did not vary substantially among user groups in CarLink II relative to CarLink I.

TABLE 5: Occupation Distribution of CarLink Participants Relative to Bay Area Residents [a]

	Mgr./ Admin.	**Service/ repair**	**Sales/ office**	**Prof./ tech.**	**Prod./ const.**	**Other**
CarLink I (N=43)	18.2%	0.0%	9.1%	68.2%	2.3%	2.3%
CarLink II (N=102)	18.1%	0.0%	11.4%	64.7%	0.0%	5.7%
	Mgr./ Admin.	**Service/ repair**	**Sales/ office**	**Other**		
Bay Area	43.7%	12.8%	25.6%	17.9%		

[a] Note that occupation categories available from the 2000 U.S. Census and the CarLink survey differed.

Vehicles Per Household

CarLink II participants owned or leased an average of 1.75 vehicles per household at the start of the program. Overall, the number of vehicles per household of CarLink II participants was similar to the Bay Area population. Figure 3, below, presents a comparison of the household vehicle distribution of CarLink II participants and the Bay Area population.

FIGURE 3: Distribution of Number of Vehicles per Household for CarLink II

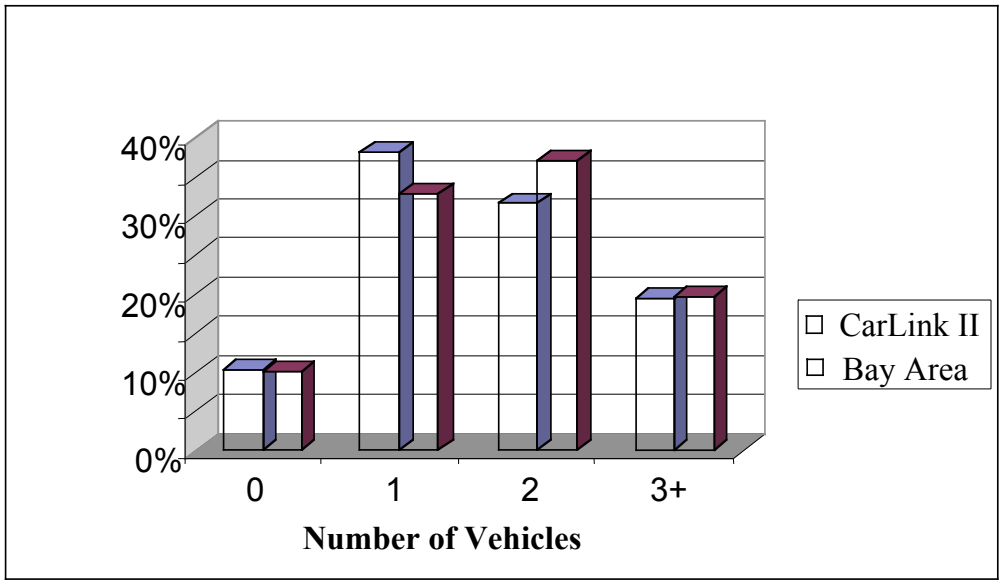
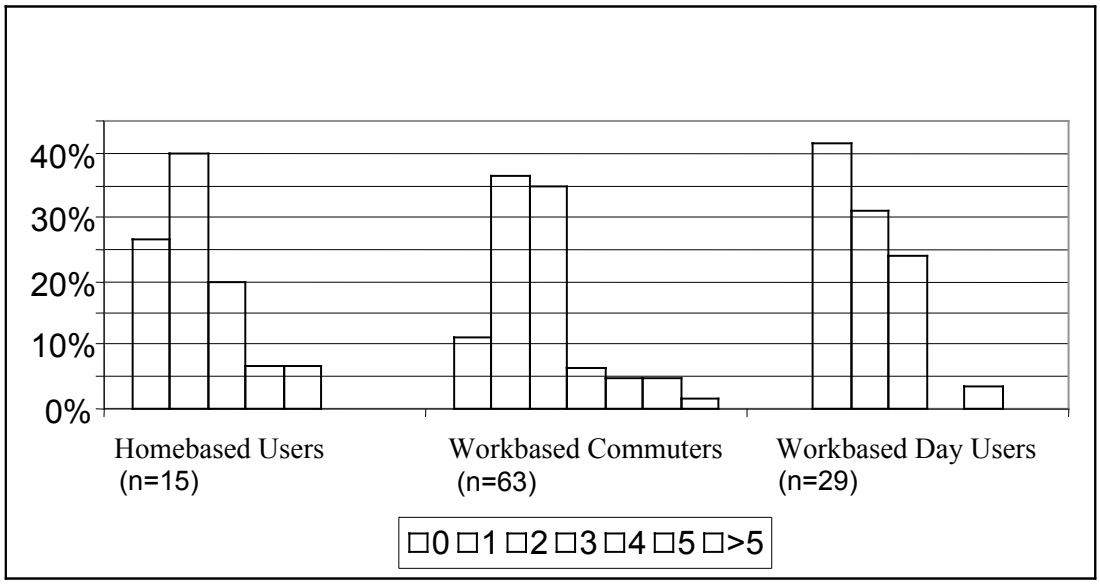


