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ROUNDTRIP CARSHARING IN NEW YORK CITY
AN EVALUATION OF A PILOT PROGRAM AND SYSTEM IMPACTS

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Contents

Table of Figures

Table of Tables

Abstract

Carsharing is a form of shared mobility where members can access vehicles dispersed around a city on an as-needed basis. According to the Society of Automotive Engineers (SAE), carsharing is formally defined as "A service that provides the traveler with on-demand, short-term access to a shared fleet of commercially-owned motor vehicles typically through a membership and the traveler pays a fee for use. Carsharing mobility providers typically own and maintain the vehicle fleet and provide insurance, gasoline/charging, and parking." New York City (NYC) implemented a pilot program that provides dedicated on- and off-street parking spaces for carsharing vehicles within established zones. This pilot program was aimed at supporting the growth of carsharing and facilitating expansion into communities that traditionally have had less access to carsharing systems. This study evaluated the behavioral and environmental impacts of carsharing in NYC and explored the effects of the pilot program—beginning in June 2018 and was evaluated through September 2019. The study team deployed three surveys to different user populations and collected activity data from two carsharing operators (Zipcar and Enterprise CarShare) to inform the analysis of data that spanned a period from April 1st, 2017 to September 30th, 2019. Both systems were roundtrip carsharing systems, and the results are combined across systems.

The study found that roundtrip carsharing in NYC mostly serves as a substitute for car rental, other personal vehicle modes, and personal vehicle ownership. The analysis showed that the broader pilot program had a modest impact on user behavior through carsharing (i.e., reduced vehicle ownership, reduced VMT, and mode shift). It also found that the pilot program likely expanded the membership base of carsharing to demographic cohorts that are traditionally underrepresented in carsharing populations (i.e., increased participation by lower education levels, lower household incomes, minority demographics). The study also examined vehicle ownership impacts and changes in vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. Analysis of survey and activity data indicated that 7% of NYC carsharing members avoided a car purchase, and 0.61% of members got rid of a car they already owned due to carsharing. Across the membership base, VMT was reduced by 7% and GHG emissions were reduced by 6%. These findings showed that carsharing reduced VMT and delivered associated environmental benefits within NYC, and more broadly had a substantive impact on travel behavior among members in form of mode shift away from personal automotive modes.

Executive Summary

Carsharing began its current modern and continuous presence in the U.S. in 1998, and it is one of the most mature forms of shared mobility. According to the Society of Automotive Engineers (SAE), carsharing is formally defined as "A service that provides the traveler with on-demand, short-term access to a shared fleet of commercially-owned motor vehicles typically through a membership and the traveler pays a fee for use. Carsharing mobility providers typically own and maintain the vehicle fleet and provide insurance, gasoline/charging, and parking." The service enables members to access a fleet of vehicles dispersed around a city on an as-needed basis, often through the use of a smartphone application. Members typically pay by time or by distance, and often pay a monthly or yearly membership fee. Carsharing services have been in New York City (NYC) for nearly two decades. In June 2018, the NYC Department of Transportation implemented a pilot program that provided dedicated on-street spaces in established zones throughout the city and off-street spaces in municipal parking facilities. This pilot program was aimed at supporting the growth of carsharing and facilitating expansion into communities that traditionally have had less access to carsharing systems.

This study evaluates the behavioral and environmental impacts of the two main carsharing operators participating in the pilot within NYC: Zipcar and Enterprise CarShare. A third carsharing operator, ReachNow, was initially part of the network of carsharing operators in New York City. However, this operator withdrew from the city before the pilot began. The pilot project started with 285 spaces, with 230 parking spaces within the 14 on-street parking zones and 55 parking spaces in the off-street municipal facilities. The number of allocated spaces fluctuated during the pilot due to construction and other interruptions in availability. The scope of the study covered the vehicles within the pilot spaces as well as the broader NYC fleets of both operators, as the entire network was accessible to all members. Impacts on net vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions were computed for the final year of the evaluation period, which was October 2018 to September 2019. The average number of carsharing vehicles deployed during this period was 2,526 and the number of members served in the population was 128,668.

The study team conducted three surveys and collected activity data from operators to inform the analysis. These data collection efforts included: 1) a retrospective survey launched in April 2018 targeting residents who were carsharing members prior to the pilot program (N=2,700), 2) a before survey launched in July 2018, administered quarterly for a year to those who joined carsharing within each quarter after the launch of the pilot program (N=1,051), 3) an after survey launched in September 2019 that assessed behavioral changes and attitudes of carsharing users with both services as a result of the pilot program and due to carsharing in NYC more broadly (N=841), and 4) carsharing vehicle activity data from both operators detailing the number of trips and mileage driven in total and by individual members, as well as member totals, vehicle totals, and average vehicle fuel economies (collected between April 2017 through September 2019). The total number of respondents for the retrospective, before, and after surveys was 2,700, 1,051, and 841, respectively. The study has standard limitations associated with survey data, in that changes in behavior were self-reported assessments. Such dynamics are often inherent in studies evaluating impacts where respondents report the causality of behavioral change as a result of the system. Other limitations, such as sampling bias by frequency of use, are addressed in a process of weighting.

These data were used to analyze who uses carsharing in NYC and why and how they use these services. Survey and activity data were combined to understand the demographic profile of users, derive travel behavior impacts, vehicle ownership impacts, as well as VMT and GHG emissions impacts as a result of carsharing and the pilot program. Overall, the study found the following key results:

- **NYC carsharing users are wealthier and have higher educational attainment than the general population.** This finding, derived from the member surveys, is generally consistent with demographic findings from many previous shared mobility studies. The sample distributions also showed higher proportions of White respondents (i.e., between 49.4% to 57.3% depending on the survey, relative to 31.9% of the population) and lower proportions of Black or African American respondents (i.e., between 8.5% to 12.9% depending on the survey, relative to 21.7% of the population). It is important to note, however, that the survey samples became more diverse as the pilot program progressed, suggesting that the pilot may have increased racial diversity among members.

- **Carsharing in NYC often serves as a substitute for car rental and other personal vehicle modes, and it is employed for additional mobility rather than a primary transportation mode.** Results from the member surveys show that carsharing members most commonly substitute for car rental, transportation network companies (TNCs also known as ridesourcing and ridehailing, like Uber and Lyft), taxis, and commuter rail and bus. Although some users replace carsharing with personal vehicle driving, the majority of members in NYC did not have a car prior to joining and joined carsharing for additional mobility.

- **The pilot program expanded the membership base of carsharing from its traditional demographics.** Analysis of survey data of respondents that lived or worked within or near the pilot zones suggested that the parking pilot program had a modest impact on carsharing usage and user behavior. It further suggested that the pilot program expanded the membership base of carsharing to have greater demographic diversity. The analysis found that younger, lower-income, and more racially diverse respondents lived or worked near the pilot program zones as compared to respondents who neither lived nor worked near the zones.

- **About 8% of members either sold a vehicle or avoided a car purchase due to carsharing in NYC.** Consistent with previous studies, the results found that personal vehicle suppression, the avoidance of a car purchase was the largest impact, with about 7% of the member population estimated to suppress a vehicle. Personal vehicle shedding was found to be 0.61%. This spread of impact is larger than has been identified in other studies, as was likely the result of relatively low car ownership rates that exist in New York City as compared to other North American cities.

- **Carsharing in NYC reduced VMT and GHG emissions among members by 7% and 6%, respectively.** Vehicle shedding and suppression, as well as changes in driving in personal vehicles and changes in use of other shared modes (taxis, TNCs, etc.), led to reductions in miles driven by carsharing users. Combining these changes in driving facilitated by carsharing with the driving that occurred on carsharing vehicles themselves allows the calculation of net VMT and GHG emissions impacts. Overall, findings suggest that carsharing activity reduced annual VMT by about 38.7 million miles and produced an annual net reduction of about 12,000 metric tons in GHGs per year within the city.

The results of these analyses show that carsharing has had a substantive impact on travel behavior within NYC. The findings suggest that carsharing reduced net vehicle ownership, VMT, and GHG emissions among members. Analysis also shows that the pilot program expanded the carsharing membership base to include a more diverse demographic. These and other impacts resulting from travel behavior shift suggest that carsharing is playing a productive role as a transportation demand management tool within NYC.

Introduction

Carsharing has been the longstanding mainstay of the modern shared mobility industry in the United States. It is based on the concept that access to shared, publicly available vehicles can alter the equation of mobility for the surrounding community. When vehicles are shared, automotive mobility can be accessed without the need for personal vehicle ownership and the high capital and maintenance costs that come with it. Carsharing has grown considerably in the United States with a presence in most major cities, and it has evolved into several new business models. Three of the most prominent models include 1) round trip carsharing: where vehicles must return to the location at which they started, 2) free-floating (or one-way) carsharing: where vehicles can start and end at different locations within a zone, and 3) peer-to-peer (P2P) carsharing: where personal vehicles can be entered into a fleet to be shared by individuals. All of these models have seen their share of success within specific markets. Roundtrip carsharing, which is the subject of this study, was the first business model and in many ways has proven to be one of the most enduring. As a system, it positions vehicles at fixed locations such as dedicated street parking or off-street parking spaces throughout the urban environment. Members of carsharing systems can access vehicles through a reservation or effectively through real-time access as facilitated by a smart phone app. Members pay by time or by distance, and often pay a monthly or annual membership fee. Other vehicular expenses, such as gasoline, insurance, taxes, and maintenance, are managed by the operator. Members can drive a car without having their own auto insurance.

