Impact of Carsharing on Household Vehicle Holdings

Results from North American Shared-Use Vehicle Survey

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Carsharing has grown considerably in North America during the past decade and has flourished in metropolitan regions across the United States and Canada. The new transportation landscape offers urban residents an alternative to automobility, one without car ownership. As carsharing has expanded, there has been a growing demand to understand its environmental effects. This paper presents the results of a North American carsharing member survey ($N = 6{,}281$). A before-and-after analytical design is established with a focus on carsharing's effects on household vehicle holdings and the aggregate vehicle population. The results show that carsharing members reduce their vehicle holdings to a degree that is statistically significant. The average number of vehicles per household of the sample drops from 0.47 to 0.24. Most of this shift constitutes one-car households becoming carless. The average fuel economy of carsharing vehicles used most often by respondents is 10 mi/gal more efficient than the average vehicle shed by respondents. The median age of vehicles shed by carsharing households is 11 years, but the distribution covers a considerable range. An aggregate analysis suggests that carsharing has taken between 90,000 and 130,000 vehicles off the road. This equates to 9 to 13 vehicles (including shed autos and postponed auto purchases) taken off the road for each carsharing vehicle.

The emergence of carsharing in North America has changed the transportation landscape of metropolitan regions across the continent. Carsharing systems provide members with access to an automobile for short-term daily use. Automobiles owned by carsharing providers are distributed throughout a network of locations. Members can access the vehicles at any time with a reservation and are charged per time and often per mile. They benefit by obtaining personal automobility without the need to own a private vehicle; this can result in considerable monetary savings.

Modern carsharing began in North America during the mid-1990s, starting in Canada and then spreading to the United States. Carsharing has since grown to include more than 20 major metropolitan regions throughout the United States and Canada. As of July 2009, carsharing as an industry had more than 378,000 members served by 9,818 vehicles throughout North America. As carsharing has gained prominence in North American cities, there has been an increasing demand for knowledge about its environmental effects and how regional policy makers might react to its expansion.

This paper reports on carsharing's effect on vehicle holdings among member households. The study results are based on a survey of carsharing members in organizations operating throughout North America during late 2008. The survey was designed primarily to evaluate the greenhouse gas effects of carsharing. The evaluation of these effects, strictly related to household travel, are reported in Martin and Shaheen (*1*). The survey assessed several aspects of carsharing's effect on households including changes in vehicle ownership, vehicle miles/kilometers traveled, carsharing use, and public transit shifts.

Carsharing can facilitate reductions in household vehicle ownership because the service largely eliminates the need for a private vehicle to complete trips. In this way, carsharing can provide a member with an automobile only when needed. Typically, several members throughout the day access a shared-use vehicle. Vehicles are usually parked throughout an urban region in areas where there is a large enough market to support it. Carsharing vehicles generally are not used for commuting. Because members incur hourly and sometimes mileage charges, use of a carsharing vehicle for a full day's auto-commute could quickly become prohibitively expensive. In cities, personal vehicles are allocated a large amount of urban space in the form of parking and roadways. This allocation is a costly component of infrastructure to the public and private sector. Furthermore, vehicle ownership costs are predominantly fixed versus variable. This means that if an automobile is absolutely necessary for either work or non-work trips, then the household is likely to own a vehicle. With vehicle ownership and its prepaid costs, the automobile quickly becomes a relatively competitive mode considering its marginal costs in contrast with alternatives. Carsharing, by facilitating shared vehicle use, eliminates the need for fixed ownership costs. Car-dependent urban residents can save money and adjust to a less car-dependent lifestyle.

This paper has four main sections. First, a review of the relevant carsharing literature is provided, focusing on previous studies that have evaluated vehicle-holding effects. Second, the study methodology is presented. Third, survey results are discussed with respect to vehicle holdings and carsharing's aggregate effect on the vehicle population. Finally, conclusions and issues for future study close the paper.

LITERATURE REVIEW

Carsharing did not take hold in North America until the late 1990s; the continent's first demonstration of carsharing was the Short-Term Auto Rental (STAR) program. Established in 1983 in San Francisco,

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STAR was a 55-vehicle pilot that terminated after 18 months of operation. Walb and Loudon evaluated STAR and found that 17% of members sold a vehicle and 43% postponed a vehicle purchase (*2*). Carsharing would not gain traction until the launch of CarSharing Portland more than a decade later (*3*). Evaluations of CarSharing Portland found that, similar to STAR, 26% of members sold a car and 53% avoided a purchase (*4*). Carsharing returned to San Francisco with the launch of City CarShare in March 2001. Cervero initiated a before-and-after study to evaluate the effects of City CarShare on member and nonmember (control) travel behavior 3 months before the launch and 9 months after (*5*). Interestingly, two-thirds of members came from zero-car households, and 20% were one-car households. Cervero's early City CarShare results were consistent with past work in North America; it was found that demographics among members were similar and that changes in vehicle miles traveled or vehicle kilometers traveled (VMT or VKT) were not substantial. Early carsharing adopters were primarily carless and used carsharing as a means to augment their mobility (*5*).