Figure 4, below, shows vehicles per household by CarLink II user groups. Participants who belonged to a household without access to a vehicle should be able to significantly improve their mobility. Over a quarter of Homebased Users and a tenth of Workbased Commuters had no vehicle in their household. One third of Homebased Users had household incomes of less than $50,000 (compared to 11 percent of Workbased Commuters). The lower relative incomes of Homebased members help explain their lower car ownership levels and their participation in CarLink II.

FIGURE 4: Distribution of Number of Vehicles per Household for CarLink II



Attitudinal Profiles

In this section, the results of the initial questionnaires are summarized to develop an attitudinal profile of early adopters. When possible, comparisons are made to CarLink I participants.

First, participants were asked to rate on a five-point scale how much they agreed or disagreed with ten statements describing attitudes about their current transportation mode. Each question reflected positive and negative modal attributes. A current transportation mode attitudinal scale score was created for each respondent. As a group, Homebased Users were neutral to their current mode. Workbased Commuter and Day User attitudes were slightly positive towards their current mode. Similarly, the CarLink I study found that 77 percent were satisfied with their current mode. These results suggest that CarLink participants did not join CarLink because of a general dissatisfaction with their current transportation mode.

Second, respondents were asked to rank a list of negative attributes for their current (pre-CarLink II) transportation mode. The top four choices for all participants are listed in Table 6, below. Participants' least favorite aspect, "Spend too much time in traffic," suggests that traffic congestion may be a predictor of CarLink II participation. CarLink I results also suggested that participants may be more sensitive to congestion than the general population. The second least favorite aspect, commute time (or "it takes too long to get places") was not improved through CarLink II participation—given the additional time required to mode shift (link to transit with CarLink). Average CarLink commute times were longer than non-CarLink I and II commutes. However, there is evidence that CarLink I and II travel times were higher quality and less stressful than non-CarLink travel times.

TABLE 6: Participants' Least Favorite Attributes of Transportation Modes before CarLink II (N-107)

Least Favorite	Spend too much time in traffic
Second Least Favorite	It takes too long to get places
Third Least Favorite	It is not flexible enough
Fourth Least Favorite	It is too expensive

Finally, a set of participant attitudinal (or psychographic) questions was included in the questionnaire. Attitudinal scales provide researchers with a means of characterizing participant response to a series of related questions. Responses to these questions were pooled to three measures, experimental, vehicle hassle, and environment. These attitudinal questions and scales were found to be significant (Cronbach's Alpha Score) in Shaheen's (17) analysis of a larger longitudinal carsharing survey (207 respondents).

- **Experimental** is how willing participants are to try new experiences;
- **Vehicle hassle** is how difficult and unpleasant participants find maintaining a private vehicle; and
- **Environment** is the degree to which participants believe that it is important to change behavior to help the environment.