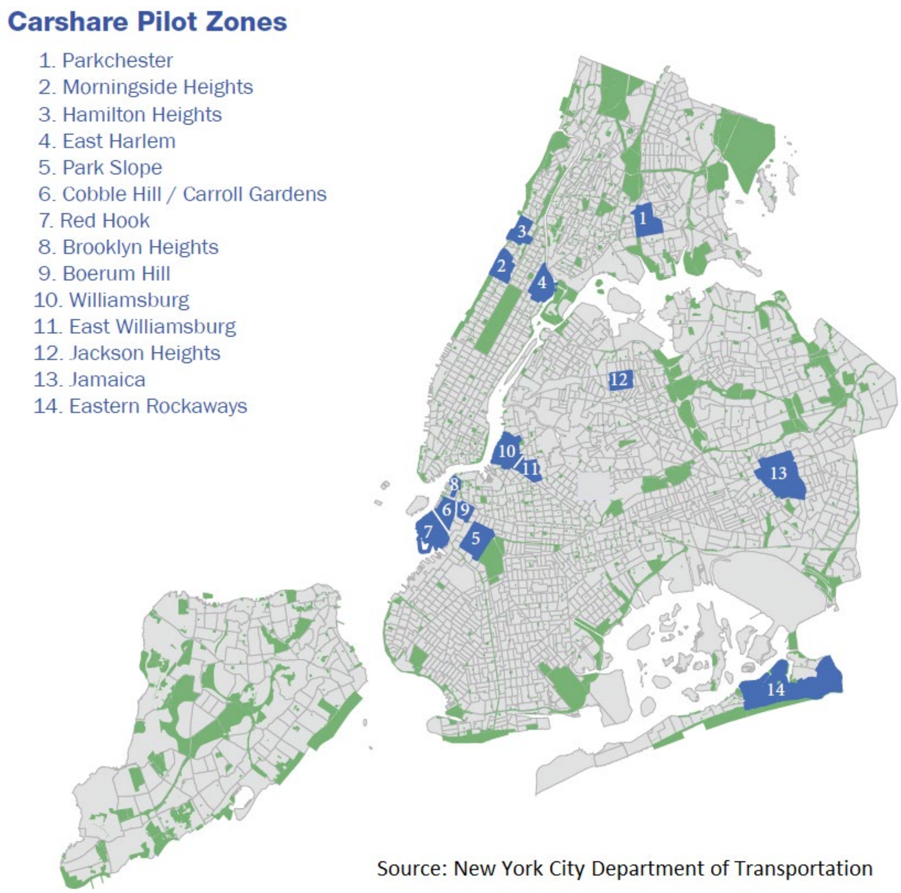
The benefits that members gain from carsharing are generally straight-forward. Members receive access to vehicles on an as-needed basis. This can reduce the need for personal vehicle ownership among members. Reduced vehicle ownership can have a number of impacts on key metrics of interest to policy makers and municipalities. One of the most prominent impacts relates to overall vehicle miles traveled (VMT). If shared access to a vehicle enables a reduction in personal vehicle ownership, then a large amount of miles are not driven on those personal vehicles. This reduction in vehicle ownership includes both vehicles that are sold by households (e.g., shed), and those that are not acquired as a result of carsharing (e.g., suppressed). At the same time, carsharing system operations also cause VMT as a result of member use, and not everyone who uses the system is getting rid of a car or avoiding the purchase of one. The net effect of these two forces produces overall VMT changes from carsharing. Previous research has found that carsharing reduces VMT and GHG emissions (Martin and Shaheen, 2011). But beyond VMT impacts, there are several other effects brought on by carsharing. These include increased mobility, reduced parking demands, reduced transportation costs by members, and other benefits.

This report presents the results of an evaluation of carsharing in New York City. The New York City Department of Transportation implemented a pilot program, providing dedicated spaces for carsharing vehicles within established zones across the city. This project conducted a series of surveys and analyses of activity data to ascertain the impacts of carsharing in New York City more broadly as well as the pilot program specifically. The report begins with a brief background on the pilot program and then a review of previous research on carsharing. We next present the methodology, data sources, and results from the analysis. The report concludes with a summary of findings across multiple metrics of impact, including vehicle ownership, VMT/greenhouse gases (GHGs), mode shift, and other responses to the program.

Background on Carsharing Pilot Program

The New York City Department of Transportation (NYC DOT) established the carshare pilot program through Local Law 47 of 2017 and Local Law 50 of 2017. The pilot allowed up to 300 on-street parking spaces to be allocated for carsharing across 14 pilot zones. In addition, the pilot also allowed 300 parking spaces in municipal parking facilities to be used by carsharing operators. When the pilot launched in June 2018, NYC DOT distributed 230 on-street spaces and 55 spaces in municipal parking facilities to Enterprise CarShare and Zipcar. The pilot program aimed to support the growth of carsharing and facilitate the expansion into communities that traditionally have had less access to carsharing systems. The pilot regions were distributed across neighborhoods in the city that were economically and geographically diverse. Deployments were focused on areas likely to have residents that may give up a car or lacked other options for transportation. The regions were spread across Manhattan, the Bronx, Queens, and Brooklyn. The municipal parking facilities were distributed throughout Brooklyn, Queens, and the Bronx. The participating carsharing operators, including Enterprise CarShare and Zipcar, also operated throughout New York City before the pilot. Figure 1 shows an annotated map of the pilot zones of the pilot program. Additional background on the pilot program can be found at https://nycdotcarshare.info/.

Figure 1: Annotated Map of Carshare Pilot Zones



Source: New York City Department of Transportation

Background on Carsharing

A Brief History of Carsharing

Carsharing first began in 1948 in Zurich, Switzerland under a cooperative called "Sefage" (Shaheen et al., 1999). Various early systems and pilot projects continued through the subsequent decades, but most programs survived only for short periods of time. Modern carsharing arguably began in the late 1990s. Outside an experiment conducted in San Francisco in the 1980s, carsharing began its current continuous presence in the U.S. in 1998, and the industry has expanded significantly since then (Martin et al., 2016). The industry expanded through growth within major cities, where city-specific organizations defined the early principles and lessons learned from impacts. However, consolidation was already happening even during these early years, with Zipcar and Flexcar expanding rapidly, and then merging under the name of Zipcar in 2007. As the 21st century entered its second decade, many of the larger city-specific operations closed or merged with major operators including Enterprise CarShare and Getaround. As of 2018, there were over two million carsharing members in North America (Shaheen and Cohen, 2020). The market for carsharing has also diversified, and programs have served an array of market segments, including: neighborhood residential, residential developments, businesses, government fleets, low-income markets, and college/university markets (Shaheen et al., 2008). In terms of business models, most U.S. carsharing operators employ either a business-to-consumer (B2C) model, where an operator maintains a vehicle fleet, or a peer-to-peer (P2P) model, where members rent out their privately-owned vehicles as part of a peer network (Shaheen et al., 2018b). Carsharing services can either be roundtrip: where vehicles must be returned to the same space they were retrieved from, or one-way: where vehicles can be dropped off anywhere within a specified zone (free-floating) or from one station to another (station-based). In New York City, Zipcar is the largest and presently only carsharing operator. Enterprise CarShare was a more recent entrant into the market and was a participant in the study, but it suspended operations in the city in March 2020. Car2go, which eventually merged with ReachNow (and later became ShareNow), introduced free floating (one-way) carsharing services into the market, but also exited New York City (and the broader United States) during the pilot period due to financial challenges.

Selected Previous Research Carsharing Impacts

Several past studies have documented the impact of carsharing on travel behavior, vehicle ownership and the resulting changes in VMT and GHG emissions. Many studies on carsharing have shown overall reductions in private vehicle ownership among members of both roundtrip and one-way systems. A study of North American roundtrip carsharing members found that 25% of members sold a personal vehicle and another 25% postponed a vehicle purchase, due to carsharing. The study also found that one roundtrip carsharing vehicle replaces 9 to 13 private vehicles among members (Martin and Shaheen, 2011). Similarly, a multi-city study of car2go (later known as ShareNow), a free-floating carsharing operator, found that each free-floating carsharing vehicle removed seven to ten privately-owned vehicles as a result of private vehicles sold and purchases avoided (Martin et al., 2016).

These reductions in vehicles on the road have also led to net reductions in driving and GHG emissions. Martin and Shaheen (2011) found a net VMT reduction of 27% to 43% and GHG reductions of 34% to 41% per roundtrip member. Martin et al. (2016) found more modest VMT and GHG emission reductions due to free-floating carsharing, ranging from a 6% to 16% reduction in VMT and a 4% to 18% reduction in GHG emissions, depending on the city. While magnitudes differ, more than a dozen studies across different operators and in various cities have found that carsharing reduces net VMT and GHG emissions among members.

Modal shift results are more mixed. Previous research has found that while the majority of carsharing users do not experience changes in their public transit use, a greater portion of members decrease their public transit use than those that increase their use, due to the availability of carsharing (Martin et al., 2016). Similarly, a study of P2P carsharing operators in the U.S. showed mixed impacts on public transit use (Shaheen et al., 2018b). Meanwhile, some studies show that members increase their use of active transportation modes, like biking and walking, due to carsharing (Martin and Shaheen, 2011; Martin et al., 2016). A summary of shared mobility policy and impacts was produced by Shaheen et al. (2019). Among the outputs of that work was a summary of many impact studies on different types of carsharing. Table 1 as summarized and excerpted from Shaheen et al. (2019) presents a review of impacts as determined for round trip carsharing systems by previous studies. Table 2, which immediately follows, is also excerpted from the same work and summarizes impacts as determined for free-floating and P2P carsharing systems. It should be noted however that while P2P carsharing systems operate in various regions of North America, they are currently illegal in New York State, including New York City.

Table 1: Summary of Roundtrip Carsharing Impact Studies

Operator and Location	**Authors, Year**	Number of Vehicles Removed from the Road Per Carsharing Vehicle	Members Selling Personal Vehicle %	Members Avoiding Vehicle Purchase %	VMT/VKT Change % per Member
Round Trip Carsharing Studies					
Short-Term Auto Rental - *San Francisco, CA*	(Walb & Loudon, 1986)		15.4	43.1	
Arlington Carsharing (Flexcar and Zipcar) *Arlington, VA*	(Price & Hamilton, 2005)		25	68	-40
	(Price, DeMaio, & Hamilton, 2006)		29	71	-43
Carsharing Portland - *Portland, OR*	(Katzev, 1999)		26	53	
	(Cooper, Howe, & Mye, 2000)		23	25	-7.6
City Carshare - *San Francisco, CA*	(Cervero, 2003)		2.5	60	-3.0[a]/- 58.0[b]
	(Cervero & Tsai, 2004)	6.8	29.1	67.5	-47.0[a]/ 73.0[b]
	(Cervero, Golub, & Nee, 2007)				-67.0[a]/ 24.0[b]
PhillyCarshare - *Philadelphia, PA*	(Lane, 2005)	10.8[c]	24.5	29.1	-42
TCRP Report –- *North America*	(Millard-Ball, ter Schure, Fox, Burkhardt, & Murray, 2005)				-63
Surveyed Members of Eleven Carsharing Companies	(Martin & Shaheen, 2011)				-27
	(Martin, Shaheen, & Lidicker, 2010)	9.0-13.0	23	25	
Zipcar - *U.S.*	(Zipcar, 2005)	20	32	39	-79.8
Modo - *Vancouver, Canada*	(Namazu & Dowlatabadi, 2018)	5		55	

[a] Reflects existing members' reduction in VMT/VKT.
[b] Reflects only trial members' reduction in VMT/VKT.
[c] Reflects vehicles removed by members who gave up a car.