Lane administered a 500-person online and mail-in survey to members of PhillyCarShare in November 2003. Roughly 60% of members who joined were from zero-car households. Members were demographically similar to the early adopters of City CarShare. Lane evaluated vehicles sold as a result of membership as well as vehicles not acquired. He estimated that each PhillyCarShare vehicle removed roughly 23 cars from the road (*6*).

As carsharing evolved, researchers began to uncover more pronounced effects on VMT or VKT. City CarShare effects were revisited by Cervero and Tsai in 2004 and Cervero et al. in 2007 (*7, 8*). By the third study, VMT or VKT reductions attributable to carsharing were becoming more evident as member VMT or VKT was found to decrease relative to nonmember VMT or VKT. VMT or VKT reductions among carsharing members appeared to occur during the first 2 years, but large variations existed in the group. Overall mean mode-adjusted VMT or VKT, which accounted for occupancy levels, was found to drop 67% for carsharing members, contrasted with a 24% increase for nonmembers (*7*). For more history on the carsharing industry, see Shaheen et al. and Shaheen and Cohen (*9–11*).

Until now, most North American carsharing studies have focused on one organization in a single city (*12*). Many of these evaluations have taken place during periods in which the organization was just starting. Finally, in most studies, vehicle effects have been just one evaluation component, and few studies have attempted to characterize the vehicles that have been shed by members with respect to fuel economy, age, and annual miles or kilometers driven. This study addresses those gaps by focusing on carsharing's effect on household vehicle holdings.

METHODOLOGY

This study's data were generated from an online survey of North American carsharing members in late 2008. Individual carsharing organizations directed their members to take the survey through an e-mail solicitation. Respondents completed a single survey. Researchers designed the questionnaire to provide the data necessary for a before-and-after analysis.

Respondents were asked key questions about their household's travel lifestyle during the year before they joined carsharing. This included parameters such as annual VMT or VKT made on personal household vehicles (if any) and travel on nonmotorized modes and public transit. Respondents were then asked to evaluate the same annual parameters "at present," because this permitted simpler recollection and prevented respondents from self-assessing the "after" time frame in which they may have shifted to a new set of travel patterns. Not surprisingly, carsharing used by a single household member can affect the travel patterns of other household members. For example, a married couple may commute to jobs in different locations, both by automobile. The husband joins carsharing and switches to a public transit commute, but the household retains "his" car because it is newer, and they shed the wife's vehicle. Because this and many similar scenarios are possible, the unit of analysis of this survey is the member's household.

To evaluate vehicle holdings, the survey collected the make, model, and year of each vehicle in the household before the household joined carsharing and at the time of the survey. The make, model, and year of each vehicle were used to determine the vehicle's fuel economy. Each vehicle dating back to 1978 was linked to an appropriate entry in the Environmental Protection Agency (EPA) fuel economy database. Vehicles manufactured before 1978 are not listed in EPA's database; these vehicles were given a standard combined fuel economy of 15 mi/gal (15.7 L/100 km). In a small number of cases, vehicle information was partially complete, and an average fuel economy factor from the year or model was assigned.

Other information collected included the make and model of the carsharing vehicle that members drove most often. In addition, they were asked whether they would have purchased a car in the absence of carsharing. This permitted an evaluation of whether or not members viewed carsharing as a vehicle replacement or substitute at the time of the survey.

Researchers also asked questions that would aid them in identifying factors and events that would confound the analysis. If a confounding factor was found, then the respondent would be removed from the analysis. For instance, moving residential locations or changing jobs are fairly common occurrences that correspond with many life events. Some moves are local or unsubstantial, but others cause notable travel shifts. Respondents were asked whether they had moved their home or work since joining carsharing. If either had changed, respondents were asked whether their travel had changed more as a result of the move or carsharing. If respondents stated that the move had equal or dominant effects on their driving, they were removed from the final analysis.

Two key carsharing submarkets were not included in the analysis: college and exclusive business or government use. Respondents that identified themselves as part of these submarkets were removed because the survey design was focused on assessing the effects of the neighborhood or residential carsharing model, which is the dominant model in the industry.

Finally, carsharing contains a subset of people who are members of the organization, but otherwise do not regularly use the service. These members, called inactive members, exist for several reasons. One reason is that some carsharing organizations have had zero-cost membership plans. Low or no fixed cost membership plans permit a person to be a carsharing member much in the same way that one is a public library member. In evaluating the environmental effects of carsharing, it is questionable to consider changes from an inactive member's household as attributable to carsharing. Hence, respondents that identified themselves as inactive members are assigned a zero impact.

Another reason for respondent removal was misanswered questions, which made their effects incalculable. For consistency, the final data set used in this study is the same one used in Martin and Shaheen, which contains a more complete discussion of the data processing methodology (*1*). All respondents that completed the survey, regardless of the above considerations, were entered into a drawing for a $100 credit to their carsharing account. The participating North American organizations in the survey included (*a*) AutoShare, (*b*) City CarShare, (*c*) CityWheels, (*d*) Community Car Share of Bellingham, (*e*) Communauto, (*f*) Community Car, (*g*) Co-operative Auto Network, (*h*) I-Go, (*i*) PhillyCarShare, (*j*) VrtuCar, and (*k*) Zipcar (in the United States and Canada). The survey launched in early September 2008. Two reminders were sent via each organization, and the survey closed on November 7, 2008. Most organizations (each organization is generally located in a single city) distributed survey solicitations to all their members. Because of Zipcar's size and geographic distribution, the sample was capped at 30,000 members and targeted at specific markets. This included 5,000 each in New York City; Boston, Massachusetts; Washington, D.C.; Portland, Oregon; and Seattle, Washington. An additional 2,500 (each) in Vancouver, British Columbia, and Toronto, Ontario, Canada, also received survey invitations from Zipcar.

