City CarShare

Longer-Term Travel Demand and Car Ownership Impacts

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Four years after the introduction of City CarShare in the San Francisco, Bay area in California, 29% of carshare members had gotten rid of one or more cars, and 4.8% of members' trips and 5.4% of their vehicle miles traveled were in carshare vehicles. Matched-pair comparisons with a statistical control group suggest that, over time, members have reduced total vehicular travel. However, most declines occurred during the first 1 to 2 years of the program; 3 to 4 years after City CarShare's inauguration, earlier declines had leveled off. Because many carshare vehicles are small and fuel-efficient but can carry several people, the trend in per capita gasoline consumption also is downward. Mindful of the cumulative costs of driving, carshare members appear to have become more judicious and selective when deciding whether to drive, take public transit, walk, bike, or even forgo a trip. Coupled with reduced personal car ownership, these factors have given rise to a resourceful form of automobility in the San Francisco Bay area.

Previous studies of the impacts of the pioneering City CarShare program in San Francisco, California, suggested that carsharing had stimulated motorized travel in its first year (*1*); however, 2 years into the program, these impacts had been tempered (*2*). In part because some City CarShare members had reduced car ownership levels, net vehicle miles traveled (VMT) were reduced by the program's second anniversary (*2*).

This paper examines the longer-term impacts of the City CarShare program on travel demand and car ownership; it complements earlier studies that focused on short- and intermediate-term impacts (*1, 2*). Particular attention is given to the question of whether the travel-reduction evidence uncovered 2 years into the program had been sustained or gained momentum at 4 years after the program's inception, or perhaps had been short-lived and reversed course. As in the earlier studies, a matched-pair comparison of travel patterns between members and a statistical control group of nonmembers is used. Factors that explain carshare members' travel choices and car-shedding behavior also are modeled. Details on the research method as well as short- and intermediate-term impacts were published in earlier reports (*3–5*) and in-depth discussions of the longer-term findings in a more recent report (*6*).

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TRENDS AND USAGE

City CarShare was launched in the city of San Francisco in early March 2001. The program gained steady popularity during its first 4 years; the monthly number of reservations increased from less than a thousand during the first year to much more than 5,000 by mid-2005 (Figure 1). [Note: In this paper, a reservation is counted as a formal lease of unlimited duration by a City CarShare member, marked by a member picking up and returning a car to a point-of-departure (POD) car pick-up location. The reader should keep in mind that multiple trips can be and usually are made as part of one reservation.] The number of monthly reservation hours increased from 5,000 in 2001 to more than 20,000 in 2005. CarShare vehicles logged 106,000 miles in May 2005—double the mileage of 3 years earlier. The number of PODs grew from 6 in the second month of the program to 43 by mid-2005, and the number of vehicles available to be reserved increased from 12 to 87 over the same period. Part of the growth is explained by program expansion into the East Bay (i.e., cities of Berkeley and Oakland, California) in 2003.

The recent trend in active City CarShare membership has been upward as well, from more than 1,800 in September 2002 to 3,800 in May 2005. By mid-2005, the typical City CarShare reservation duration was 3 h and 45 min, and the average distance driven during the reservation period was 20 mi.

CITY CARSHARE TRAVEL CHARACTERISTICS

To augment City CarShare's reservation logs, a survey was conducted of usage among 79 vehicles (62 in San Francisco and 17 in the East Bay) that were located in 40 PODs (26 in San Francisco and 14 in the East Bay) in March 2005, 4 years after the City CarShare inauguration. It was the second in-vehicle survey conducted of City CarShare usage; the first had been conducted in autumn 2002 (*2, 5*). All members leasing vehicles during the 20-day survey period were asked to fill out a self-administered 1-page clipboard survey about their carshare usage on returning cars to PODs. In all, 619 responses were received. The findings of these in-vehicle survey are discussed in this section, compared with the 2002 survey results as appropriate.

User Profiles

Four years into the City CarShare program, surveyed users were evenly split between male and female, with a mean age of 39.6 years. The racial or ethnic distribution was 77.1% white, 6.5% Asian, 4.5% African American, 4.2% Latino, and 7.7% Other. Median household income was $50,000, similar to the regional average from the 2000 census. Around one-third of surveyed users lived alone, and more

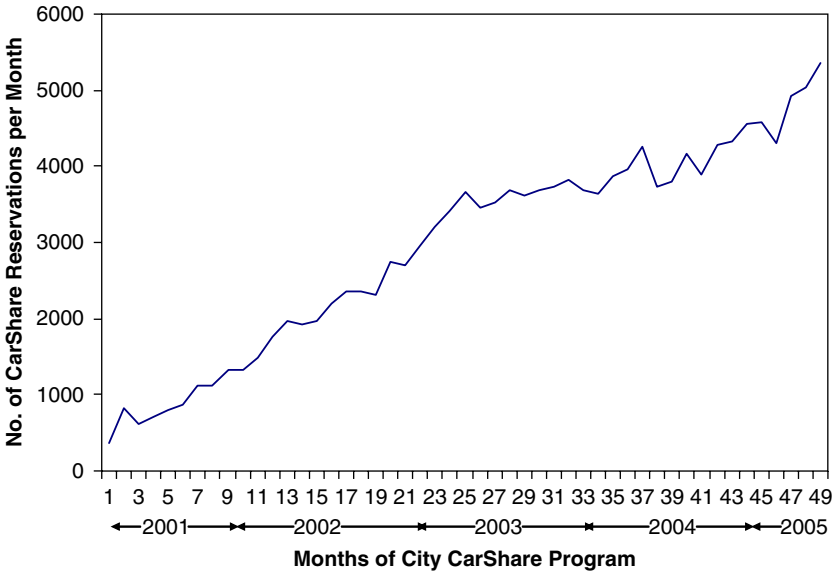

FIGURE 1 Trends in San Francisco City CarShare reservations, April 2001 to May 2005.

than three-quarters were from carless households. Carsharing in the Bay Area appeared to serve a fairly distinct and unique market: moderate-income, nontraditional households without cars.