Table 2: Summary of One-way and P2P Carsharing Impact Studies

Operator and Location	**Authors, Year**	Number of Vehicles Removed from the Road Per Carsharing Vehicle	Members Selling Personal Vehicle %	Members Avoiding Vehicle Purchase %	VMT/VKT Change % per Member
One Way Carsharing Studies					
Car2Go (U.S. and Canada)	(Martin & Shaheen, 2016)	7.0-11.0	2.0-5.0	7.0-10.0	-6.0 to -16
Car2Go (Vancouver, Canada)	(Namazu & Dowlatabadi, 2018)	6		55	
Car2go (San Diego, CA)	(Shaheen, Martin, & Bansal, 2018a)				
P2P Carsharing					
Getaround, RelayRides (Turo), and eGo Carshare *U.S.*	(Shaheen, Martin, & Bansal, 2018b)		0.14	0.19	
Getaround *Portland, OR*	(Dill, McNeil, & Howland, 2017)			0.44	

Although a pattern of carsharing impacts have emerged within past research, more research is needed to determine whether impacts have changed over time due to the growing presence of other shared mobility options (e.g., transportation network companies (TNCs) such as Uber and Lyft, micromobility) and across different geographies and land-use types. Overall, research has shown that carsharing, while sometimes reducing the use of public transit, has generally had a positive impact of personal mobility and enabled reductions in VMT. In the sections follow, we present the methodology and results of this study implementation.

Methodological Overview

The study employed several instruments to evaluate the impact of carsharing in New York City and the impact of the pilot program. These instruments included several surveys and carsharing vehicle activity data.

Surveys

The methodology consisted of conducting three different surveys to members of carsharing organizations operating in New York City. The first survey deployed was the retrospective survey that targeted residents who were members of carsharing services before the beginning of the pilot. This survey was intended to assess transportation behavioral trends and vehicle ownership patterns of these users before introducing the pilot. The retrospective survey was initially launched in April 2018 (N=2,700), and it included responses from ReachNow members in addition to Zipcar and Enterprise

CarShare members. For those who opted in, there was opportunity to enter a drawing for an incentive for one of twenty $50 Amazon gift cards to respondents.

The second survey deployed was a before survey that was administered to persons who joined one of the participating carsharing services after the launch of the pilot program. The purpose of the survey was to establish a baseline measure of new members' travel behavior and vehicle ownership so that a comparison could be made to the travel behavior measurements of a later survey. The before survey was launched in July 2018 (N=1,051). As with the retrospective survey, for those who opted in, there was an opportunity to enter a drawing for an incentive for one of twenty $50 Amazon gift cards to respondents with each survey. There were four before survey releases, with one deployed at the end of each quarter during the first year of the pilot to capture travel behavior relatively soon after the person joined carshare.

The third and final survey was the after survey, which was launched in September 2019 (N=841). This survey focused on capturing behavioral changes and attitudes of carsharing users in response to the pilot service as well as carsharing in New York City more broadly. The after survey contained special questions that asked respondents about the direct impacts of the carsharing and the pilot service. For those who opted in, there was an opportunity to enter a drawing for an incentive for one of twenty $50 Amazon gift cards to respondents.

All three surveys consisted of questions that addressed four major subject areas: 1) introduction and household structure; 2) vehicle ownership, suppression, and shedding; 3) travel patterns and mode shift; and 4) demographics. Brief descriptions of these questions and their purpose are provided as follows.

1) Intro and Household: A number of questions were included in each survey to construct a profile of respondents' carsharing memberships and also learn more about the household composition of each respondent. The household questions were also included to determine the appropriate wording in several questions administered later in the survey. Namely, vehicle ownership questions sometimes need to be asked in the context of the household, and sometimes they need to be asked in the context of an individual. For example, people living in the same dwelling as roommates often share expenses, but not income. In such cases, we ask vehicle ownership questions of the respondent in the context of being an individual. But, when people living together share income (married or not), then we ask such questions in the context of being a household.

2) Vehicle Ownership, Suppression, and Shedding: Questions were asked in each survey to construct a profile of respondents' vehicle holdings before, during, and after the pilot service was implemented. These questions sought to determine whether respondents had shed any vehicles, and if so, whether it was due to carsharing in New York City. Additionally, the survey asked questions about whether carsharing services had caused them to delay or avoid acquiring a vehicle, which we refer to as personal vehicle suppression. The answers to these questions were used to conduct an analysis of greenhouse gas emission impacts from carsharing services in New York City.

3) Travel Patterns and Mode Shift: Questions were asked in each survey to construct a profile of respondents' travel behavior patterns before and after the pilot service, and to measure the direction of mode shift due to the use of carsharing. Furthermore, several questions assessed the magnitude of change in mode use as a result of carsharing. These questions helped to evaluate the degree to which carsharing enabled mode shift across the spectrum of travel options available to residents of New York City.

4) Demographics: To understand the demographic profile of respondents within each of the three surveys, questions asked respondents for their age, race, ethnicity, income, and transportation expenses. The profile of these demographic attributes could be compared to the distributions of the broader populations. The surveys also asked respondents to provide the nearest cross streets to their home and work locations, which permitted a better understanding of commute demands of carsharing members, as well as helped to inform the spatial distribution of member residence and member employment.

Questions within these broad categories served to inform the behavioral and user impacts that members of carsharing operations experience as a result of the system. They served to measure the nature and magnitude of behavioral change, in the form of vehicle ownership impacts and travel behavior impacts that otherwise would not be possible without access to shared automobiles. While these behavior changes may reduce the need for personal vehicle ownership, there is also the flip side of the service provision. The mobility provided by carsharing vehicles puts VMT on New York City roads and also needs to be measured. To evaluate this activity, we worked with vehicle activity data as provided by the carsharing operators participating in the pilot. This served to achieve a number of objectives. It allowed us to analyze distributions of frequency of use as well as overall VMT by member activity. The first function permits us to better understand how our population compares to the sample as it relates to impacts. One assumption we make about our sample respondents is that they are more likely to be frequent users of the carsharing system. Frequent system users are naturally important to any system. But when it comes to measuring impacts, their increased likelihood to respond to a survey (about anything they use) means that the sample is more likely to be balanced towards frequent users. This would not be a problem if frequency of use was an attribute that was independent of impacts. However, this is not the case. Frequent users are more likely to be impacted by the system they use, and in the case of carsharing, this can mean that more frequent users of carsharing may be more likely to shed or suppress a vehicle as a result of use. At the same time, less frequent users, who do not exhibit as profound of impacts, are underrepresented in the sample relative to their share of the population. Hence, considering the impacts of the raw sample, absent any adjustment of this imbalance could lead to an overrepresentation of frequent users within the population. By weighting the sample according to frequency of use, we can evaluate and account for the likely overrepresentation of very frequent users within the sample and provide a more accurate assessment of impacts at the scale of the overall member population. This weighting in turn aligns the behavioral impacts derived from the sample with the population level VMT observed in the activity data that is explained in the following section.

The evaluation team worked with the participating carsharing operators to deploy the survey to existing members. For the retrospective survey, the operators that participated in survey disbursement included ReachNow, Zipcar, and Enterprise CarShare. Only the latter two participated in the before and after surveys, as ReachNow withdrew from New York City before the launch of the pilot in June 2018. The Qualtrics platform was used to construct each of the three online surveys. Additionally, for those after survey respondents who did not take the before survey, the evaluation team included questions from the retrospective survey that allowed it to assess impacts and changes to travel behavior as a result of carsharing. This mechanism was made possible through the use of de-identified hashes that were assigned to each respondent of the before and after surveys (described further in the next section).

Several limitations were inherent in the survey. First and foremost, the impacts for mode shift, vehicle ownership, and commuting patterns are self-reported. This is an expected limitation that is generally associated with this data collection method. Additionally, a number of responses had to be filtered out due to being incomplete, and others were excluded as duplicate responses. As noted earlier, the survey sample can be biased by frequency of use, and this needs to be considered and accounted for to the extent possible. Despite these limitations, the survey and activity data combined can provide an accurate snapshot of how citywide behavioral and vehicle ownership trends are changing due to carsharing.

Activity data design

In order to determine the overall trips taken by members, VMT, and GHG emissions produced by the program and to weight impacts from the survey to the population level, we requested activity data from the operators involved in the pilot program. These activity data were anonymized into de-identified IDs (DeIDs) before transmission to the research team and have no personally identifiable information embedded within them. DeIDs across operators were created as emails that were encrypted with the same hash function and shared salt, which is a fixed and preferably long string of characters that is added to the end of each string and run through the hash algorithm. This adds additional security, because an attacker would not only have to guess the email being hashed, but also the hash itself. Given the length of standard salts, a successful guess is highly improbable. At the same time, the salt does not interfere with the fact that an email hashed with a salt attached to it will always produce the same unique output. So DeIDs would still match if a respondent was a member of two or more carsharing systems (this assumes that they registered with the same email to each operator). Hashes are one-way encryptions that cannot be decrypted without the original input and salt. Data requested from the operators included the following information for each month of operations between April 1, 2017 and September 30, 2019:

Totals per month:

- Total miles driven on all vehicles
- Total number of trips on all vehicles
- Total number of vehicles in NYC fleet
- Total number of members in NYC

User distributions for each month:

- Distribution of miles driven by user

- Distribution of trips made by user (frequency of use)

Totals by respondent DeID for each month:

- Miles by respondent DeID
- Trips by respondent DeID

Average fleet fuel economy for each month

- Average fuel economy of all carsharing vehicles in fleet

The total miles, trips, vehicles, and members per month were used to calculate the aggregate VMT and trips taken during the course of the study. These data are also important for understanding the overall scale of activity enabling behavioral change within the user population. The frequency of use distributions were used to understand how user behavior varies across the entire population. These data, along with respondent totals, are used to calculate weighted VMT and GHG impacts that are reflective of the entire carsharing member population. Lastly, the average fleet fuel economy for each month was used to calculate the energy impacts of the program by converting total VMT into GHG emissions. Fuel economy factors were derived from the EPA Fuel Economy Database and emissions were calculated in units of carbon dioxide-equivalents (CO_2-e).

Results

Demographics

To assess how representative the survey samples were of the broader population of New York City (NYC), the demographics for each survey are compared to the demographic statistics provided by the 2018 1-year estimates from the American Community Survey (ACS) for the city. These attributes for gender, age, and education are presented in Table 3. The results show that the retrospective and before surveys had higher proportions of males than the general population. The gender split for the after survey was closer to the split of population for the city.

The age distribution also provides some important insights. First, the 18-24 year old cohort was slightly underrepresented in the three surveys while those between 25 and 34 years of age were overrepresented. Second, those in the 35 to 44 category were also overrepresented in the population. While the 55 to 64 age category for the three surveys was closer in representation to the population, older ages were underrepresented in the survey sample. This suggests, as has been found by other carsharing studies, that the distribution of carsharing users in NYC is slightly younger than the general population. Concerning education, the survey respondents suggest that overall members attained higher levels of education in comparison to the general population. Considerably higher proportions of the respondents across all surveys attained more 4-year degrees and post-graduate degrees than the general population, which indicates that overall, the distribution of carsharing users in NYC are more educated than the general population. Table 3 presents the comparative demographic distributions.