RESULTS

Study results are divided into five sections. The first describes the demographics and circumstances of joining carsharing among the sample. In the next section, carsharing's overall effect on household vehicle holdings is described. The third characterizes both shed and added vehicles in regard to fuel economy. The fourth section describes the age of and miles/kilometers driven on vehicles shed. In the final section, an analysis of carsharing's aggregate vehicle effects is presented.

Sample Demographics and Circumstances of Joining

The survey was completed by of 9,635 carsharing members. After researchers removed respondents because of confounding circumstances and misanswered questions, the final data set contained 6,281 individuals. The balance of demographics and circumstantial categorizations was not altered significantly as a result of filtering. Respondents were asked to characterize the circumstances under which they joined carsharing. Table 1 shows the circumstantial categories that were available to respondents in the survey. The table provides respondent percentage by respective categories for the full and final data set.

Table 1 demonstrates that the balance of respondents remained relatively stable across the categories, with two exceptions: (*a*) college responses, representing 6% of the data set, falls to zero and (*b*) the category "My household did not have a car, but joined carsharing to gain additional personal freedom" rose from 43% to 51% in the final data set.

Demographics are similarly affected. The distribution of income, education, and age follow the same shape in the complete and final data sets. One distinction is that the final data set is slightly older and has a higher income and education. Table 2 illustrates the sample demographics, split by the United States and Canada, as well as the complete and final sample. The demographic distinctions between the countries are small. They exhibit a similar gender balance. The age distribution shows that American members are relatively younger but have slightly more education. The income distribution of respondents in both countries corresponds well with the mode of U.S. and Canadian incomes between $40,000 and $60,000. Respondents in each country answered income questions in their respective currencies, but at the time of the survey the currencies of Canada and the United States were close to parity. Overall, sample divisions across countries showed some nominal distinctions, but they also illustrated that carsharing members have very similar demographic distributions in the United States and Canada. The sample sizes across demographics in Table 2 are different because some respondents skipped or declined to answer certain questions.

Carsharing's Effect on Vehicle Holdings

Results show that carsharing lowers the total number of vehicles held by members, and this shift is substantial. When vehicle

TABLE 1 Circumstances of Joining Carsharing

	Circumstantial Category	Percent of Respondents Completing the Survey ($N = 9{,}635$)	Percent of Respondents in Final Data Set ($N = 6{,}281$)
1	Owned at least one car, but needed an additional car for greater flexibility, and joined carsharing instead of acquiring an additional car.	9	8
2	I am in college, and I joined carsharing to gain access to a vehicle while in college.	6	0
3	Owned one car, but I joined carsharing and got rid of the car.	13	14
4	My household did not have a car, but joined carsharing to gain additional personal freedom.	43	51
5	My household did not have a car, but changes in life required a car and I joined carsharing instead.	6	7
6	My employer joined carsharing, and I joined through my employer.	5	3
7	A car of mine stopped working, and instead of replacing it I joined carsharing.	8	8
8	Owned more than one car. Got rid of at least one car and joined carsharing.	3	3
9	I live in an apartment building with a designated carsharing vehicle, and I joined through its membership arrangement.	0	0
10	I joined carsharing for reasons other than those listed above. Please explain:	9	7

Question: Please select the statement that best characterizes the circumstances under which you joined carsharing.

TABLE 2 Demographic Distributions by Country and Data Set

Demographic Attribute	U.S. Carsharing (%)	Canadian Carsharing (%)	Total Final (%)	Total Complete (%)
Gender	N = 4,229	N = 2,024	N = 6,253	N = 9,578
Male	43.9	46.3	44.7	43.4
Female	56.1	53.7	55.3	56.6
Age (years)	N = 4,201	N = 1,996	N = 6,197	N = 9,482
Younger than 20	0.1	0.1	0.1	0.6
20–30	37.6	30.6	35.3	39.3
30–40	29.5	34.2	31.0	29.1
40–50	16.0	19.0	16.9	15.8
50–60	11.2	10.9	11.1	10.4
60–70	4.9	4.6	4.8	4.1
70–80	0.6	0.7	0.6	0.6
80–90	0.2	0.1	0.1	0.1
Education	N = 4,235	N = 2,028	N = 6,263	N = 9,591
Grade school	0	0	0	0
Graduated high school	2	4	2	2
Some college	10	17	12	12
Associate's degree	3	5	4	4
Bachelor's degree	43	39	42	42
Master's degree (MS, MA, MBA)	28	26	27	27
Juris doctorate degree (JD)	5	1	4	4
Doctorate (PhD, EdD, etc.)	8	6	8	8
Other	1	3	2	2
Income (household, $US)	N = 4,247	N = 2,034	N = 6,281	N = 9,536
Less than 20,000	6	6	6	8
20,000–40,000	18	16	17	18
40,000–60,000	19	23	20	19
60,000–80,000	14	17	15	14
80,000–100,000	11	12	11	11
100,000–120,000	7	7	7	7
120,000–140,000	4	4	4	4
More than 140,000	12	6	10	9
Decline to respond	9	10	9	10