According to address information from survey respondents, most members resided in the densest parts of San Francisco, where parking is constrained and expensive. Most members lived within 0.5 mile of a POD (Figure 2); at a 3-mph walking speed, such members were within a 10-min walk of a City CarShare vehicle.

Trip Patterns and Purposes

The spatial distribution of City CarShare trips is mapped in Figure 3. Many trips were lateral and cross-jurisdictional in nature, taken to points outside of San Francisco, Oakland, and Berkeley and along corridors not well served by public transit.

More than half of City CarShare reservations were to multiple destinations; three-leg circuits made up 27% of reservations. The

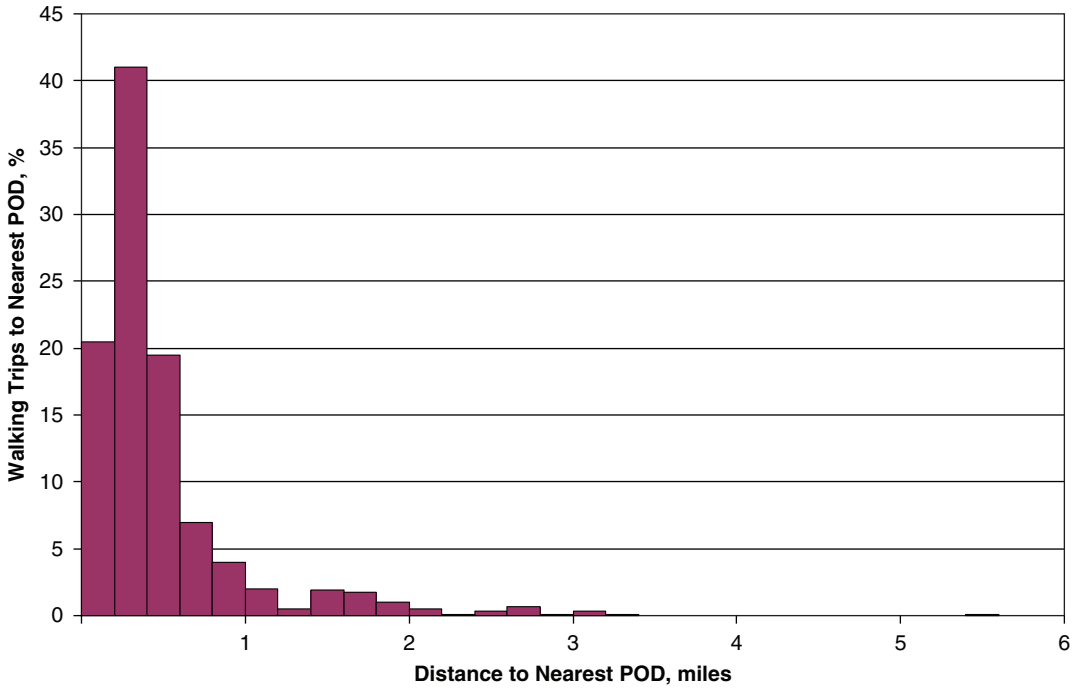

FIGURE 2 Distribution of walking distances to nearest POD from members' residences, 2005.

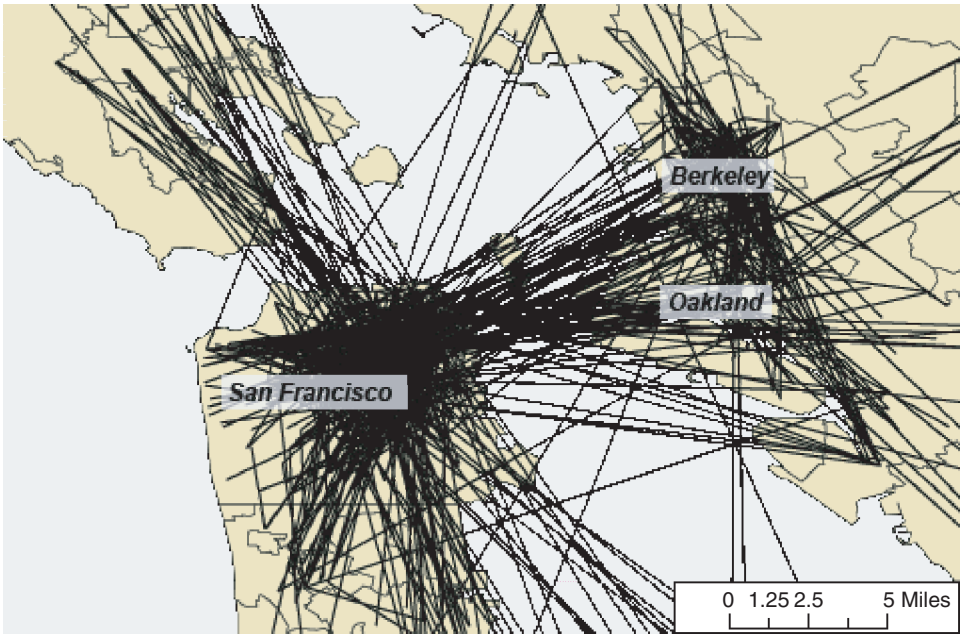

FIGURE 3 Desire line map of surveyed CarShare trips, 2005 in-vehicle survey.

share of reservations from a POD to a destination and back (i.e., two trip legs, or an unlinked trip) was 41%.