Table 3: Gender, Age, Education for Three NYC Carsharing Surveys vs. 2018 1-year ACS estimates

DEMOGRAPHICS	*2018 1-year ACS*	*Retrospective Survey* *April 2018*	*Before Survey* *July 2018 to April 2019*	*After Survey* *September 2019*
Gender	N = 8,398,748	N = 2,616	N = 1,020	N = 724
Male	47.7%	59.9%	53.6%	49.7%
Female	52.3%	39.5%	46.0%	49.7%
Other, please specify:	-	0.6%	0.4%	0.5%
Prefer not to answer	-	2.0%	2.0%	0.1%
Total % (without prefer not to answer)	100%	100%	100%	100%
Age	N = 6,659,492	N = 2,586	N = 998	N = 817
18 to 24	10.7%	3.4%	7.6%	5.0%
25 to 34	22.5%	28.6%	38.6%	35.9%
35 to 44	17.2%	30.4%	30.3%	29.3%
45 to 54	15.9%	18.4%	12.9%	16.3%
55 to 64	15.0%	11.9%	5.0%	8.1%
65 to 74	10.5%	6.0%	4.6%	4.2%
75 or more years	8.2%	1.4%	1.0%	1.3%
I prefer not to answer	-	0.0%	0.0%	0.4%
Total % (without prefer not to answer)	100%	100%	100%	100%
Education	N = 6,659,492	N = 2,555	N = 979	N = 797
Currently in High School or less than High School	16.8%	0.6%	1.2%	1.0%
High School Degree or Equivalency	24.1%	4.7%	10.2%	10.0%
Some College or Associate's Degree	22.2%	10.8%	17.1%	12.0%
Bachelor's Degree	22.3%	44.7%	39.4%	40.0%
Post-Graduate Degree	14.6%	39.3%	32.1%	37.0%
Prefer not to answer	-	3.8%	4.9%	4.0%
Total % (without prefer not to answer)	100%	100%	100%	100%

Table 4 presents the demographic distributions for samples and populations of income and race/ethnicity. The income distribution for the three surveys suggested that members on average have a higher income as compared to the general population. While 41.3% of the NYC household population made less than $50,000 in 2018, 16.6%, 31.4%, and 23.6% of the respondents to the retrospective, before, and after survey respectively reported household incomes under that limit. Furthermore, the three surveys had higher proportions of respondents making over $100,000 in comparison to the ACS estimates. These distributions suggest that the carsharing population is wealthier than the general population. With respect to the race/ethnicity, the survey sample distributions show that higher proportions of the respondents were White in comparison to the population. Most other race/ethnicities were slightly less represented relative to the population, including Black or African Americans, Asians, and Hispanic/Latinos (see Table 4).

It is important to note that the proportion of Black or African Americans did increase in the before (12.7%) and after surveys (12.9%) relative to the retrospective survey (8.5%). This suggests that the survey sample became more diverse as the pilot progressed. One of the reasons for this shift was that before survey respondents represented a population of newer carsharing members, as well as a population of carsharing members that joined from within or near the pilot areas. The pilot areas were chosen to be in areas with a greater racial diversity. Thus, simply by this geographic positioning, the pilot program may have encouraged increasing racial diversity among members. The findings presented in Table 4 are generally consistent with the demographic findings of previous shared mobility studies, including bikesharing and TNCs.

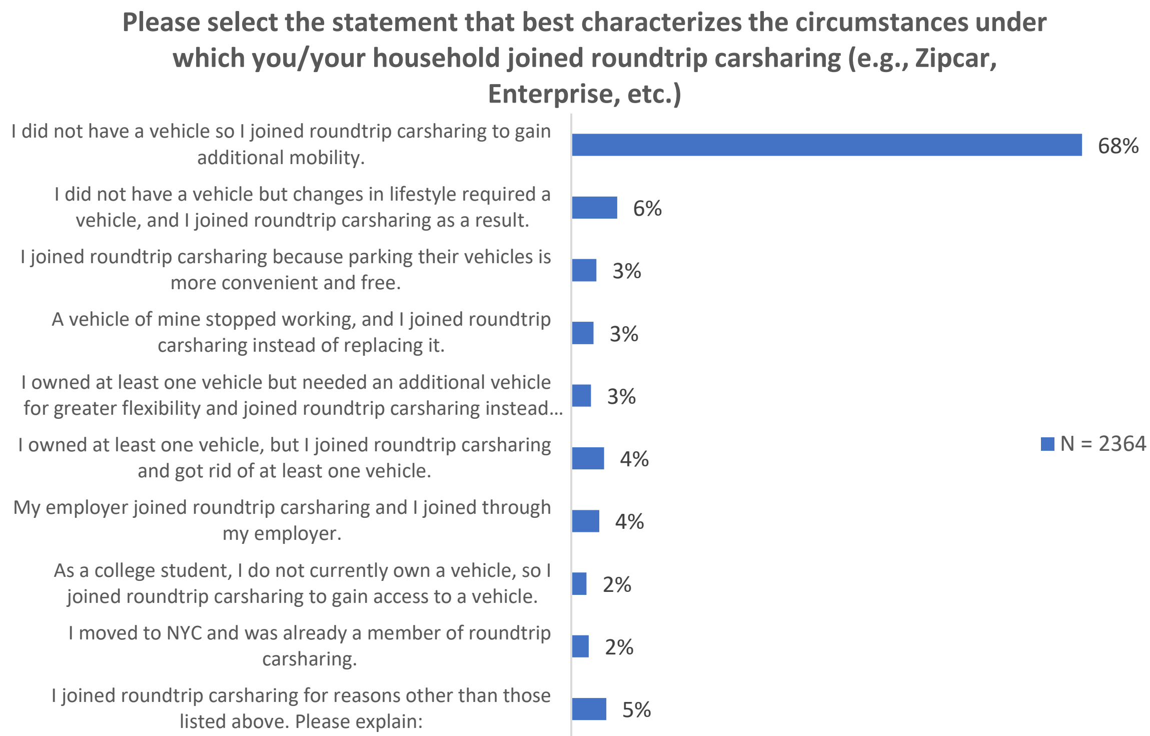
Table 4: Income and Race/Ethnicity for Three NYC Carsharing Surveys vs. 2018 1-year ACS estimates

DEMOGRAPHICS	*2018 1-year ACS*	*Retrospective Survey* *April 2018*	*Before Survey* *July 2018 to April 2019*	*After Survey* *September 2019*
Income	N = 3,184,496	N = 2264	N = 911	N = 724
Less than $10,000	8.9%	1.9%	4.1%	1.4%
$10,000 to $14,999	5.6%	1.3%	2.4%	0.8%
$15,000 to $24,999	9.1%	2.3%	5.0%	4.7%
$25,000 to $34,999	7.6%	3.9%	9.3%	6.2%
$35,000 to $49,999	10.1%	7.2%	10.6%	10.5%
$50,000 to $74,999	14.3%	12.5%	14.1%	14.8%
$75,000 to $99,999	11.1%	11.9%	12.5%	13.5%
$100,000 to $149,999	14.4%	20.1%	17.0%	18.2%
$150,000 to $199,999	7.5%	13.8%	8.9%	9.0%
$200,000 or more	11.4%	25.0%	16.0%	20.9%
Prefer not to answer	-	14.3%	11.7%	12.8%
Total % (without prefer not to answer)	100.0%	100.0%	100.0%	100.0%
Race/Ethnicity	N = 8,398,748	N = 2757	N = 969	N = 761
White	31.9%	57.3%	49.4%	51.1%
Black or African American	21.7%	8.5%	12.7%	12.9%
American Indian and Alaska Native	0.2%	0.3%	0.0%	0.1%
Asian	14.1%	9.0%	10.5%	9.9%
Native Hawaiian and Pacific Islander	0.0%	0.1%	0.2%	0.1%
Hispanic or Latino	29.2%	8.2%	16.9%	16.8%
Two or more races	2.2%	15.5%	8.8%	7.9%
Other	0.8%	1.2%	1.4%	1.2%
Prefer not to answer	-	5.3%	6.4%	8.4%
Total % (without prefer not to answer)	100%	100%	100%	100%

Travel Behavior Impacts

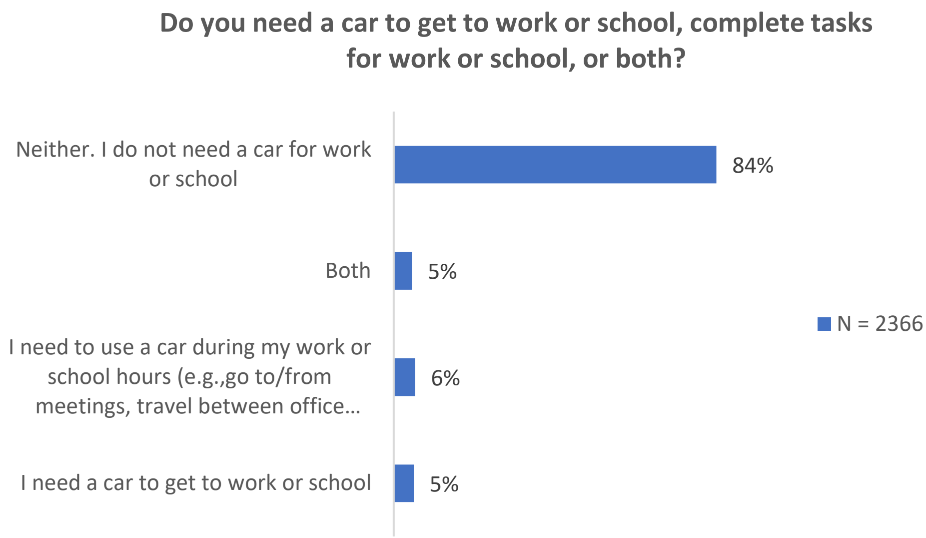
One of the main objectives of this research project was to gather insight on how carsharing is impacting the travel patterns of residents of New York City. A number of questions were presented in the three surveys to gauge the impact that carsharing services had on various aspects of life for system users. One of those questions inquired about the reasons that prompted residents of the city to adopt carsharing. Figure 2 shows the responses to a question in the retrospective survey that asked respondents to select the best statement that described the circumstances under which they joined carsharing. An overwhelming majority (68%) of respondents indicated that they joined roundtrip carsharing services to acquire additional mobility. In the first retrospective survey, an analogous question was asked for one-way carsharing, which was still operating at the time of this survey, the distribution of those responses (not shown) revealed similar results.