holdings are changed there are four possible actions that a household can take: the household can shed, add, retain, or replace a vehicle. Vehicle replacement involves the shedding and adding of a vehicle in the same household. For instance, in a household that sheds two vehicles and adds one, the added vehicle is counted as a replacement. Similarly, in a household that sheds one vehicle and adds two, one of the added vehicles is a replacement and the other is an added vehicle. Figure 1 illustrates the breakdown of the change in vehicle holdings across these four categories, as well as a t-test on the paired sample mean. In addition, a bootstrap simulation of "before" and "after" means is presented. Bootstrap simulations replicate the repeated sampling of data, which in this case illustrates that the sample mean is normally distributed given the sample size.

The columns show the action taken by households that held the stated number of vehicles before joining carsharing. Vehicles retained impose no change in the overall vehicle count. The total number of vehicles held by households before joining carsharing is the sum of those shed and retained (2,968). This number amounts to just under one vehicle for every two households and reflects that many households that join carsharing are carless. The net change in vehicles is the sum of vehicles added and vehicles replaced (as they are distinct) minus the total number of vehicles shed. This net change across the sample is a reduction of 1,461, resulting in a sample vehicle count after joining carsharing of 1,507. Thus, the sample dropped the total number of vehicles by about 50%. By virtue of its magnitude and the large sample size, this drop is statistically significant ($p < .01$). The average vehicles per household before carsharing is 0.47, and the average vehicles per household after carsharing is 0.24. The Canadian average before carsharing is 0.31 vehicle per household and 0.13 vehicle per household after. The U.S. average before carsharing is 0.55 vehicle per household and 0.29 vehicles per household after. Both of these changes are statistically significant.

A fair number of the households that changed their vehicle holdings owned more than one vehicle. In addition, some households increased their vehicle holdings, whereas others shed only some of their vehicles. Table 3 presents a cross-tabulation of household vehicle holdings before and after joining carsharing and shows how households in the sample transitioned to new vehicle holding states.

The total column at the far right of Table 3 shows the distribution of households by vehicle holdings before the households joined carsharing. That is, 62% of households joining carsharing owned no vehicle when they joined, and 31% of households owned one vehicle. The bottom row total shows the distribution of households by vehicle holdings after the households joined carsharing. The shift toward carless households is substantial; they make up 80% of the after sample. Most of this shift is made up of one-car households becoming carless households. The second largest shift in holdings involves two-car households transitioning into one-car households—4% (n = 228). This is followed by two-car households transitioning into carless households—1% (n = 68). The diagonal cells of the table show households that did

Vehicle Change Category	Zero Car Households	One Car Households	Two Car Households	Three Car Households	Four Car Households	Five or more Car Households	Total
Vehicles Shed	0	1437	486	70	37	16	2046
Vehicles Retained	0	480	340	68	15	19	922
Vehicles Added	219	21	5	1	0	0	246
Vehicles Replaced	0	187	122	19	10	1	339
Net Change (Added+Replaced-Shed)	219	-1229	-359	-50	-27	-15	-1461

Paired Test Variables	Paired Differences t-test							
	Mean	Std. Deviation	Std. Error Mean	99% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Vehicles After - Vehicles Before	-0.233	0.559	0.007	-0.251	-0.214	-32.955	6280	0.00

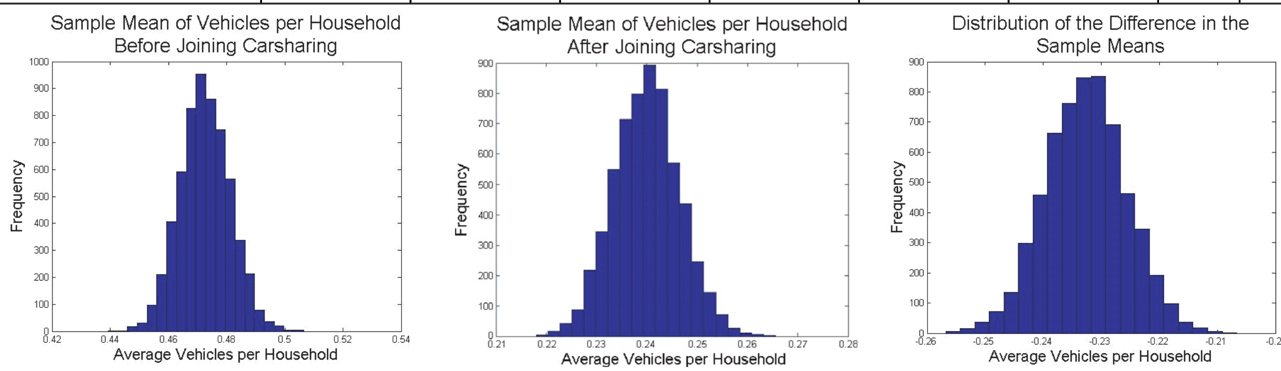

FIGURE 1 Profile and statistical evaluation of change in vehicle holdings.

not change the number of vehicles owned. Given the large change in vehicles discussed earlier, a paradoxical but accurate observation is that a majority of carsharing households do not change their vehicle holdings. However, this is true only when carless households are included, which have no vehicles to shed. Only 12% of the sample ($n = 782$) were households that had a vehicle before carsharing and maintained the same vehicle stock.