The distribution of trip purposes among City CarShare users was similar in 2005 (4 years into the program) and 2002 (1.5 years into the program). Figure 4 illustrates that in both years, around 3 out of 10 reservations were mainly for shopping. Next in frequency was social or recreational travel, followed by personal business. Journeys to work constituted only around 1 out of 10 carshare reservations. Carsharing for social or recreational excursions tended to be of the longest duration (on average, 4 h and 41 min), whereas the average duration for all trip purposes was 3 h and 56 min. City CarShare vehicles used for shopping were returned, on average, within 3 h and 25 min, the shortest usage of all trip purposes—as was the case in 2002.

Trip Occupancies and Modes

That the average vehicle occupancy for CarShare trips reported by users surveyed in March 2005 was 1.44 people (including the driver), less than the 1.59 value in 2002. Around two-thirds of carshare trips were driven alone. The highest occupancies were for trips to school (nearly 2 people); in contrast, the least discretionary trips (i.e., personal purposes, medical care, and work) were made mainly by solo drivers.

City CarShare users were asked what modes they would have otherwise used had carshare vehicles not been available for the particular trips being surveyed. Results indicate that 3 out of 10 trips likely would not have been made, but 28.6% would have been by

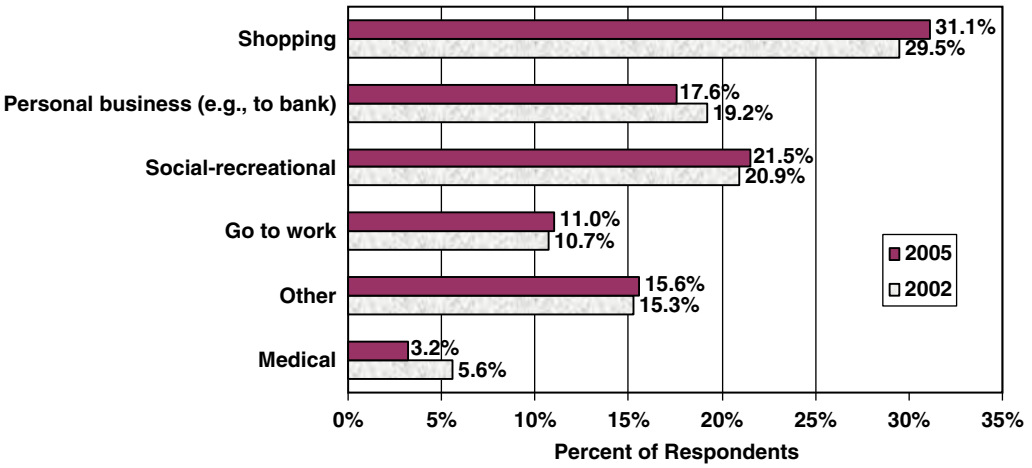

FIGURE 4 Distribution of trip purposes using City CarShare vehicles, March 2005 and September–October 2002, in-vehicle survey.

transit, higher than any other modal option. Only 11% of trips would otherwise have been by private car (as a driver or a passenger), comparable to the share that would have been nonmotorized (i.e., by foot or bike). Stratification by trip purpose indicates that nearly 40% of shopping trips would not have been made if carsharing had not been available. For personal business, school, medical, and work trips, carsharing mainly substitutes for transit.

City CarShare users also were asked how they reached PODs: 77.8% walked, 13.8% took public transit, 5.6% biked, 1.6% drove alone (including using a motorcycle), and 1.2% got a ride. The respectable shares of transit and bicycle access trips suggest that policy strategies such as integrated transit–carshare pricing (as practiced in Switzerland) and putting bicycle racks in or near PODs might induce carsharing.

Car Preference

Four years into the City CarShare program, various vehicles were available to members, including compacts, sedans, and minivans. This variety contrasts with the early years, when only Volkswagen Beetles were available. Surveyed users were asked why they selected particular vehicles. Half of the respondents were indifferent to the vehicle type, 26.5% took the only car available, 18.7% said they needed the particular car they reserved, and 5.6% wanted a different car that was unavailable. No associations were found between the desire for a particular type of car and factors such as the age, gender, income, or household type of the carshare member.

CARSHARE MEMBER CHARACTERISTICS

The remainder of this paper draws on the results of the fifth of a series of surveys conducted of City CarShare members and a statistical control group. Besides compiling personal, household, and background information about car ownership, the five surveys also solicited detailed travel-diary information for all trips (not only in carshare vehicles, as was the case with the in-vehicle survey). Complete travel-diary information enabled the impacts of the City CarShare program on travel behavior to be gauged.

The first set of background and travel-diary surveys was conducted several weeks before City CarShare's March 2001 inauguration (*3*). People who signed up to join the program immediately (members) and those hoping to someday become members (hereafter called nonmembers) were surveyed. (These nonmembers functioned as an ideal control group, because they displayed comparable levels of motivation—having taken the time to sign up for the program—but had not formally joined because of reasons such as the lack of PODs in their neighborhoods.) Similar surveys then were conducted of members and nonmembers 3 months, 9 months, and 2 years into the program (*3–5*). The fifth and latest travel-diary survey, conducted in May 2005, was a little more than 4 years after City CarShare's inception (*6*).

In all, 527 members and 45 nonmembers responded to the fifth survey (with response rates of 18.7% and 32.1%, respectively), with responses from not only San Francisco (399 respondents) but also elsewhere in the Bay Area (173 respondents). Survey mailbacks and financial incentives were used to increase response rates. A total of 2,475 individual trip records were obtained from members and 233 from nonmembers.