Figure 2: Reasons for Joining Roundtrip Carsharing (from Retrospective Survey)



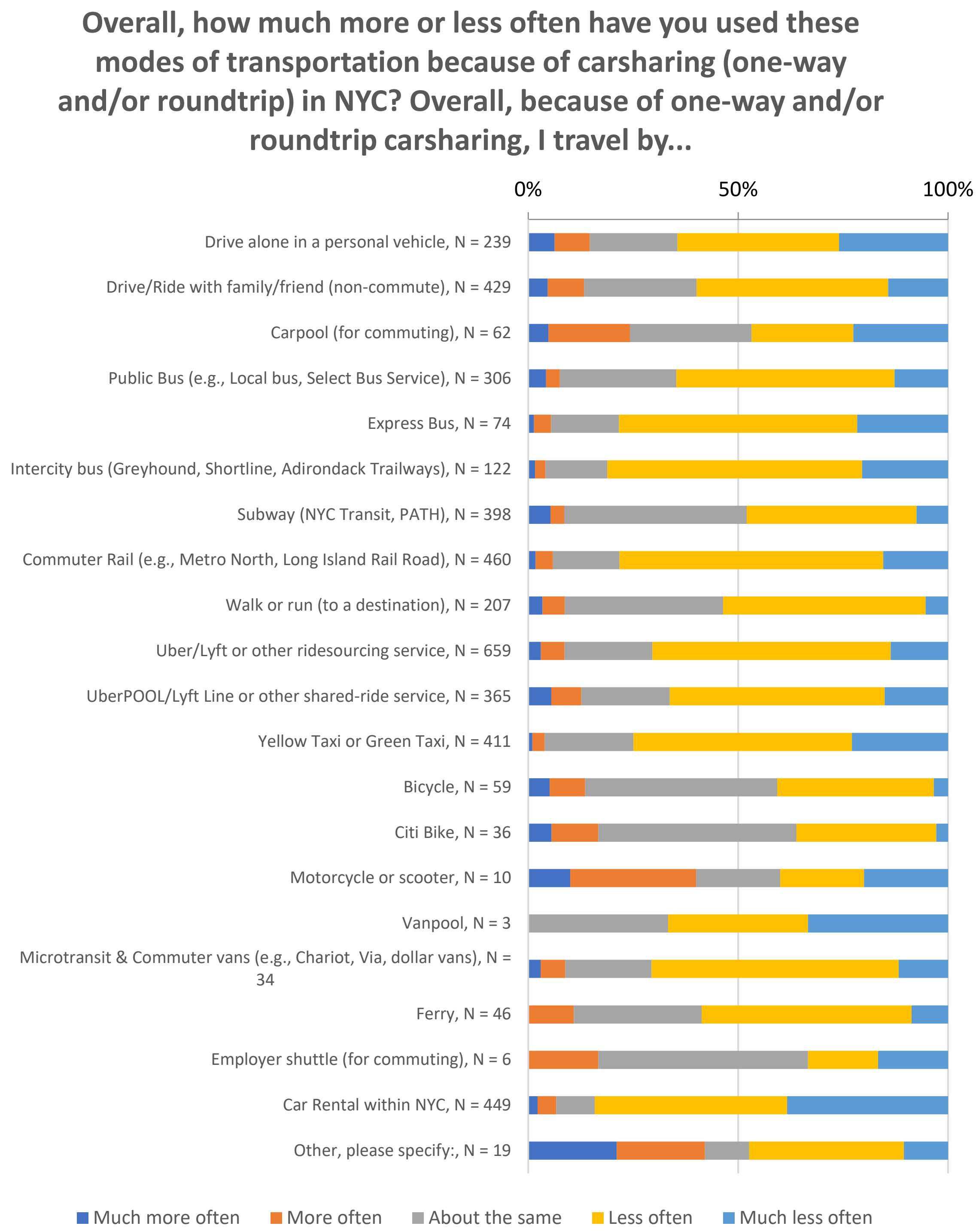
The results from Figure 2 suggest that additional mobility is an important motivator for users in joining roundtrip carsharing. The responses concerning the trip purposes of carsharing trips also support this finding. For example, a majority of respondents indicated that they used roundtrip carsharing for social/recreational trips to locations outside of the five boroughs, while a majority of respondents of one-way carsharing indicated that they used the service for social/recreational trips to locations within the city. A relatively small share of respondents indicated using either form of carsharing for commuting to work or school. This is a common finding for carsharing, where the nature of the service and cost structure does not economically facilitate its use for commuting. Respondents were also asked whether they needed a car to travel to work or school. Most respondents, as seen in Figure 3, answered that they do not need a car for trips to work or school. This finding held for the analogous questions across all surveys administered. Collectively, these results support the finding that carsharing was primarily used for non-work trips requiring an automobile.

Figure 3: Respondent Need of Car to Travel to Work and/or School (from Retrospective Survey)



The surveys also included questions that asked respondents how carsharing impacted their use of other modes of transport. In the first retrospective survey, respondents were asked how one-way carsharing and roundtrip carsharing impacted their mode use separately. The before and after surveys asked only about roundtrip carsharing since the one-way (free-floating) operators did not participate in the pilot. The results showed that considerable portions of respondents reported that no change in mode use had occurred due to carsharing. Yet other modes exhibited more substantial shifts. For example, the mode that had the highest percent of respondents indicating change in use was car rental. The general mode shift impacts of carsharing across all modes are presented in Figure 4 for the retrospective survey. The distribution of responses indicates the change in mode as a result of carsharing on a Likert scale, where respondents could effectively indicate their shift in usage was either “Much more often,” “More often,” “About the same,” “Less often,” or “Much less often.”

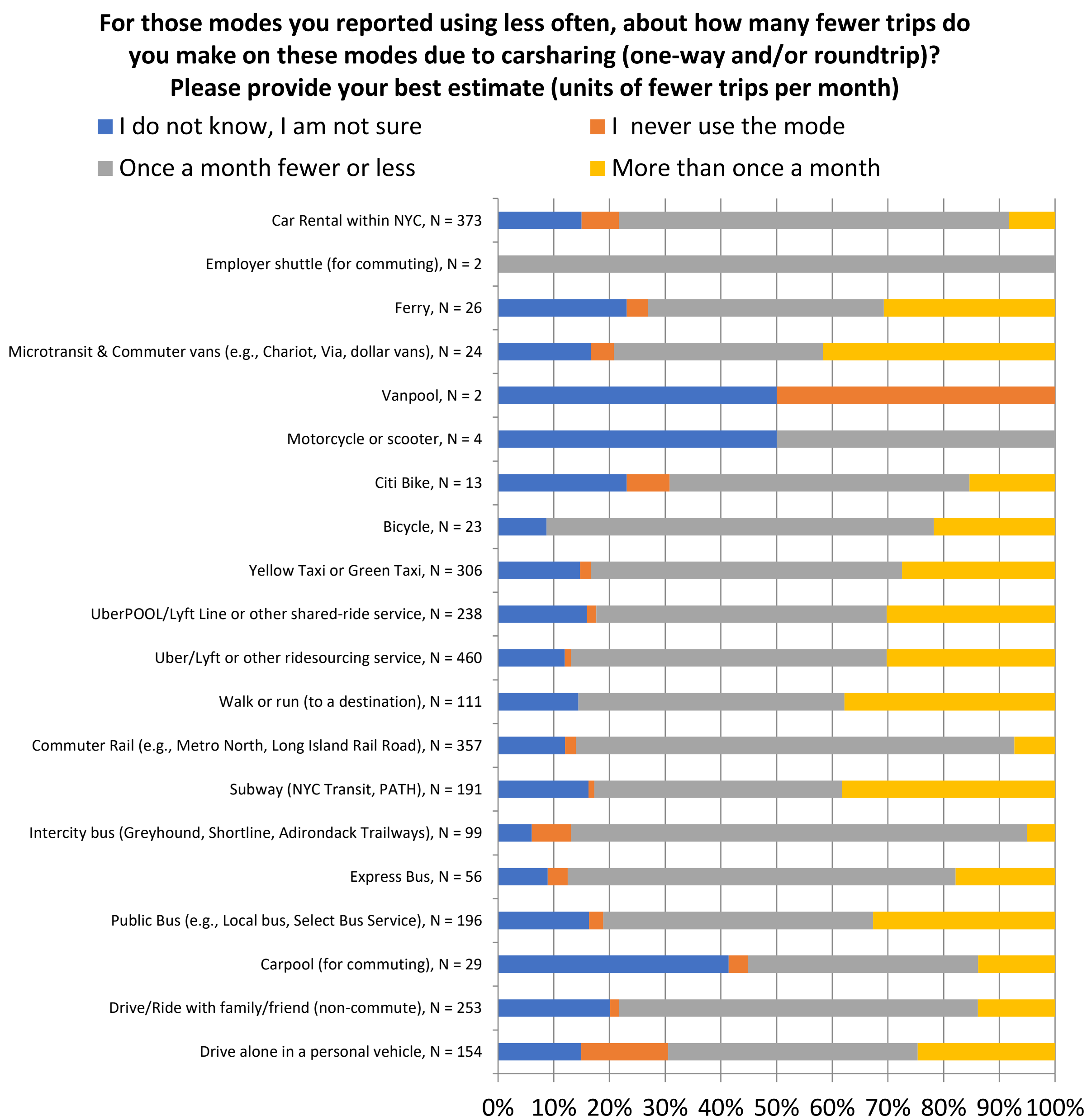
Figure 4: Change in Mode Use Due to Carsharing (from Retrospective Survey)



The results from the retrospective survey show most of the shift is notably away from other modes, including drive alone, public transit, and the active modes of walking and bicycling. The highest levels of substitution occurred with modes that directly compete with carsharing including the aforementioned car rental, TNCs and taxis, as well as commuter rail and bus. However, some shift towards each mode as a result of carsharing was also noted for a minority of users.

The ordinal scale responses presented in Figure 4 are relative to the person, meaning that using a mode 'less often' can mean different things to different people. A follow-up question was designed to assess a more precise magnitude of change. Respondents that used one or more modes 'less often' or 'much less often' were asked to estimate the reduction in frequency of travel of those modes. Figure 5 presents the distribution of reduction in frequency of use across all modes with a consolidation of responses into four aggregated categories. The figure shows the magnitude of how much less respondents are using each mode due to carsharing (e.g., now using the mode once a month fewer or less than that). Notably, Figure 5 shows that the largest declines in frequency of use occurred for walking and transit modes, but also notably for TNCs, taxis, and drive alone.