The results allowed for the identification of potentially critical issues to successful recruitment and modal choice. Responses, which are evaluated on the five-point scales—ranging from "Strongly Agree" to "Strongly Disagree"—were assigned a point value (-2 to +2, with 0 being neutral) and averaged over several questions to calculate a respondent rating. The results of the psychographic questions are provided in Table 7, below.

TABLE 7: Psychographic Scale Scores from CarLink II and I

	EXPERIMENTAL	VEHICLE HASSLE	ENVIRONMENT
CARLINK II			
Homebased User (N=15)	0.94	-0.38	0.98
Workbased Commuter (N=63)	0.64	-0.40	1.03
Workbased Day User (N=29)	0.62	-0.50	1.01
Total Users (N=107)	0.68	-0.43	1.10
CARLINK I			
Total Users (N=44)	0.51	0.40	1.04

The results indicate that CarLink II participants exhibited a tendency to experiment (average score of 0.68). This tended to be most strongly true for Homebased Users, most likely, because of their lower vehicle ownership rates, lower household incomes, and somewhat younger ages. CarLink I participants indicated a similar comfort level with respect to experimentation.

All the CarLink II user groups tended to disagree that "vehicles are a hassle." The score was negative for each user group, and the total score was –0.43 (indicating that CarLink II participants did not perceive vehicles as a hassle). This result differs from the average 0.40 score obtained for vehicle hassle in CarLink I. These results indicate that CarLink II participants may have been motivated more by a desire to get out of traffic (as indicated by their least favorite aspect of their current transport mode) as opposed to a desire to reduce vehicle hassle.

Concern for the environment obtained the highest score (relative to the other attitudinal measures). The average score for CarLink II was 1.04, and the average score for CarLink I was 1.35. These results indicate that reducing automobile effects on the environment may have been an important motivating factor for joining CarLink.

The next section focuses on CarLink II travel impacts. Reference to CarLink I data are made when possible.

CARLINK II TRAVEL EFFECTS

An important difference between CarLink and neighborhood carsharing programs is CarLink's emphasis on the transit commute or linkage. The CarLink model is designed specifically to provide door-to-door connectivity for participants commuting to work via transit. To capture changes in travel due to CarLink, survey methods recorded participants' travel before-and-after joining CarLink. A number of evaluation criteria are analyzed, including mode choice, VMT, travel time, travel stress, household vehicle fleet size, and parking.

Commute Travel

Prior to joining CarLink II, participants used a variety of modes to get to work (see Table 8). Many members already took more than one mode to commute (e.g., anyone using Caltrain would use one or more additional modes to travel to the station from home and work), so the total percentages of mode use sum to over 100 percent. Over a third of participants (39.6 percent) used Caltrain as part of their normal commute prior to joining CarLink II, including over half of Homebased Users (56.3 percent). High pre-CarLink Caltrain use is not surprising because much of the recruitment occurred at Caltrain facilities or at businesses with good Caltrain access. However, enough participants were new to Caltrain to show sizable changes in mode choice. This was particularly evident in solo driving, which was reduced by 22.9 percentage points on average for all members. Similarly, promising modal shifts were obtained for CarLink I (a 23.2 percentage point increase in BART use and a 43.5 percentage point reduction in drive alone for the commute travel). CarLink II shows a slight reduction in carpooling. In CarLink I, carpooling increased by 4.6 percentage points, but this is likely because of carpooling requirements built into the program.

TABLE 8: Before-and-After Commute Mode Shares for CarLink II Participants

MODES	BEFORE			AFTER			PERCENTAGE POINT CHANGE		
	HB[a] (N=15)	WB[b] (N=92)	All (N=107)	HB (N=8)	WB (N=51)	All (N=59)	HB	WB	All
Drive Alone	37.5%	64.1%	60.2%	12.5%	41.2%	37.3%	-25.0%	-22.9%	-22.9%
Carpool	12.5%	10.9%	11.1%	0.0%	11.8%	10.2%	-12.5%	0.9%	-0.9%
Bus/Shuttle	25.1%	22.8%	23.2%	37.5%	13.7%	15.3%	12.4%	-9.1%	-7.9%
Caltrain	56.3%	35.9%	39.6%	100.0%	56.9%	62.7%	43.7%	21.0%	23.1%
Bike	12.5%	5.4%	6.5%	0.0%	3.9%	3.4%	-12.5%	-1.5%	-3.1%
Walk	43.8%	22.8%	25.9%	50.0%	52.9%	52.5%	6.2%	30.1%	26.6%
Other	6.3%	2.2%	3.7%	12.5%	11.8%	11.9%	6.2%	9.6%	8.2%
CarLink	0.0%	0.0%	0.0%	100.0%	56.9%	62.7%	100.0%	56.9%	62.7%