In this section, carshare usage and the socio-demographic attributes of members are discussed, then changes in car ownership levels and travel demand are compared among surveyed members and nonmembers.

Market Shares

By the end of City CarShare's fourth year, carsharing made up 4.8% of members' total trips. This percentage was up from 2.2% 3 months into the program but down from 8.1% at the 9-month mark and 6.5% in 2003, some 2 years into the program. Thus, although carshare activities surged in the early years of City CarShare, the novelty of carsharing might have worn off over time, with market shares dipping in recent years.

Adjusted for trip length, carsharing made up 5.4% of total VMT by members at the end of the fourth year—also up from the 3-month mark but considerably down from what was recorded 9 months and 2 years into the program. Still, the most popular form of conveyance by members—representing 47.6% of all trips in May 2005—was nonmotorized transport (i.e., walking or cycling). Rail transit comprised most of the mileage logged by City CarShare members in 2005 (33.5%), even more than the miles traversed in private cars.

Member Profiles

City CarShare's members in the first wave were fairly unrepresentative of the Bay Area's and even San Francisco's population, drawn from professionals who did not own cars and lived either alone or in nontraditional households. Although still unique in its composition, City CarShare's membership was slightly more representative of the city's population as a whole by the end of the second year. This pattern generally held 4 years after City CarShare's launching.

In May 2005, the mean age of City CarShare members was 39 years, 3 years older than the average for the city of San Francisco in 2000 (according to the census) and what was found among carshare users from the in-vehicle survey. Also, 54% of surveyed members were women, and 82.8% were white (considerably above the 49.6% and 48.8% shares for San Francisco and Alameda County, respectively, in 2000). The median annual personal income of members was $58,150 in 2005, above the census averages for San Francisco and the East Bay.

In terms of household types, City CarShare attracted a comparatively large share of individuals who lived with one or more unrelated adults—21% of members surveyed in May 2005 versus 17.4% of San Francisco, Oakland, and Berkeley households in 2000. Around 35% of members lived alone in 2005, similar to the citywide average. Overall, the members' mean household size was 1.93 compared with 2.3 for San Francisco as a whole (2.63 for the nine-county Bay Area at large).

Car Ownership Patterns and Trends

According to a prior survey, City CarShare members had begun to shed private cars by City CarShare's second anniversary. The convenience of having a fleet of vehicles available on demand appeared to prompt some carsharers to get rid of second cars, put off car purchases, or perhaps forgo car ownership altogether. Did this pattern hold 4 years after City CarShare's inauguration?

In May 2005, 62.8% of members were from zero-vehicle households and 28.7% were from one-vehicle households. Thus, 91.5% were from households that had zero to one vehicle—above the 83.3% share during the program's first year and 90.3% during the second as well as the average of 70.6% for all San Francisco households in 2000. The share of members residing in zero-car households increased by 21% between the 9-month and 4-year anniversaries of City CarShare. This increase was countered by drop-offs in the shares of members living in households with one or more cars.

The May 2005 survey asked members whether they had reduced, increased, or not changed the number of vehicles (including motorcycles, recreational vehicles, and trucks) in their households since joining City CarShare; nonmembers (i.e., the control group) were asked about vehicle ownership changes since January 2001. Although levels of car shedding were similar among members and nonmembers, members were less likely to increase car ownership (Table 1). Compared with the survey results from 2003, when members were asked whether they had gotten rid of private vehicles within the past 2 years, the degree of car shedding among members appeared to have leveled off. In 2003, 29.1% of surveyed members had gotten rid of one or more vehicles within the past 2 years—a higher share than found in the 2005 survey.

EVALUATION

This section addresses the central question of this research: Over the longer run, some 4 years following City CarShare's inception, has carsharing significantly affected travel behavior, and if so, in what direction? Has the sharing of cars in the Bay Area's densest and most populous urban centers reduced motorized travel (as was found 2 years into the program) or perhaps stimulated travel (as was found early on)?

All trips made by each surveyed person are included in the analyses that follow. (Each person was asked to complete a 24-h travel diary for 1 of 2 weekdays of their choosing; the 2 days were randomly selected over a 2-week survey period.) Changes in mean trip distance, travel time, VMT, and several additional indicators of travel consumption are examined below for the period between February 2001 (several weeks before City CarShare's inauguration, called Survey 1) and May 2005 (several months after the program's fourth anniversary, called Survey 5). This is a longer-term before-and-after analysis. A second set of analyses is presented for the intermediate- to longer-term period, from March 2003 (representing the program's second anniversary, called Survey 4) to May 2005 (Survey 5).

For the analyses carried out in this section, data for people living outside of San Francisco (i.e., mainly the East Bay) were omitted. This exclusion was necessary to make valid comparisons with earlier years, when PODs were limited to the city of San Francisco. Removing cases with non–San Francisco residences reduced the 2005 sample size by 30%; however, this loss in statistical power was necessary to ensure "apples-to-apples" comparisons.

The travel consumption statistics for the three survey periods are summarized for members in Table 2 and for nonmembers in Table 3. The statistical results are summarized in this section. For more details on these findings, see the full report by Cervero et al. (*6*).

Travel Distances and Times

Compared with Survey 1 (pre-carsharing) and Survey 4 (second anniversary), mean daily travel distances of City CarShare members decreased slightly by Survey 5 (fourth anniversary), as shown in Table 2. For nonmembers, they rose over the longer term but largely stabilized between 2003 and 2005 (Table 3). However, none of these changes were statistically significant.