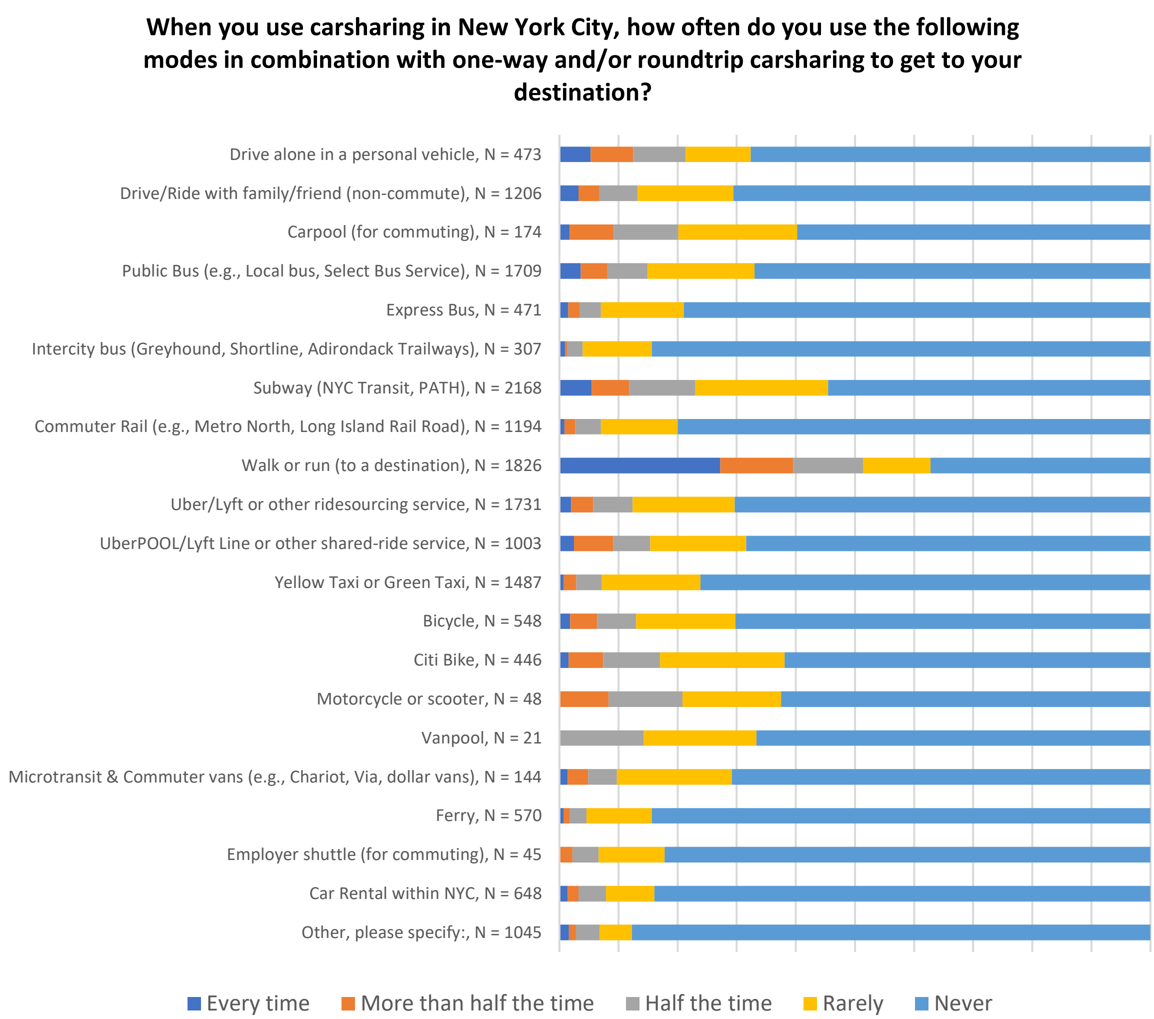
Figure 5: Magnitude of Reduction in Frequency of Use of Mode Use from the first Retrospective Survey



Building on these findings, a couple questions were included in the surveys that asked respondents about their recent trip using roundtrip or one-way carsharing. The questions asked respondents to select the mode they would have used if carsharing was not available on their most recent trip (with a carsharing vehicle). The results show that driving alone or with a friend or family member were selected far less frequently relative to other options such as car rental, Uber/Lyft, commuter rail, or not taking the trip at all.

Follow-up questions in both the retrospective and after surveys further explored why reductions in public transit occurred. The top three responses (respondents could only pick one) were 'public transit routes do not serve the places I go well enough,' (n = 194, 30%) 'carsharing is faster,' (n = 165, 26%) and 'carsharing allows me to better transport packages and groceries' (n = 94, 15%). These results suggest that for about 70% of respondents that reduced their use of public transit, that carsharing offered better convenience in terms of access, speed, or function. Figure 6 shows how often respondents in the retrospective reported using other modes in combination with carsharing to complete trips. Note that the modes most often combined with carsharing included walking, public transit, and Citi Bike bikesharing.

Figure 6: Combination of Mode Use with Carsharing

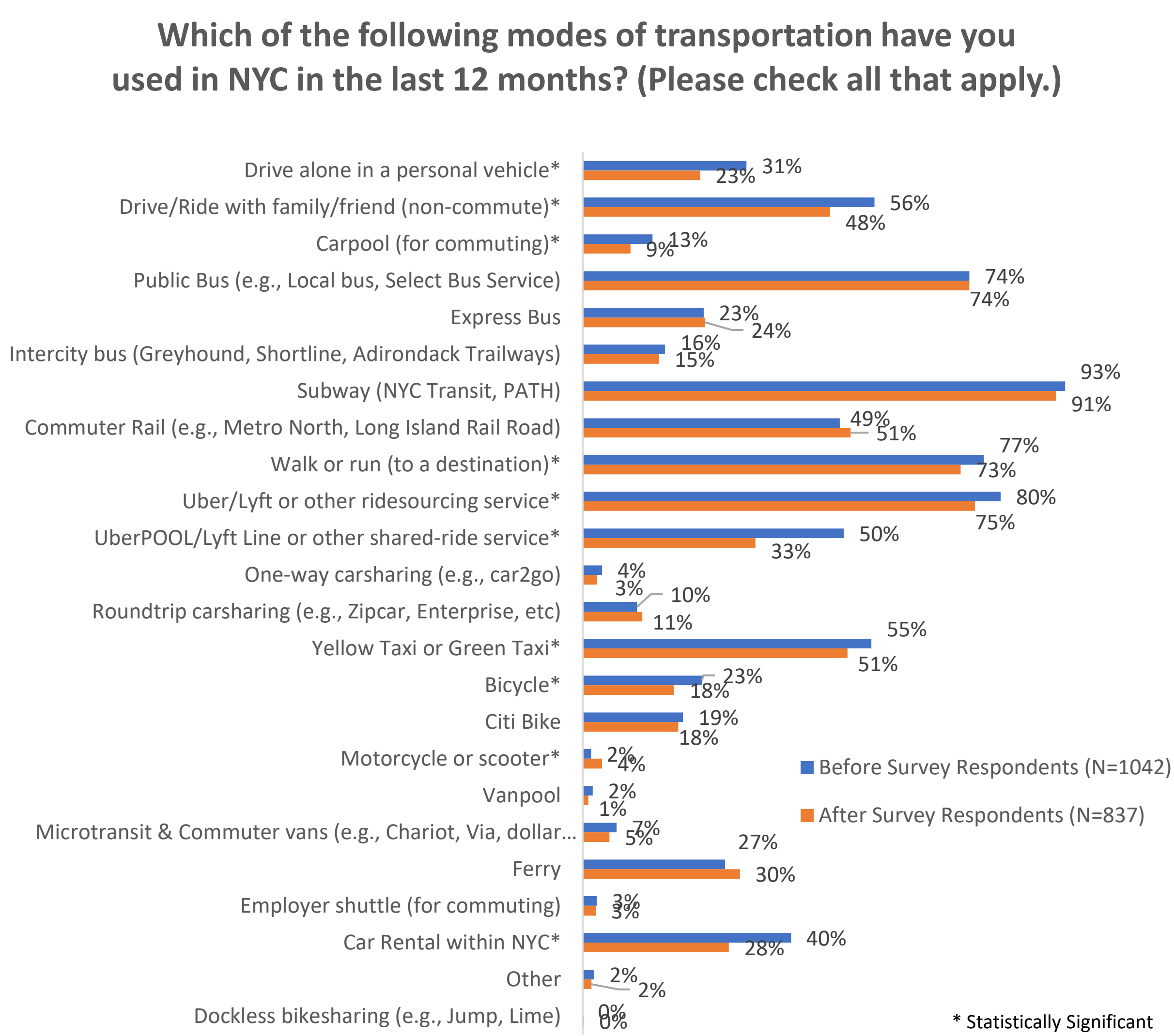


In the sections that follow, we explore comparisons between the before and after surveys implemented during the pilot and later review data that reveal insights on the pilot program impacts and how the response to specific questions as well as other data provides insights on the impact of the pilot zones.

Analysis of the Before and After Surveys

A more direct comparison of the results of the before and after surveys can provide a deeper understanding of how behaviors and perceptions have changed over the course of the pilot. A number of analogous questions related to travel behavior, commuter patterns, and vehicle ownership are presented from the two surveys. Figure 7 displays the response breakdown for the mode choice questions asked in the before and after surveys respectively. The comparison shows a modest reduction in the use of certain personal vehicle modes, while usage rates of public transit remain relatively constant. Note that the comparison of response evaluates whether people used the mode at all during the last 12 months. It does not directly compare changes in use within respondents, but changes in the distribution of the same question across the two surveys. Most of the other modes' proportions stayed fairly constant between the two surveys. Note that the after survey includes dockless bikesharing as a mode while the before survey did not, as this was added in the update to the after survey.

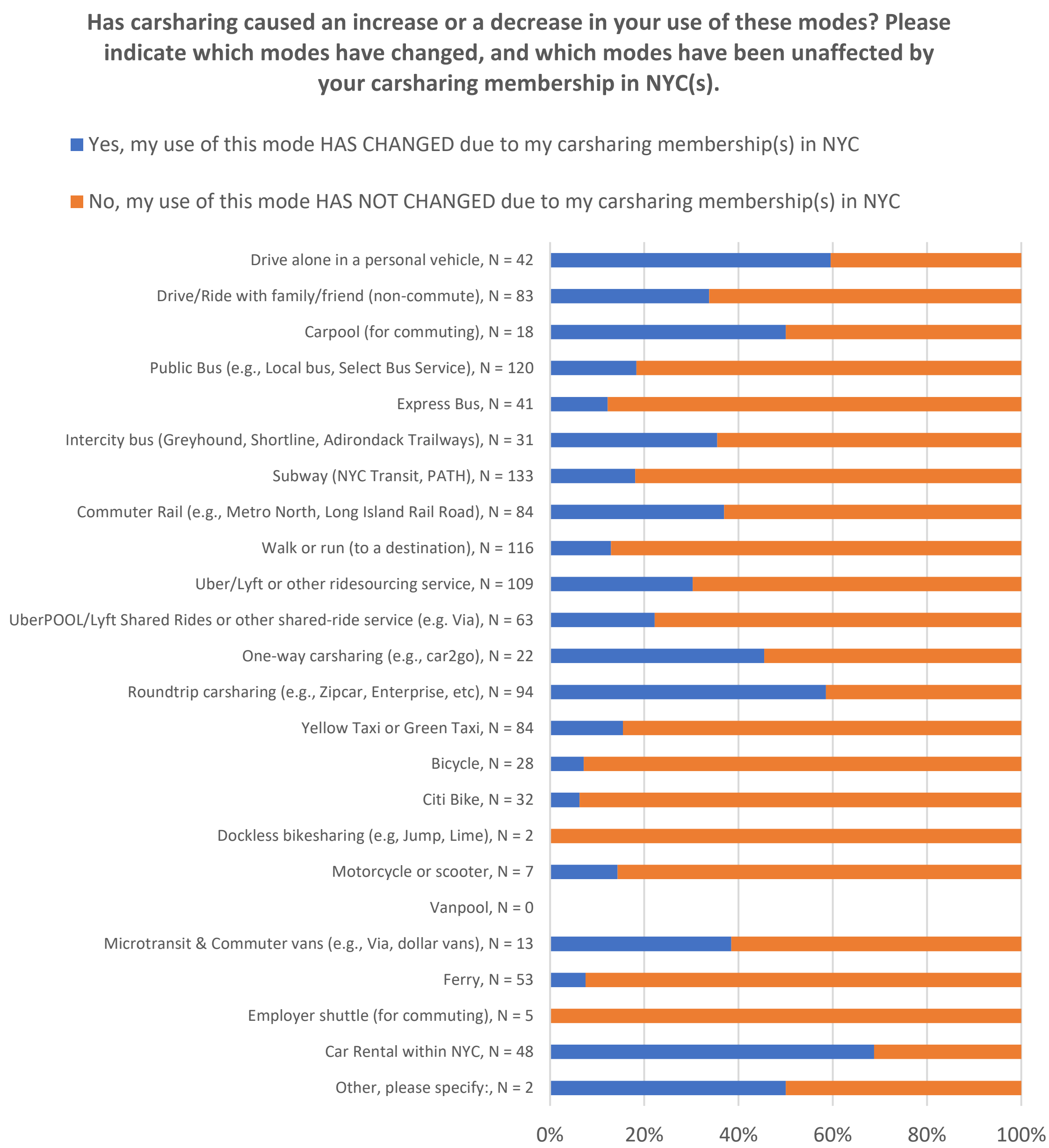
Figure 7: Mode Choice over preceding 12 months for Before Survey Respondents