[a] HB is Homebased User. [b] WB is Workbased Commuters and Day User.

Changes in commute VMT are shown in Table 9, below. VMT includes all miles traveled in a private automobile or in a CarLink II vehicle. Carpool trips were adjusted to avoid double counting. While on average VMT decreased as members converted from driving solo to taking the train, for some participants VMT rose. Based on interviews and focus groups, researchers learned that increased VMT occurred when a veteran Caltrain user, who had been walking, biking, or taking a shuttle, shifted to a CarLink vehicle to access home or the station. Since the majority of Homebased Users were previously Caltrain riders, this resulted in a slight net VMT increase of 1.2 miles per day per person for this user group. However, the Workbased group (both Workbased Commuters and Day Users) reported a significant decrease of 27.2 VMT per day per person. This reduction in VMT occurred even though some CarLink II employer subscribers had previously operated a shuttle service, and one was within walking distance of the station (less than one mile). In interviews, participants stated that the hassle of getting from the station to the worksite (especially via the shuttles) was often high enough that they used their personal vehicles more than they would have liked. Similarly, the CarLink I study found that the average reduction in daily commute travel was 18.5 miles as a result of CarLink I participation.

TABLE 9: Before and After Average Daily Round Trip Commute VMT and Travel Time (Minutes) for CarLink II Participants

	BEFORE	AFTER	CHANGE
VMT	(N=107)	(N=64)	
Homebased Users	10.4	11.6	1.2
Workbased Commuter & Day User	34.4	7.2	-27.2
Total	30.8	7.8	-23
Travel Time (Minutes)	(N=107)	(N=64)	
Homebased Users	71.8	108.3	36.5
Workbased Commuter & Day User	90.2	120.8	30.6
Total	87.4	118.9	31.5

Time is another important factor for commuters. Table 9, above, shows that after participants joined CarLink II, their average round trip-commute time increased by over one-half hour. Since most pre-CarLink II commutes did not involve Caltrain, researchers anticipated increased travel times. Time spent waiting for trains tends to increase commute times, regardless of transit mode efficiency. Although commute travel times increased overall, commute stress generally decreased, as indicated in Table 10 (below). However, some members mentioned some difficulty in arranging their schedules with other carpool members in the final CarLink II interviews and focus groups. Similarly, in CarLink I, the results of focus groups and in-person interviews with participants indicated that average commute travel times increased, but average commute stress was reduced. CarLink I Workbased Users stated that relaxing during their BART commute was a significant program benefit. Because most Homebased Users commuted via BART prior to CarLink I, they did not generally experience stress reduction.

TABLE 10: The Effect of CarLink II Participation on Commute Stress

	HOMEBASED USERS (N=9)	WORKBASED USERS [a] (N=55)	ALL (N=64)
Greatly increased	0.0%	1.8%	1.6%
Increased	12.5%	7.1%	7.8%
No change	25.0%	44.6%	42.2%
Decreased	62.5%	39.3%	42.2%
Greatly decreased	0.0%	7.1%	6.3%

[a] Workbased includes both Workbased Commuters and Day Users

All Travel

This section explores the effect of CarLink II on participant and household travel behavior beyond commute travel. For example, it is possible that exposure to transit in CarLink II may have encouraged its greater use for non-commute travel. In addition, the availability of an extra car in a participant household may have increased auto use.