Mean travel times decreased steadily for both groups over the three survey periods but more rapidly for nonmembers. Because average travel times decreased while distances increased, average travel speeds rose markedly among members, partly from the substitution of City CarShare trips for travel formerly made on foot or by bicycle. Clearly, carsharing has enhanced mobility, allowing members to conveniently reach more Bay Area destinations and to do so quickly. However, changes in travel times were not statistically significant at the 0.05 probability level for members or nonmembers.

Vehicle Miles Traveled

Did carsharing affect VMT? During City CarShare's first 2 years, average daily VMT decreased slightly for members yet increased for nonmembers. Although factors such as fuel prices (which increased) and rainfall (which was much lower during Survey 5 than Survey 1) might have affected VMT during the survey periods, these potential confounders affected both members and nonmembers equally, meaning that their influences are netted out in comparing trends.

By City CarShare's fourth anniversary, carshare members' VMT had decreased noticeably from earlier levels. VMT decreased for nonmembers relative to 2003 levels but was higher than in 2001. Most of the decline for members appeared to be attributable to mode shifts (e.g., higher shares of walk and bicycle travel) and a shortening of mean daily travel distances. Changes were not statistically significant for members or nonmembers.

However, adjusting for mode and occupancy levels for car trips did yield statistically significant results, more so than any of the travel consumption metrics (defined in the Table 2 footnote). As listed

TABLE 1 Changes in Household Motor Vehicle Ownership: Members and Nonmembers

Change in Motor Vehicle Ownership	Members (A) (%)	Nonmembers (B) (%)	Difference Between Members and Nonmembers (A – B) (%)
Reduced by two and more	2.0	8.9	–6.9
Reduced by one	22.2	15.6	6.6
Did not change	58.4	43.2	15.2
Increased by one	15.8	28.9	–13.1
Increased by two and more	1.6	4.4	–2.8
Total	100.0	100.0	

TABLE 2 Trends in Daily Travel, Members: Surveys 1, 4, and 5

	Cross-Sectional Survey Results					
	Survey 1 (February 2001)		Survey 4 (March 2003)		Survey 5 (May 2005)	
Performance Measure	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Travel distance	15.7	21.2	15.7	17.7	14.6	12.8
Travel time	114.4	120.6	108.3	77.5	96.4	50.7
VMT (vehicle miles traveled)	4.50	11.32	4.40	13.31	3.02	5.68
MVMT (mode-adjusted VMT)	2.80	7.28	1.49	4.86	.93	1.40
Gasoline consumption	0.074	0.231	0.047	0.167	0.03	.116

	Long-Term Before-and-After Analysis		Intermediate to Longer-Term Analysis	
	Diff. of Means (S5 – S1)	*t*-Statistic (2-tailed *p*-value)	Diff. of Means (S5 – S4)	*t*-Statistic (2-tailed *p*-value)
Travel distance	−1.1	−0.393 (0.69)	−1.1	−0.736 (0.462)
Travel time	−18.0	−1.218 (0.224)	−11.9	−1.899 (0.058)
VMT	−1.48	−1.031 (0.303)	−1.38	−1.504 (0.133)
MVMT	−1.87	−2.323 (0.021)	−0.56	−1.899 (0.058)
Gasoline consumption	−0.044	−1.501 (0.134)	−0.017	−1.241 (0.21)

Travel distance = total daily highway network travel distance, in miles; travel time = total daily highway-network travel duration, in minutes; VMT = vehicle miles traveled over highway network [representing total miles logged in motorized vehicles; all nonvehicle (i.e., walk and bicycle) trips were assigned zero values]; MVMT = mode-adjusted VMT (representing total miles logged in motorized vehicles adjusted for occupancy levels and accounting for whether new vehicle trips are added; values for walking, bicycle, and transit are zero since none of these trips add vehicles to city streets); gasoline consumption = estimated gallons of gasoline consumption per day adjusted for occupancy level and fuel economy of vehicles used for each trip; equals [MVMT/miles per gallon (mpg)] wherein mpg was estimated for city highway conditions given the make, year, and model of vehicle used for a trip; S1 = Survey 1 (February 2001—2 weeks prior to City CarShare); S4 = Survey 4 (March 2003—end of City CarShare's second year of operation); and S5 = Survey 5 (May 2005—2 months into the fourth year of operation).

TABLE 3 Trends in Daily Travel, Nonmembers: Surveys 1, 4, and 5

	Cross-Sectional Survey Results					
	Survey 1 (February 2001)		Survey 4 (March 2003)		Survey 5 (May 2005)	
Performance Measure	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Travel distance	19.2	19.6	23.2	28.4	22.6	30.4
Travel time	149.9	206.0	125.1	93.0	98.7	74.7
VMT	6.73	15.49	13.10	28.30	9.51	26.44
MVMT	5.45	13.14	9.42	20.85	6.7	18.88
Gasoline consumption	0.212	0.596	0.464	1.290	0.310	0.712

	Long-Term Before-and-After Analysis		Intermediate to Longer-Term Analysis	
	Diff. of Means (S5 – S1)	*t*-Statistic (2-tailed *p*-value)	Diff. of Means (S5 – S4)	*t*-Statistic (2-tailed *p*-value)
Travel distance	−3.4	0.483 (0.630)	−0.6	0.067 (0.947)
Travel time	−51.2	−1.544 (0.125)	−26.4	−1.044 (0.299)
VMT	2.78	0.466 (0.642)	−3.59	−0.431 (0.668)
MVMT	1.28	0.287 (0.775)	−2.69	−0.446 (0.657)
Gasoline consumption	0.098	0.549 (0.584)	−0.154	−0.520 (0.604)

in Table 2, members' mean mode-adjusted VMT (MVMT) decreased by 67% over the longer term (2001 to 2005) and by 38% over the intermediate term (2003 to 2005). These drops are dramatic and statistically significant at the 5% probability level for the longer term and nearly the 5% level for the intermediate- to longer-term period. Such declines were attributable to a combination of not only shifts to green modes and shorter travel but also relatively high occupancy levels for private car trips, including those in City CarShare vehicles. The mean MVMT for nonmembers rose in the first 2 years but has fallen some since 2003, as for members, although these relationships were not statistically significant (Table 3).