As noted by the asterisk, the differences in the proportion of use for several modes are statistically significant. These include modes that are expected to be directly impacted by carsharing. Namely, the after survey sample shows that there was a statistically significant drop in the share of members 1) Driving along, 2) Driving and Riding with family or friends, 3) Carpooling, 4) using Uber/Lyft in a single ride or 5) in a pooled manner, 6) Bicycle, and 7) Car Rental within NYC. While not directly evaluating self-reported change, these data reflect the share of members using the mode at all. Impacts on change in mode use are further explored below.

Respondents were asked how their mode use had changed in response to carsharing. The results to this question are presented in *Figure 8*. The results show that that a number of respondents decreased driving alone and taking car rentals in response to carsharing. Impacts of carsharing on the use of other modes was present but found to be less pronounced for members who joined during the pilot. But impacts are notable with several transit modes, including the longer distance modes of commuter rail and intercity bus.

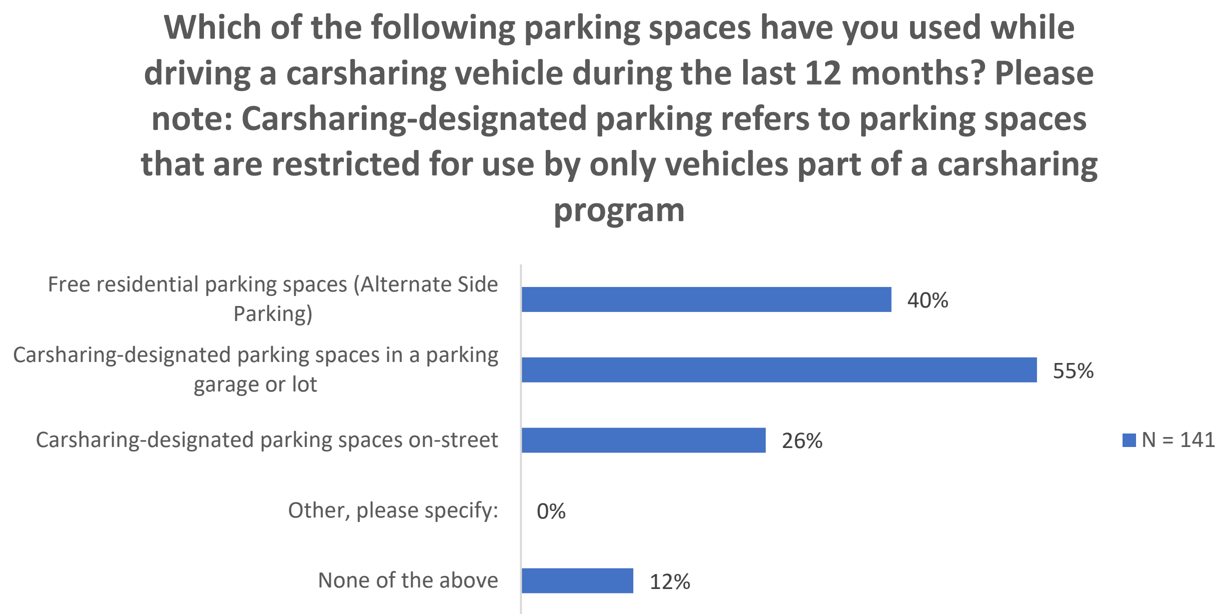
Figure 8: Change in Mode Use Due to Carsharing As Reported by After Survey Respondents



Pilot Programs Impact

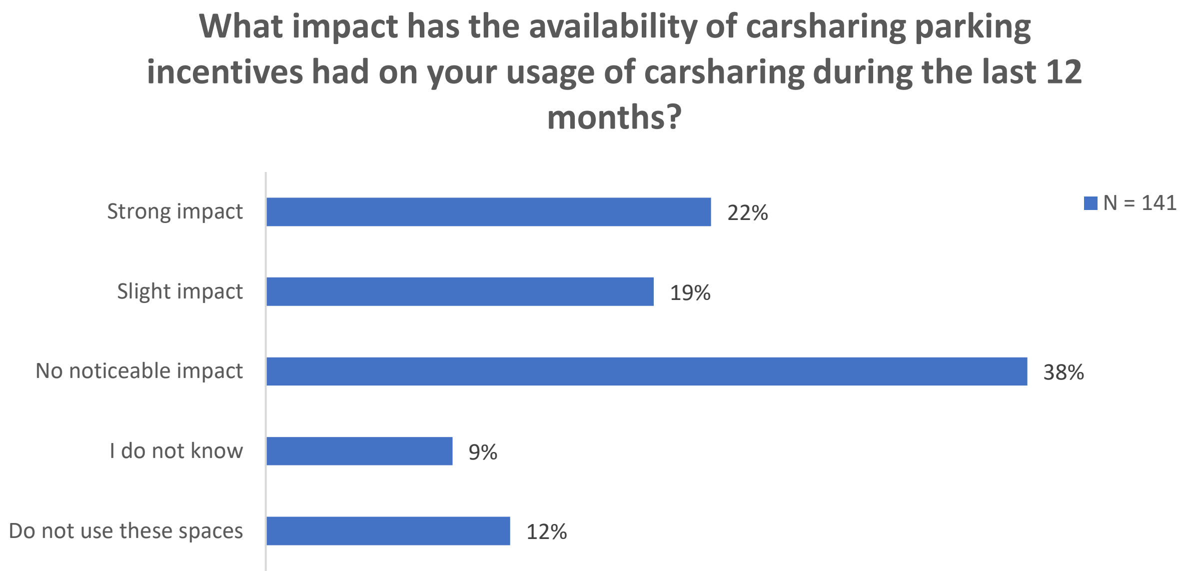
An important objective of this study was to examine the impacts that the pilot project had on carsharing use of New York City residents. Two questions were included in the after survey and were asked to the subsample of those who had taken the before survey. The first question asked the respondents to select which parking spaces they had used while operating a carsharing vehicle, and these results are displayed in Figure 9. Respondents could select all that apply, and so the percentages of responses are greater than 100%. The results show that 55% reported using a space in a parking garage or lot, 40% reported using free residential parking spaces, and 26% reported using designated on-street spaces. Only a small share of respondents (12%) reported using none of these special spaces. The distribution suggests that users of carsharing were active in taking advantage of the designated spots set aside for carsharing use by the city.

Figure 9: Parking Spaces Reportedly Used by NYC Carsharing Users



For respondents that used these spaces, an additional question was asked to assess the degree to which the spaces had an impact on their use of carsharing. Figure 10 shows the distribution of responses. It reveals that 22% of respondents felt that the spaces had a strong impact and another 19% felt the spaces had a slight impact on their usage of carsharing. Also, 43% reported the spaces as having no impact, while the remaining share reported that they did not know (10%) or did not use these spaces (14%). Thus overall, 41% of respondents within this subsample reported that the space made a difference with respect to their use of carsharing.

Figure 10: Impacts of Pilot Parking Spaces on Carsharing



In an effort to take a more in depth look at the impacts of the pilot program, a spatial analysis was performed on the home and work locations reported by respondents in the after survey. This was done in order to make a comparison between respondents who either lived or worked near locations of the parking spaces assigned during the pilot program. The geographic coordinates of both the on-street parking spaces and those located in parking garages throughout the city were obtained through New York City's open data website. These coordinates were plotted in using Geographic Information System (GIS) software. Next, the coordinates of the respective home and work locations respondents were geocoded using Google Maps API. These were known through intersections (of their choice) reported by respondents that were relatively close to their home or work location. A one-mile buffer was generated around each of the parking locations included in the pilot program. Data of respondents whose work or home locations were contained in the buffer zones was compared to the data of those whose work or home locations were contained outside the buffer zones. A map of the parking locations are presented in Figure 11.

Figure 11: Map of Parking Locations Included in Pilot

Responses were categorized based on the home location, work location, and their positioning with respect to one-mile radius spatial buffers around pilot locations. The number of responses successfully geocoded per category are presented in the table below.