The issue of total auto and transit use was explored by asking participants to assess how their personal and household travel behavior changed after joining CarLink II. The results are presented in Table 11, below. Over half of the participants stated that their drive alone travel decreased or greatly decreased, most likely because of increased commuting by Caltrain. Not surprisingly, one quarter of the Homebased Users indicated that their drive alone travel greatly increased, most likely because of increased access to the CarLink vehicles on evenings and weekends. At the household level, 6.3 percent of all participants indicated that vehicle use increased, 64.6 percent stated that it remained the same, and 27.1 percent said that it increased. Total participant transit use tended to increase (47.6 percent) or stay the same (42.6 percent). Most of the participants indicated that their transit use for non-commute trips did not change (71.2 percent), while 15.3 percent indicated that it increased and 13.6 percent indicated that it decreased.

TABLE 11: Change in CarLink II Non-Commute Mode Share

	DRIVE ALONE			TOTAL TRANSIT			NON-COMMUTE TRANSIT			TOTAL HOUSEHOLD VEHICLE USE		
	HB (N=8)	WB[a] (N=48)	All (N=56)	HB (N=8)	WB (N=53)	All (N=61)	HB (N=8)	WB (N=51)	All (N=59)	HB (N=6)	WB (N=42)	All (N=48)
Greatly Increased	25.0%	2.1%	5.4%	25.0%	9.4%	11.5%	12.5%	0.0%	1.7%	0.0%	0.0%	0.0%
Increased	12.5%	2.1%	3.6%	25.0%	37.7%	36.1%	12.5%	13.7%	13.6%	16.7%	4.8%	6.3%
Stayed the Same	25.0%	39.6%	37.5%	25.0%	45.3%	42.6%	37.5%	76.5%	71.2%	33.3%	69.0%	64.6%
Decreased	25.0%	50.0%	46.4%	12.5%	7.5%	8.2%	37.5%	9.8%	13.6%	33.3%	26.2%	27.1%
Greatly Decreased	12.5%	6.3%	7.1%	12.5%	0.0%	1.6%	0.0%	0.0%	0.0%	16.7%	0.0%	2.1%

[a] Workbased includes both Workbased Commuters and Day Users

Like CarLink II, the auto mode share was also reduced in CarLink I. However, in CarLink I, daily bus mode share decreased and walk/bike mode share increased (See Table 12 below).

TABLE 12: Percentage Point Change in CarLink I Mode Share for All Trip Purposes by User Group

MODE	HOMEBASED USER (N=6)	WORKBASED COMMUTER (N=13)	DAY USER (N=11)
Household Vehicle	-53.7	-49.7	N/A
Carpool	-3.9	+17.2	+4.6
Bus	-8.3	-25.8	-5.4
Bike	-14.3	+1.7	+10.8
Walk	-16.3	+12.7	+5.6
Recreational Public Transit	-24.0	+21.8	N/A
Drive Alone	-13.2	-25.6	-6.5

Note: Questions about "Recreational Public Transit" and "Drive Alone" modes were asked separately. Thus, "Recreational Public Transit" is a subset of "Bus" and, "Drive Alone" is a subset of "Household Vehicle" use.

In sum, these results suggest that the CarLink II program had a positive overall effect on participant transit use including non-commute travel and tended to reduce drive alone and vehicle travel by both the participants and their households.

Household Fleet Size

After joining a commuter carsharing program with direct transit linkages, participants may rely less upon their personal vehicles and thus might reduce their household fleet, lowering household costs and perhaps discouraging unnecessary trips. The final CarLink II questionnaire asked participants about the status of their personal vehicles after joining CarLink. As shown in Table 13 (below), over half (52.2 percent) of the respondents reported no change in personal vehicle use after they joined CarLink. Eleven percent of Homebased Users and five percent of Workbased Users (Workbased Commuters and Day Users) sold a personal vehicle or put it in storage. No one purchased a personal vehicle. Although 51.6 percent said they would buy a car in the next year in the initial questionnaire (i.e., at the time they joined CarLink II), only 27.5 percent said so in the final questionnaire. The significant reduction in expected new car purchases may be a result of CarLink II or economic downturn during this period.