The MVMT declines of members 4 years into the program are more substantial than those found for the period between 2001 and 2003, suggesting that carshare membership instills a resourcefulness in travel habits, whether in the form of multiple-occupant carshare travel or taking transit, walking, or cycling when not driving carshare vehicles. This finding supports one of the original hypotheses of this research: that over the long haul, carsharing promotes judiciousness in travel behavior, tied to participants becoming more mindful of the marginal costs of driving a car.

Fuel Consumption Metric

Even though numerous San Franciscans began driving in lieu of traveling by transit, foot, or bicycle on joining City CarShare, members' average daily fuel consumption decreased steadily during the program's first 4 years. This decrease likely reflected a combination of reducing members' private car ownership, switching to more fuel-efficient City CarShare vehicles, and carrying passengers for many carshare trips (thus increasing average occupancy levels relative to private car trips). Although the changes were not statistically significant, the relatively low *P* values for both evaluation periods were not inconsequential.

By comparison, mean fuel consumption rose among nonmembers during the first 2 survey periods and decreased between 2003 and 2005. Such declines might have been attributable to spikes in gasoline prices between 2003 and 2005; however, because this is a matched-pair study, such factors are controlled for (presumably, rising gasoline prices affected both members and nonmembers similarly over the evaluation period).

Net Impacts

Before-and-after comparisons over the first 4 years of the City CarShare program reveal marked declines in travel consumption among members compared with nonmembers. However, most of these declines accrued during the first several years of the program, and levels of travel suppression seem to have stabilized or perhaps slightly reversed over the intermediate to longer term. In other words, VMT declines between 2001 and 2003 that might have been attributable to carsharing did not hold over to the period between 2003 and 2005.

This inference of stabilized or slightly reversed impacts during the intermediate- to longer-term period is drawn from Table 4, which lists the results for the difference of difference of means (i.e., the degree to which changes in travel over two time points differed among members and nonmembers). For example, even though mean daily VMT (in unadjusted and mode-adjusted terms) among members decreased between 2003 and 2005, it decreased even more for nonmembers (reflected by the positive difference of difference of means values for VMT and MVMT under intermediate to longer-term analysis). Average daily VMT did decrease more for members over the longer-term (2001 to 2005); however, as noted earlier, reductions occurred mainly during the first 2 years. Because of large within-group variations, none of the changes in the difference of difference were statistically significant.

Although absolute differentials listed in Table 4 are not particularly large, they were more substantial in relative terms (Figure 5). For example, the longer-term percentage point differential for MVMT was –90.3—a product of a mean 66.8% decline for members and a 23.5% increase for nonmembers over the period between 2001 and 2005. In relative terms, the biggest longer-term environmental benefits of carsharing in the San Francisco Bay Area came from reduced gasoline consumption, followed by reduced VMT and reduced travel distances.

PREDICTIVE MODELS

This section presents the results of predictive models that shed additional light on City CarShare's longer-term impacts. All models are based on results of the fifth (2005) survey.

Changes in Car Ownership Model

What factors influenced changes in car ownership? Carsharing members were asked to list the cars that they had acquired and gotten rid of since joining City CarShare. Their responses were analyzed by estimating an ordinal logit model that predicted five rank-ordered outcomes: net reduction of two or more cars, net reduction of one car, no change, net increase of one car, or net increase of two or more cars. The resulting model has a reasonably good statistical fit (Table 5).

TABLE 4 Difference of Difference of Means: Changes of Members Minus Changes of Nonmembers, Weekday/Workday

	Long-Term Before-and-After Analysis (Surveys 1 to 5)		Intermediate to Longer-Term Analysis (Surveys 4 to 5)	
	Difference of Means	*t*-Statistic (2-tailed *p* Value)	Difference of Means	*t*-Statistic (2-tailed *p* Value)
Travel distance	–4.50	–0.457 (0.648)	–0.5	–0.048 (0.962)
Travel time	33.20	0.693 (0.489)	14.50	0.460 (0.646)
VMT	–4.26	–0.576 (0.565)	2.21	0.239 (0.811)
MVMT	–3.15	–0.597 (0.551)	2.13	0.337 (0.436)
Gasoline consumption	–0.14	–0.683 (0.495)	0.14	0.443 (0.658)