Characteristics of Vehicles Added and Shed

The analysis above illustrates carsharing's effect on vehicle counts in the sample; however, the vehicle characteristics are not revealed. This section reports on key attributes including fuel economy, vehicle age, and miles/kilometers driven of vehicles shed. Figure 2 presents three graphs that outline fuel economy distributions. Two of these graphs

TABLE 3 Household Vehicle Holdings Before and After Joining Carsharing

Before Joining Carsharing	After Joining Carsharing: Zero-Car Household	One-Car Household	Two-Car Household	Three-Car Household	Four-Car Household	Five-or-more Car Household	Total
Zero-car household	3,686	182	14	3	0	0	3,885 (62%)
One-car household	1,250	646	21	0	0	0	1,917 (31%)
Two-car household	68	228	112	5	0	0	413 (7%)
Three-car household	7	11	8	19	1	0	46 (1%)
Four-car household	3	2	3	3	2	0	13 (0%)
Five-or-more-car household	2	1	0	0	1	3	7 (0%)
Total	5,016 (80%)	1,070 (17%)	158 (3%)	30 (0%)	4 (0%)	3 (0%)	6,281

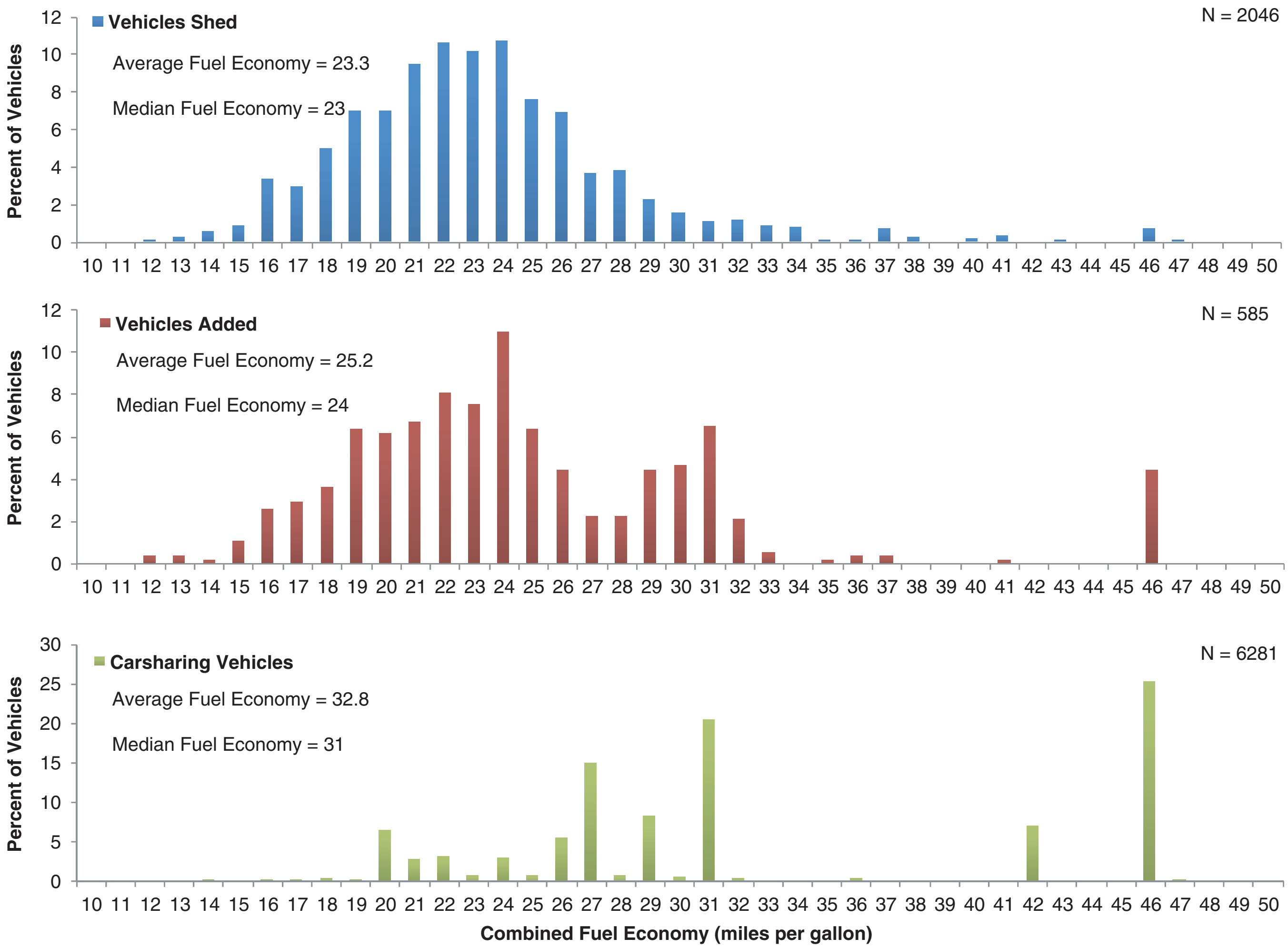

FIGURE 2 Fuel economy distribution of household vehicles shed or added and carsharing vehicles driven.