In the final CarLink II questionnaire, 44.4 percent of Homebased Users and 11.7 percent of Workbased Users (Workbased Commuters and Day Users) reported that postponing or avoiding the purchase of a car was one of three top CarLink strengths (benefits). These findings may have no direct environmental or VMT benefits, since households may keep their cars longer, but it may represent a significant cost savings, as CarLink allows members to postpone or eliminate such a large purchase.

TABLE 13: Use of Personal Vehicle(s) After Joining CarLink II

	HB (N=9)	WB (N=55)	All (N=64)
No change in use of personal vehicles in my household	22.2%	56.7%	52.2%
Family member drives a car more frequently (e.g., "loaned" to a child)	11.1%	6.7%	7.3%
I/We have loaned a vehicle to someone outside our immediate family	0.0%	3.3%	2.9%
I/We have sold or stored one or more of our personal vehicles	11.1%	5.0%	5.8%
I/We have purchased or leased a personal vehicle	0.0%	0.0%	0.0%
I/We did not have a vehicle when I joined CarLink	44.4%	8.3%	13.0%
Other	11.1%	15.0%	14.5%
No response	0.0%	5.0%	4.4%

Carpooling and Parking

In addition to shifting members from single occupancy vehicle travel to transit, carsharing may encourage members to carpool (part of the CarLink I and II design). Carpooling uses vehicles more intensively and thus reduces program costs. Carpooling also helps reduce external costs, such as cold start emissions and parking space use.

Parking use is particularly important to many transit agencies, as each parking space generally has a direct cost (e.g., the space itself, construction, signage, and maintenance), as well as an opportunity cost (e.g., if a potential train rider cannot find a parking space, they often drive all the way to work).

For businesses seeking to maximize their existing parking spaces, CarLink carpooling can reduce the demand for on-site parking, decreasing costs and employee frustration (if parking space is limited). For some CarLink II employer subscribers, encouraging CarLink carpooling to reduce parking demand was a stated goal. CarLink management did not require members to carpool, leaving this decision to the businesses. The overall average number of Workbased Commuters in a CarLink II vehicle, including drivers, during commutes between the train station and the work sites was 1.48 in both mornings and evenings. During the final CarLink II interviews and focus groups, researchers learned that the composition of individual carpools (i.e., specific persons in each car) varied between morning and evening. Overall the parking benefit to employers resulted in approximately one parking space serving two CarLink II vehicles on average. The impact on individual businesses varied. At some businesses, carpooling was not a goal. Thus, CarLink II may not have reduced parking demand. However, in focus groups with employees of businesses with more restricted parking, respondents said that they tended to carpool everyday, meaning each CarLink II vehicle freed up at least one space.

CONCLUSION

CarLink is a commuter carsharing model with an explicit transit and employer connection. The three CarLink user groups, Homebased Commuters, Workbased Commuters, and Day Users, each gain access to a car on an as needed basis, without the costs and hassles of ownership. The CarLink I field test and CarLink pilot program were designed to gain a stronger understanding of the long-term sustainability, technological needs, and user impacts of this model. In this paper, the authors focus on the demographic and attitudinal characteristics of CarLink users, as well as travel effects.

A typical CarLink II member was similar to the average San Francisco Bay Area resident with respect to gender and household vehicle occupancy distribution. On the other hand, CarLink I and II participants were more likely to be highly educated, in a higher income bracket, professionally employed, and younger than the average Bay Area resident. This may be a function of the location of the project (Silicon Valley) and the types of companies that joined as members (high tech firms). The demographic profile of commuter carsharing participants in other locations may be different than those in

CarLink I and II. For example, age and gender distribution varied between the CarLink I and II field tests. However, demographic attributes tended to vary in similar ways from the Bay Area average with respect to education, income, and employment for both CarLink I and II. Studies of neighborhood carsharing in Portland and San Francisco have also found that members tended to be highly educated and professionally employed (5,6).

Participants in CarLink I and II were also apt to share similar attitudes. CarLink I and II members indicated sensitivity to congestion levels, willingness to experiment, and concern for the environment. On the other hand, CarLink II members did not typically view vehicle maintenance as a "hassle," while CarLink I members did.