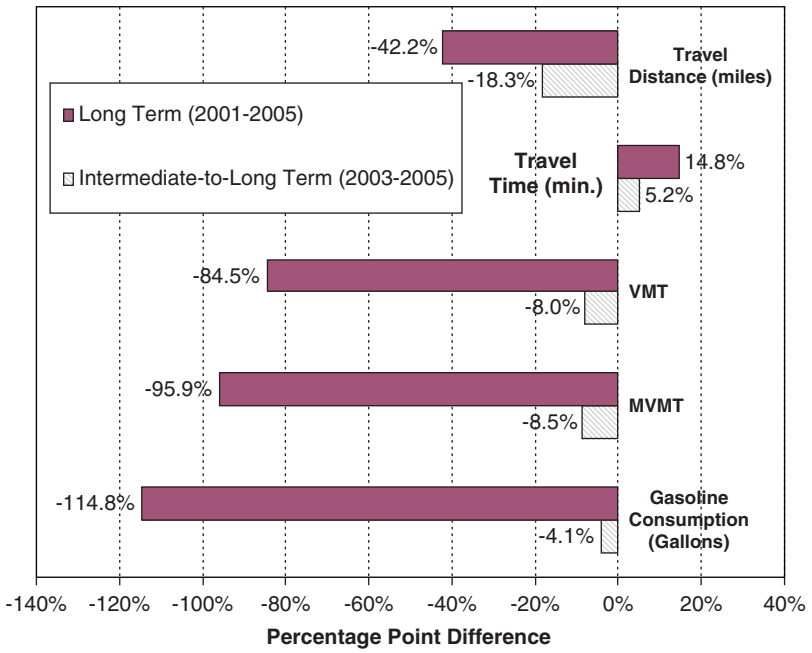

FIGURE 5 Percentage point differences in changes in mean daily travel characteristics: members relative to nonmembers, longer-term analysis (Survey 1 to Survey 5) and intermediate- to longer-term analysis (Survey 4 to Survey 5).

Of most interest are the location variables that associate predictor variables with rank-order outcomes. A negative sign on member status indicates that a value of 1 (i.e., being a CarShare member) lowers the rank order (i.e., is associated with the lower-valued categories of net declines in car ownership). Similarly, having a transit pass and having at least one POD near one's residence were associated with net declines in the number of cars in a household. City CarShare PODs generally are located in dense neighborhoods that are well served by transit, and both of these features are conducive to car-free living. Car shedding also increased with age. In contrast, driving to work and living in a household with children increased car ownership, for members and nonmembers alike.

Mode Choice Model

A multinomial logit equation was estimated that predicted carshare members' mode choices (Table 6). All modes became preferable to

TABLE 5 Ordinal Logit Estimates for Predicting Net Changes in Vehicle Ownership Among Survey Respondents

	Coefficient Estimate	Standard Error	Probability
Threshold			
Net Δ: –2 or more cars	–7.301	0.811	0.000
Net Δ: – 1 car	–4.222	0.676	0.000
No change	–0.260	0.638	0.684
Net Δ: + 1 car	3.644	0.953	0.000
Location			
Member status (1 = City CarShare; 0 = no)	–0.978	0.402	0.015
Owns a transit pass (1 = yes; 0 = no)	–0.414	0.199	0.038
POD within ½ mi of residence (1 = yes; 0 = no)	–0.497	0.225	0.028
Has children (1 = yes; 0 = no)	0.514	0.297	0.084
Age (years)	–0.029	0.010	0.003
Drive to work (1 = yes; 0 = no)	2.765	0.479	0.000
Summary statistics			
Number of cases = 530			
Model χ^2 (probability) = 61.45 (0.000)			
R^2 (McFadden) = 0.069			

TABLE 6 Multinomial Logit Model for Predicting Likelihood That Member Respondents from Survey 5 Chose City CarShare (CCS), Private Automobile (Auto), Public Transit (Transit), Bicycle, or Walking

Variable	Coefficient Estimate	Standard Error	Probability
Trip characteristics			
Total travel time differential: transit–automobile (minutes)[a] [specific to CCS]	0.403	0.079	0.000
Total travel time differential: transit–automobile (minutes) [specific to auto]	0.389	0.060	0.000
Total travel time differential: transit–automobile (minutes) [specific to transit]	0.380	0.061	0.000
Total travel time differential: transit–automobile (minutes) [specific to bicycle]	0.215	0.030	0.000
Total travel time differential squared [specific to CCS]	–0.0039	0.0021	0.065
Total travel time differential squared [specific to auto]	–0.0030	0.0014	0.028
Total travel time differential squared [specific to transit]	–0.0032	0.0017	0.060
Work trip (1 = yes; 0 = no) [specific to auto]	–0.743	0.457	0.107
Work trip (1 = yes; 0 = no) [specific to transit]	0.537	0.178	0.003
Work trip (1 = yes; 0 = no) [specific to bicycle]	0.893	0.231	0.000
Socioeconomic controls			
Age (years) [specific to CCS]	0.039	0.017	0.024
Age (years) [specific to auto]	0.041	0.018	0.025
Age (years) [specific to bicycle]	–0.027	0.018	0.134
Gender (1 = male, 0 = female) [specific to bicycle]	0.868	0.341	0.013
City carshare member (1 = yes; 0 = no) [specific to bicycle]	–1.156	0.558	0.041
Forgone vehicle purchase from 2001 to 2005 (1 = yes; 0 = no) [specific to auto]	–0.919	0.467	0.052
Bike owner (1 = yes; 0 = no) [specific to CCS]	–1.554	0.523	0.004
Bike owner (1 = yes; 0 = no) [specific to auto]	–0.712	0.525	0.178
Bike owner (1 = yes; 0 = no) [specific to transit]	–0.567	0.242	0.021
Personal income ($1,000/year) [specific to CCS]	–0.015	0.006	0.018
Personal income ($1,000/year) [specific to transit]	–0.006	0.004	0.096
Personal income ($1,000/year) [specific to bicycle]	–0.014	0.007	0.056
Possess transit pass (1 = yes; 0 = no) [specific to auto]	–0.6484	0.5283	0.223
Possess transit pass (1 = yes; 0 = no) [specific to transit]	0.8989	0.2934	0.003
Possess transit pass (1 = yes; 0 = no) [specific to bicycle]	–1.1012	0.4173	0.010
Constants			
City CarShare	–6.839	1.243	0.000
Auto	–5.284	1.243	0.000
Transit	–4.679	0.616	0.000
Bicycle	–1.149	1.253	0.361
Summary statistics			
Number of cases	1,356		
-*L* (0):	1,827.7		
-*L* (B):	1,212.3		
Model χ^2 (probability)	1,230 (.0000)		
Goodness of fit (adjusted ρ^2)	0.320		

NOTE: Model was run as a panel, because of the multiple trips per respondent. The panel identifier was significant at the 0.001 probability level.

walking (the reference mode) as travel time differentials (transit minus auto) increased. Auto choice was slightly more sensitive to travel time differentials than transit and carshare choices were. Riding a bicycle was less attractive for longer trips. Compared with walking, work trips tended to favor bike and public transit mode choices and disfavor automobile use.