show the fuel economy distribution of vehicles shed and added by carsharing households. The third graph shows the fuel economy distribution of the carsharing vehicles that respondents indicated that they used most often.

Figure 2 reveals several interesting qualities of the vehicle fuel economy distributions. For vehicles shed, it is approximately normal with a mean of 23.3 mpg (10.1 L/100 km). The distribution of vehicles added (which includes replaced vehicles) is characteristic of concatenated normal distributions with two separate means. The overall mean is 25.2 mpg (9.3 L/100 km), and the median is 24 mpg (9.8 L/100 km). The smaller bell shape to the right indicates a fair share of respondents adding vehicles with a fuel economy of about 30 mpg (7.8 L/100 km). Still further to the right is a spike of vehicles at 46 mpg (5.1 L/100 km), and this represents acquisitions of the second-generation Toyota Prius. A comparison of these two distributions shows that the autos added are slightly more efficient on average, but there is still a notable share of low fuel economy vehicles added by households. The distribution of carsharing vehicle fuel economy looks very different in shape from the other two. To start, the scales of the percents are different; three fuel economy values represent nearly 60% of the distribution. Many carsharing organizations offer a diversity of vehicles to members, but the majority are highly efficient hybrids, sedans, and compact cars. The average fuel economy of carsharing vehicles is 32.8 mpg (7.2 L/100 km) with a median of 31 mpg (7.6 L/100 km). Hence, the average carsharing vehicle used by the sample overall (United States and Canada) is a full 10 mpg more efficient than the average vehicle shed by members.

Shed Vehicles: Age and Miles or Kilometers Driven

The survey data also allow for an analysis of the miles/kilometers driven on shed vehicles. When considering passenger cars, the nationwide average VMT or VKT in 2007 is about 12,300 miles or 19,800 kilometers per year in the United States (*13*). In Canada, the average driving distance is about 8,800 mi or 14,200 km per year (*14*). The vehicles that are removed from the road as a result of carsharing are typically driven less than average, but some are driven more. The data show that nearly 75% of all vehicles shed are driven less than 10,000 mi or 16,000 km per year. More than 90% of all vehicles shed are driven less than 16,000 mi or 26,000 km per year. The average annual distance driven on a vehicle that is shed by a carsharing household is 8,064 mi or 13,000 km per year, and the median is close to 7,000 mi or 11,300 km per year. The average miles driven for vehicles shed by U.S. carsharing members is 8,200 mi or

13,200 km per year, and for shed Canadian vehicles the average is 7,700 mi or 12,300 km per year. These averages and distributional parameters are consistent with the assumption that carsharing targets primarily lower-mileage vehicles. But, it also suggests that carsharing can make it easier for some households to give up vehicles that are driven distances that are well above average. The age of shed vehicles, another important factor, influences carsharing's effect on the overall vehicle fleet. Figure 3 shows the distribution of the production year of vehicles shed by carsharing households.

The shape of the distribution is negatively skewed with the mode at the 1998 model year. Thus, the mode and the median age of the vehicles are 10 and 11 years, respectively. The average vehicle age is closer to 17 years as a result of the long tail extending back toward very old vehicles. In considering the differences between Canada and the United States, shed Canadian cars were slightly older. Given the unique shape of the distribution, the median age in both cases is more representative of the typical car shed than the average. The sample size of 2,010 is slightly smaller than the total number of vehicles shed because some respondents provided incomplete vehicle information. The distribution shows that the overwhelming majority of vehicles lie between the years 1984 and 2008, bounding a normal-shaped distribution. A fair number of vehicles shed (41%) are younger than 10 years old. The range of years within the normal-shaped distribution is well within the typical vehicle lifespan. This suggests that a large number of carsharing members may enter carsharing when their vehicle is at an age close to the point at which it would be retired.

Respondents were asked whether in the absence of carsharing, they would buy a car. The available responses ranged from "definitely not," "probably not," "maybe," "probably," to "definitely" buy a car. This question generated insight into the degree to which carsharing was, at the time of the survey, substituting for a vehicle not acquired. The results suggest that about 25% of the total sample indicated that maybe, probably, or definitely they would buy a car in the absence of carsharing. Only the responses of households that did not shed a vehicle were considered for this estimate (as a result of double counting otherwise).