The CarLink projects employed a number of systematic methods (i.e., questionnaires, travel diaries, and automatic vehicle data) to record participants' travel before and after joining CarLink. The survey analyses indicate that CarLink I and II produced a significant reduction in participant auto travel, which was measured against three key criteria: modal choice, VMT, and household vehicle ownership.

The CarLink II mode choice results indicated a significant shift from single occupancy vehicle travel to transit for participants. This was particularly true with respect to commute drive-alone trips, which were reduced between 25.0 to 23.9 percentage points across user groups, even though many participants still used personal vehicles to access transit on their non-CarLink terminus. Somewhat lower reductions in commute drive-alone trips (ranging from 6.5 to 26.6 percentage points across user groups) were found in CarLink I. In contrast, results of neighborhood carsharing studies indicate small but conflicting results with respect to modal shifts. The CarSharing Portland study (5) showed a small shift from auto mode to transit, walking, and cycling modes, while the City CarShare study (6) indicated a small decline in transit, walking, and cycling. In CarLink I and II, transit use for the commute trip increased by 23.2 and 23.1 percentage points, respectively.

The VMT results for CarLink II show that roundtrip commutes were reduced by an average of 23 vehicle miles per day (while increasing travel times by 15 minutes each way), as members shifted to Caltrain. VMT reductions were also obtained for CarLink I (18.5 miles per day) (12) and for a station-car program in San Francisco (42 percent) (11). In CarLink I and II, reductions in commute VMT were not offset by increases in non-commute travel. For example, over 50 percent of CarLink II members stated that single-occupancy vehicle use decreased or greatly decreased, while almost half saw transit use increase. Across their entire households, nearly 30 percent of member households saw an overall decrease in vehicle use. It appears that the CarLink model encourages members to plan trips more carefully. During interviews, participants said that CarLink led to more trip-chaining during their commutes and the elimination of some unnecessary trips.

Reductions in VMT for CarLink I and II are comparable to the low end of the VMT reductions found in European neighborhood carsharing studies, which ranged from 30 to 70 percent (7, 8, 9, 10). It is important to note, however, that auto travel reductions in the

CarLink studies may be somewhat underestimated because the programs included many members who had previously used Caltrain and therefore had little to risk by joining CarLink. A commuter carsharing program with a longer operating history would likely be able to recruit more risk-averse users by emphasizing stress reductions due to less traffic; this could lead to greater reductions in vehicle trips and VMT.

The vehicle ownership results for CarLink II indicate that a relatively modest number of members (5.8 percent) sold or stored their vehicle after joining the program. Some CarLink I members also indicated that they sold a vehicle after joining CarLink. The Portland and San Francisco neighborhood carsharing studies (4, 5 ,6) suggest that between 12 to 30 percent of members sold a vehicle after joining the organization. In Europe, neighborhood carsharing studies indicate that 10 to 60 percent of members sold a vehicle after joining a service.

Early U.S. results indicate that neighborhood carsharing in urban environments tend to increase auto travel among members without access to vehicles and reduce auto travel among those who owned or leased a vehicle prior to joining the organization. CarLink results (from two suburban programs) show reductions in auto ownership levels that are at least half of those found in the neighborhood carsharing organizations in Portland and San Francisco. These results suggest that the higher quality transit and pedestrian environment of the urban location of the neighborhood carsharing services facilitates auto ownership reductions. However, travel reductions (i.e., reductions in drive alone mode choice and VMT) obtained from the CarLink and station car approaches are significantly larger than those obtained from early U.S. neighborhood carsharing data. These auto ownership and modal choice results suggest that changes in auto ownership may be the key variable causing auto travel reduction in neighborhood carsharing, while the strong transit link may be the critical variable driving auto travel reduction in the CarLink model. It is unclear, however, whether the market niche for the suburban commuter carsharing model could be as extensive as neighborhood carsharing. Thus, total system-wide travel effects are unclear and require future research.

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