In terms of socioeconomic factors, bike use tended to decrease with age, whereas auto and carsharing increased. Bike ownership lowered the likelihood of motorized versus nonmotorized travel. It had the most pronounced effect on reducing carshare usage. The model also shows that carsharing, transit, and bicycle travel decreased relative to walking and driving as incomes rose. Finally, carshare members' forgoing of a car purchase over the period between 2001 and 2005 significantly reduced the likelihood of making a private car trip.

Average Daily VMT Model

The results of a best-fitting multiple regression model indicate that, after controlling for the influences of other predictors (e.g., respon-

TABLE 7 Regression Model for Predicting Respondents' Average Daily VMT; Survey 5, All Trip Purposes, All Day Types

Variable	Coefficient Estimate	Standard Error	Probability
Member status			
City CarShare member (1 = yes; 0 = no)	–7.08	3.46	0.040
Socioeconomic controls			
No. of vehicles per household member	13.07	2.09	0.000
Owns a bicycle (0 = no; 1 = yes)	–3.784	1.890	0.046
Age (years)	0.750	0.432	0.083
Age squared	–.008	0.005	0.077
Personal income, annual (in $1,000s)	–.086	0.056	0.127
Personal income, annual (in $1,000s), squared	0.0004	0.00025	0.095
Resides in San Francisco (0 = no; 1 = yes)	–3.064	2.030	0.132
Constant	4.206	10.232	0.681
Summary statistics			
Number of cases			459
F-statistics (probability)			8.214 (0.000)
R^2			0.148

dents' socioeconomic characteristics), City CarShare membership significantly reduced daily VMT (Table 7). All else being equal, City CarShare membership typically lowered daily travel by 7 vehicle miles. Residing in dense, transit-friendly San Francisco reduced the figure by another 3 vehicle miles. Owning a bicycle cut down on daily travel by nearly 4 additional vehicle miles. However, every additional car added per household member raised daily VMT by 13.

Four years into the City CarShare program, being a carshare member, owning a bicycle, and reducing car ownership all serve to shrink the transportation sector's ecological footprint in the San Francisco Bay Area.

CONCLUSIONS

Evidence from the results of five surveys of City CarShare members and nonmembers clearly indicates a net reduction in the VMT and fuel consumption of carshare members. Matched-pair comparisons reveal that mean VMT and fuel consumption of members decreased faster than those of nonmembers from 2001 to 2005, in an era of rising fuel prices. Reduced travel was matched by increased accessibility afforded to those who joined City CarShare. Increased personal benefits matched by decreased social costs (reflected in VMT and fuel consumption) suggest that carsharing is a win–win proposition—benefiting users and nonusers alike.

Even though net longer-term benefits appear to be associated with carsharing in the San Francisco Bay Area, the largest reductions in members' average VMT and fuel consumption accrued during the first several years of the program. Over the past few years, earlier declines appear to have leveled off and indeed might have eroded slightly. Although these results indicate that the benefits of carsharing are sustained over the longer term, there is nonetheless a maturation process wherein early gains appear to taper off with time. This finding suggests that if total motorized travel among the community of carsharers is to continually fall, then membership itself must expand. Even if declines in travel level off among long-time members, then this effect will be complemented by sharper drops in travel among new members as membership grows.

Part of the explanation for longer-term reductions in VMT and fuel consumption is rooted in the tendency of members to sell off and forgo the purchase of private cars. Since 2001, City CarShare members were half as likely as nonmembers to have acquired a vehicle and about as likely to have reduced car ownership. For every 100 carshare member households, this translates to a net shedding of 7 vehicles; however, for every 100 nonmember households, about 3 net vehicles were added over the period—a differential of 10 vehicles per 100 households.

In the modeling of car shedding, carshare membership was a significant predictor, with members about 12% more likely to have shed a vehicle than nonmembers. Older, childless members who lived within 0.5 mi of one or more PODs were also more inclined to shed a car.

The benefits of reducing the vehicle population in a city go beyond lowering VMT and tailpipe emissions. In a dense city such as San Francisco, car shedding also reduces the need for private parking spaces. It not only makes new residential construction more economical (thus housing more affordable) but also preserves green space and allows for more infill development. A long-term evaluation of such possible second-order community impacts would be worthwhile.

The circularity between carshare membership and car shedding is not unlike that of car ownership and induced travel. Membership was associated with reduced car ownership, and reduced car ownership was associated with more carshare travel. Not only average VMT decreased among members relative to nonmembers. Because many carshare vehicles are small, fuel efficient, and able to carry several people, per capita levels of gasoline consumption and, in turn, greenhouse gas emissions also have trended downwards. The authors believe that carshare members, mindful of the cumulative costs of driving, also have become more judicious and selective when deciding whether to drive, take public transit, walk, bike, or even forgo a trip. This behavior contrasts with the perverse incentive to drive a personal car because of the considerable sunk and hidden costs associated with private car ownership (*7*). The authors also believe that the more transparent price signals of carsharing have given rise to a more resourceful form of automobility in the San Francisco Bay Area.

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