Aggregate Carsharing Effects

Overall, the sample shows that people who joined carsharing made significant cuts to aggregate vehicle holdings. Although it is clear that these cuts are substantial in the sample, it is not yet evident how these results scale to the carsharing industry. That is, while members shed vehicles, carsharing organizations also add vehicles to urban areas, so the degree to which this substitution reduces overall vehicles is not immediately clear. To gain insight into this issue, several factors and assumptions are key.

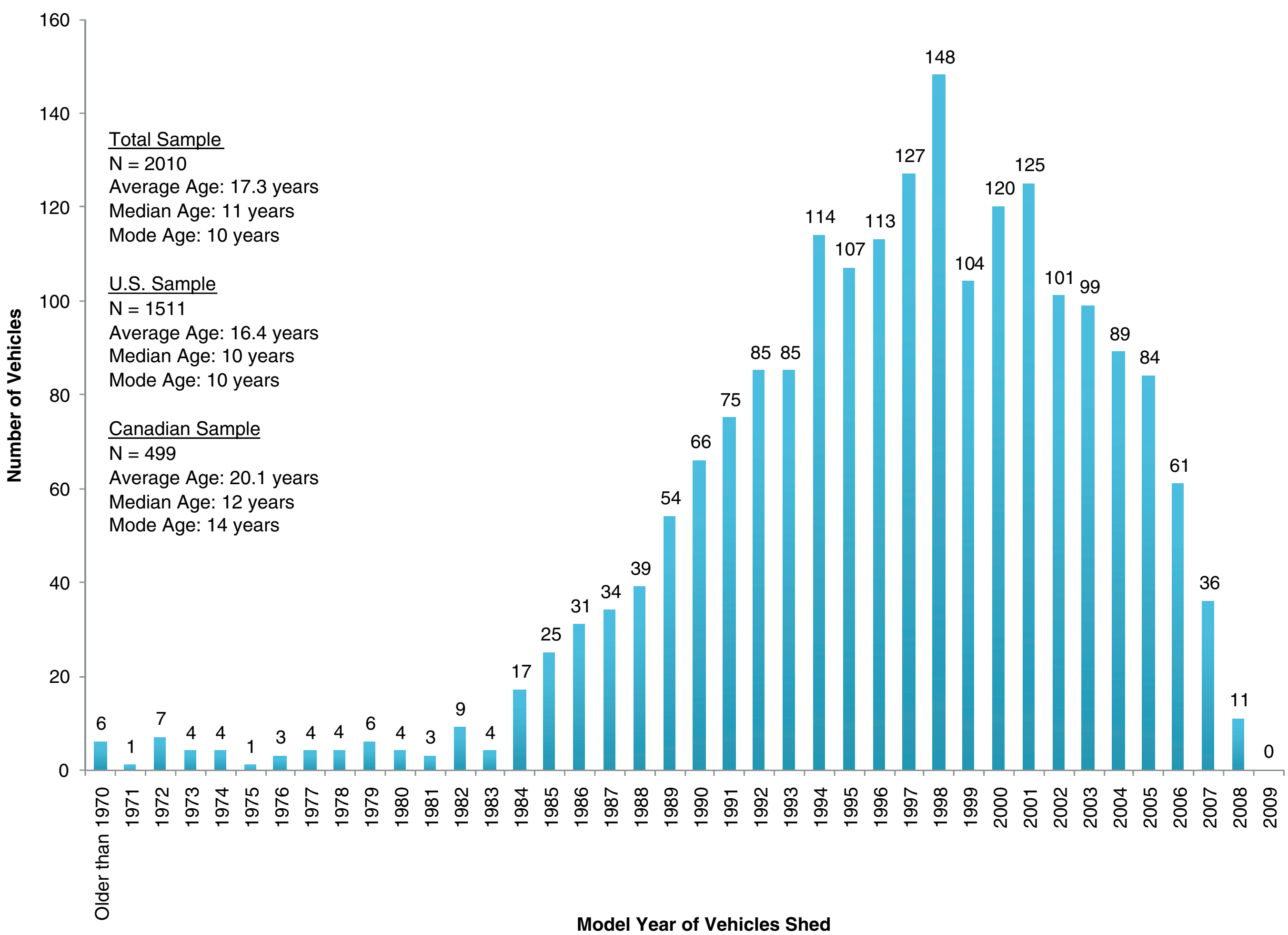

FIGURE 3 Distribution of vehicles shed by model year (vehicle age).

TABLE 4 Sensitivity Analysis of Industrywide Carsharing Effects on Vehicle Holdings

Inactive Share (%)	Active Carsharing Household Population	Total Vehicles Shed	Vehicles Shed per Carsharing Vehicle	Vehicles Avoided	Total Vehicles Removed per Carsharing Vehicle
0	314,390	73,129	7.4	78,598	15.5
5	298,671	69,473	7.1	74,668	14.7
10	282,951	65,816	6.7	70,738	13.9
15	267,232	62,160	6.3	66,808	13.1
20	251,512	58,503	6.0	62,878	12.4
25	235,793	54,847	5.6	58,948	11.6
30	220,073	51,190	5.2	55,018	10.8
35	204,354	47,534	4.8	51,088	10.0
40	188,634	43,877	4.5	47,159	9.3
45	172,915	40,221	4.1	43,229	8.5
50	157,195	36,565	3.7	39,299	7.7

Although the sample of carsharing households is random among active members, several cohorts were excluded from the sample, including college students and business or governmental fleet users that do not use vehicles for non-work trips. The share of these cohorts in the sample is 6% and 2%, respectively. Their exclusion does not imply a zero impact, but the survey design was not targeted at the analysis of these cohorts. Nevertheless, the sample of these shares in the population is applied as an approximation of the population share. Another cohort, inactive members, was excluded from the analysis. Inactive members constituted a share of approximately 8% of the complete sample. This share is likely subject to a nonresponse bias (i.e., inactive carsharing members are less likely to take the survey than active members). Thus, the sample share of 8% is likely a lower bound. By definition, inactive members have a zero impact because they continue their travel lifestyles irrespective of their carsharing membership. Nevertheless, it would be a mistake to scale the results of any carsharing sample to an industry level without acknowledging that a share of the industry membership does not use the service. The uncertainty of the inactive member share is addressable with a sensitivity analysis, and their effect on the aggregate results is important.

As shown earlier, a net of 1,461 vehicles were shed across 6,281 households. As of mid-2009, the carsharing industry had 378,000 members in North America. However, because that population includes college members, business users, and inactive members, the active member population using the neighborhood model is smaller. The population was scaled to "active members only" by subtracting college members (6%) and strictly business members (2%)—8% from the total population—to obtain the 347,390 members using the neighborhood carsharing model. The uncertainty of the inactive member share is treated through a sensitivity analysis.

In addition, some households contain more than one member. Because the unit of analysis in this study is the respondent household, questions were inserted to detect duplicate respondents from different members in the same households. In searching for duplicate responses, the survey asked questions about joint membership. The survey found that 81% of the 6,281 respondents were the sole carsharing members in the household. The remaining 19% of respondents were members living in households with someone else who was a carsharing member. The share of respondents with more than two members per household was negligible. This membership balance implies that about 19% of the population has two carsharing members in one household. Thus, translating the 347,390 carsharing members to carsharing households is computed as [347,390 (0.81) + 347,390 (0.19)/2], which equals roughly 314,390 households using carsharing. The sensitivity analysis varying the inactive share is presented in Table 4.

The left column describes the percentage of inactive members. The top row shows carsharing's effect on total vehicles shed assuming that all households are active. But as the sample revealed a share of ~10% inactive members, it is probable that the share of inactive members is between 15% and 40% across the entire population. The table illustrates the estimated total number of vehicles shed with each assumption. The fourth column to the right shows the vehicles shed per carsharing vehicle, which is the third column divided by 9,818. This result suggests that between four and six vehicles were shed per carsharing vehicle. The vehicles avoided as a result of carsharing are computed separately, because this 25% share did not shed any vehicles but did not purchase any vehicles as a result of carsharing. When vehicles avoided are considered in conjunction with vehicles shed, the likely estimates suggest that carsharing has removed between 90,000 and 130,000 vehicles from the road or between nine to 13 cars for each carsharing vehicle. This estimate is consistent with the carsharing literature (*10*).

The estimated share of inactive members is a population estimate. But this does not imply that the share is evenly distributed across all organizations. Indeed, significant variation of the true share across organizations is likely. A major factor affecting the share is pricing plans, and plans that have no or low fixed cost are the most likely to contain inactive members. Not accounting for inactive members could result in an overestimation of aggregate effects. Finally, inactive membership proportions are likely to change in the future as the industry evolves.

CONCLUSION

Evidence from this North American carsharing member survey demonstrates that carsharing facilitates a substantial reduction in household vehicle holdings, despite the fact that 60% of all households joining carsharing are carless. Households joining carsharing held an average 0.47 vehicles per household. Yet the vehicle holding population exhibited a dramatic shift toward a carless lifestyle. On the basis of assumptions with respect to the active member population, it is estimated that carsharing has removed between 90,000 and 130,000 vehicles from the road (nine to 13 vehicles per carsharing vehicle, including shed and postponed car purchases) in North America to date. The vehicles shed are often older, and the carsharing fleet average is 10 mpg more efficient than the fuel economy of vehicles shed. Inactive memberships reduce the forecast aggregate effects, but even if every other household of the population were inactive, carsharing would still be effective in reducing the overall number of household vehicle holdings.

Additional research is warranted in several areas. Shifting demographics and urban environments will demand continual future study, along with VMT or VKT effects due to carsharing. Although this study's instruments were not designed to evaluate carsharing's effect on the college or business and governmental submarkets, both of these markets are expanding and targeted evaluations are needed. Further exploration of inactive membership shares is also important. Although it is clear that they are a factor, this study does not posit a formal definition of inactive members. Such a definition would be useful for future policy development.

As carsharing continues to grow, it is possible that its relative effect may expand. Carsharing represents an attractive alternative to carless households, but such households are a minority in North America. In the future, as carsharing networks become denser and more complete, their attractiveness to vehicle-holding households may increase. Further, carsharing may expand into lower density communities (e.g., suburbs), and effects could expand as well. Thus, although carsharing already had an effect in many metropolitan regions, considerable environmental benefits may exist in the future with industry growth into new markets.

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