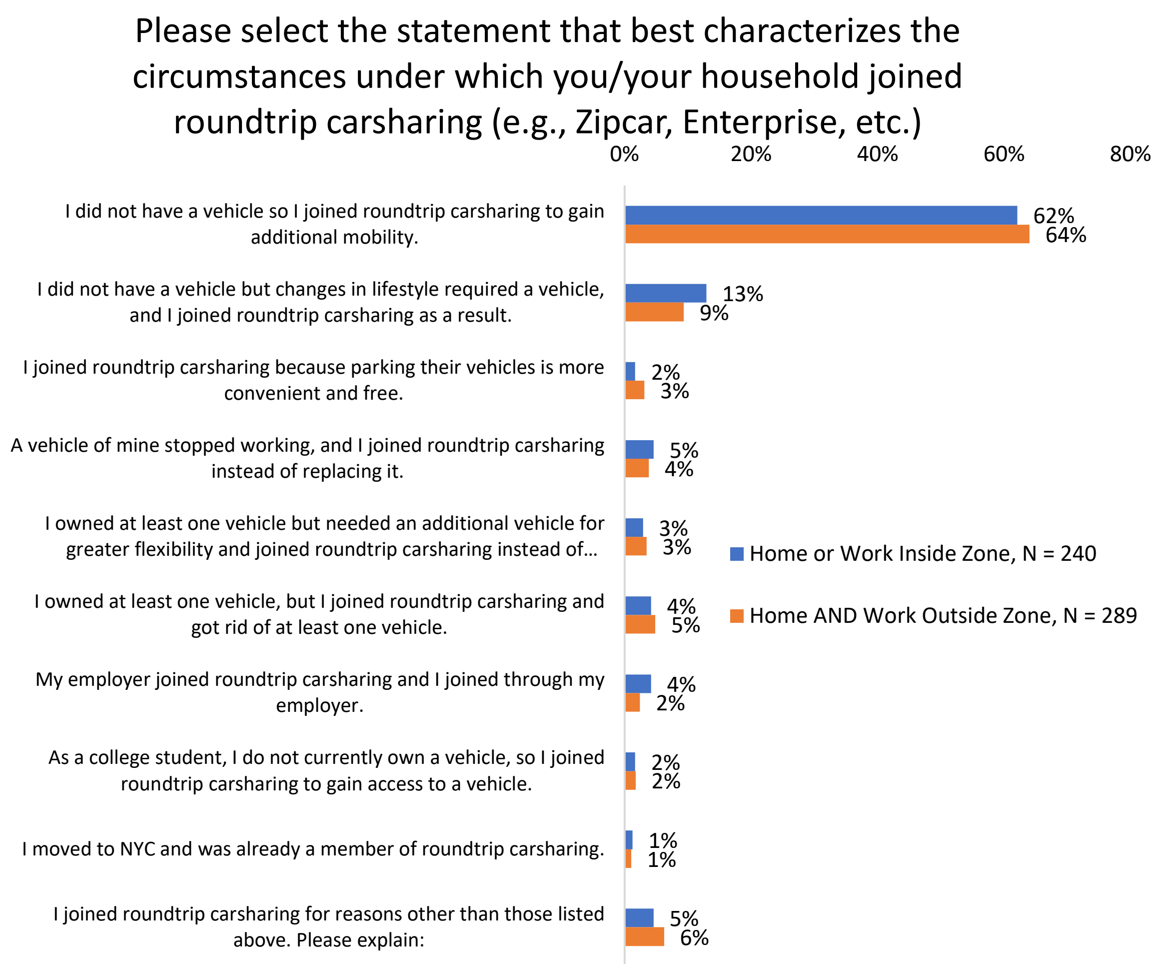
Table 5: Categorization of Spatial Data Classes

Location	Geocoded Sample
Work Inside Zone	103
Work Outside Zone	342
Home Inside Zone	190
Home Outside Zone	437
Home or Work Inside Zone	250
Home AND Work Outside Zone	299
Total Geocoded	549

Home and Work Locations of Retrospective Survey Component

As noted earlier, respondents were asked to provide the statement that best characterized the circumstances by which they joined roundtrip carsharing. For the home locations provided by respondents, the results show that there was little difference between the locations geocoded within the buffer zones and those outside the zones. In general, the distributions are nearly equivalent. Small differences exist for a few of the questions. For example, a slightly larger share (13% vs. 9%) of respondents with home or work locations inside the zone indicated that they joined carsharing instead of getting a car. Beyond this distinction and a few other small differences, the distribution of responses of those working or living within zones and those working and living elsewhere were remarkably similar. Broadly, analysis suggests that those within the pilot zone experienced impacts of similar magnitudes to the broader population.

Figure 12: Circumstances for Joining Roundtrip Carsharing - Home Locations - Retrospective Survey Component

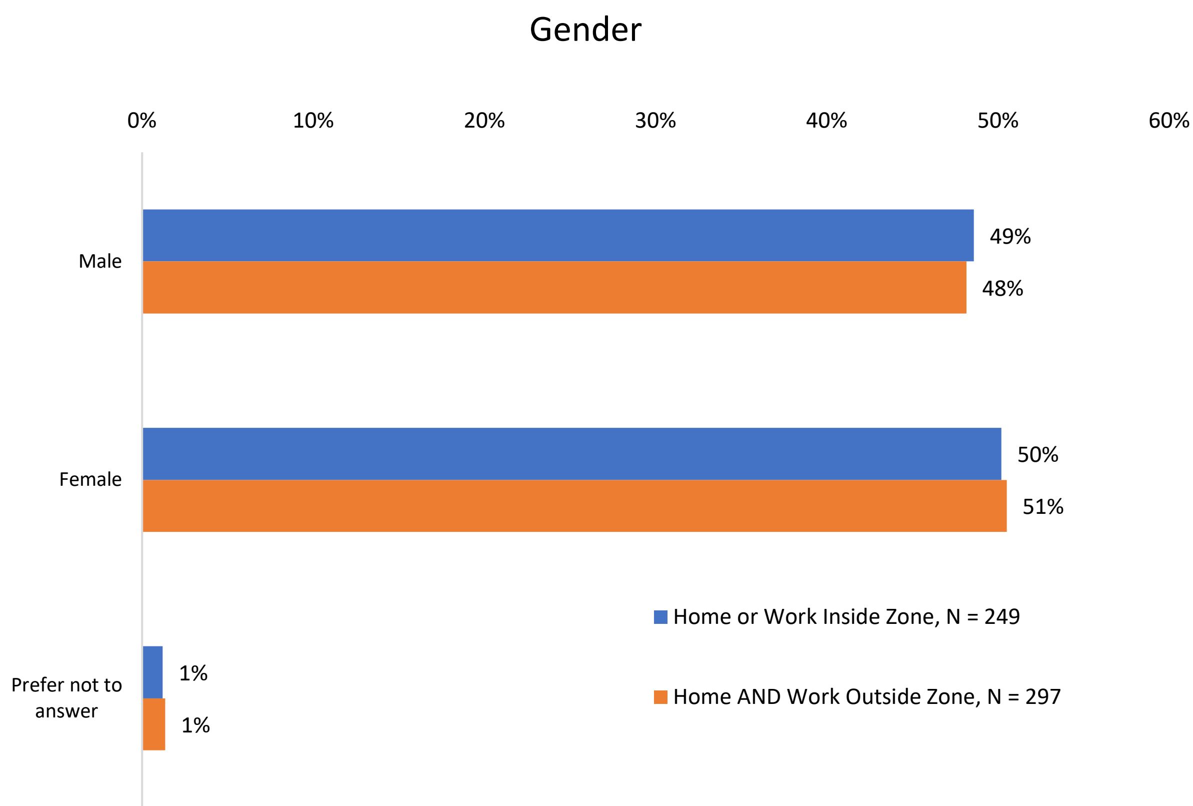


Overall, analysis of other survey questions that were stratified by association with the pilot regions show similar results with regards to impact. In addition to the results presented earlier, this may further suggest that pilot parking zones (and their associated spaces) were not by themselves strong motivators for using carsharing. However, the parking policies that encouraged the presence of carsharing within these regions likely brought new members from these areas into the membership. The data suggest that the pilot parking spaces were being used by a number of carsharing members, and the impact profile of these members was similar to that of the broader population.

Analysis also explored whether the parking pilot program enabled carsharing use across a more diverse population. Sociodemographic characteristics including gender, age, education, race/ethnicity, and income were examined across those whose home or work locations fell inside the buffer zone and compared to those whose home and work locations fell outside the buffer zones. This analysis provides more insight into the types of users who gained more access to carsharing through the pilot program.

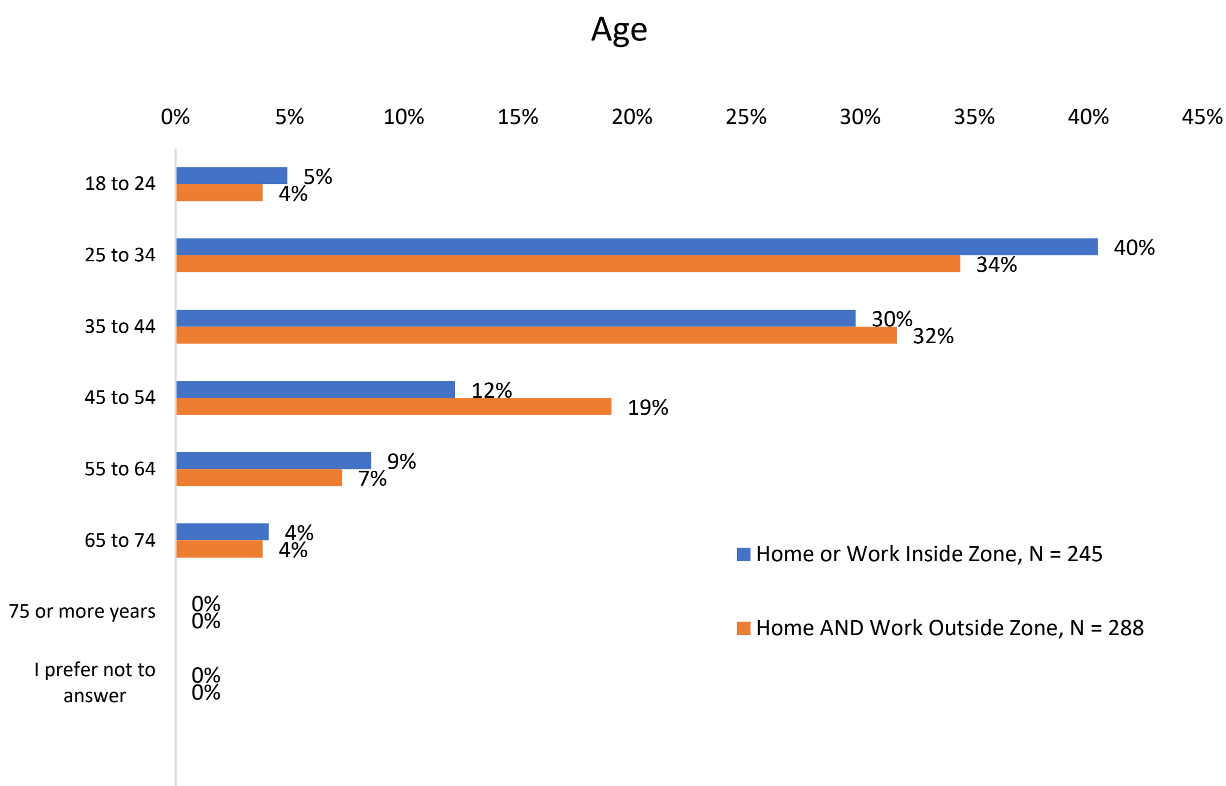
First, differences in gender balance are evaluated based on respondent association with the parking pilot zones. Shown in Figure 13, there is no major difference for the gender balance between the two populations, which suggests that the pilot program provided similar access across genders.

Figure 13: Gender by Home and Work Locations Inside versus Outside Buffer Zones



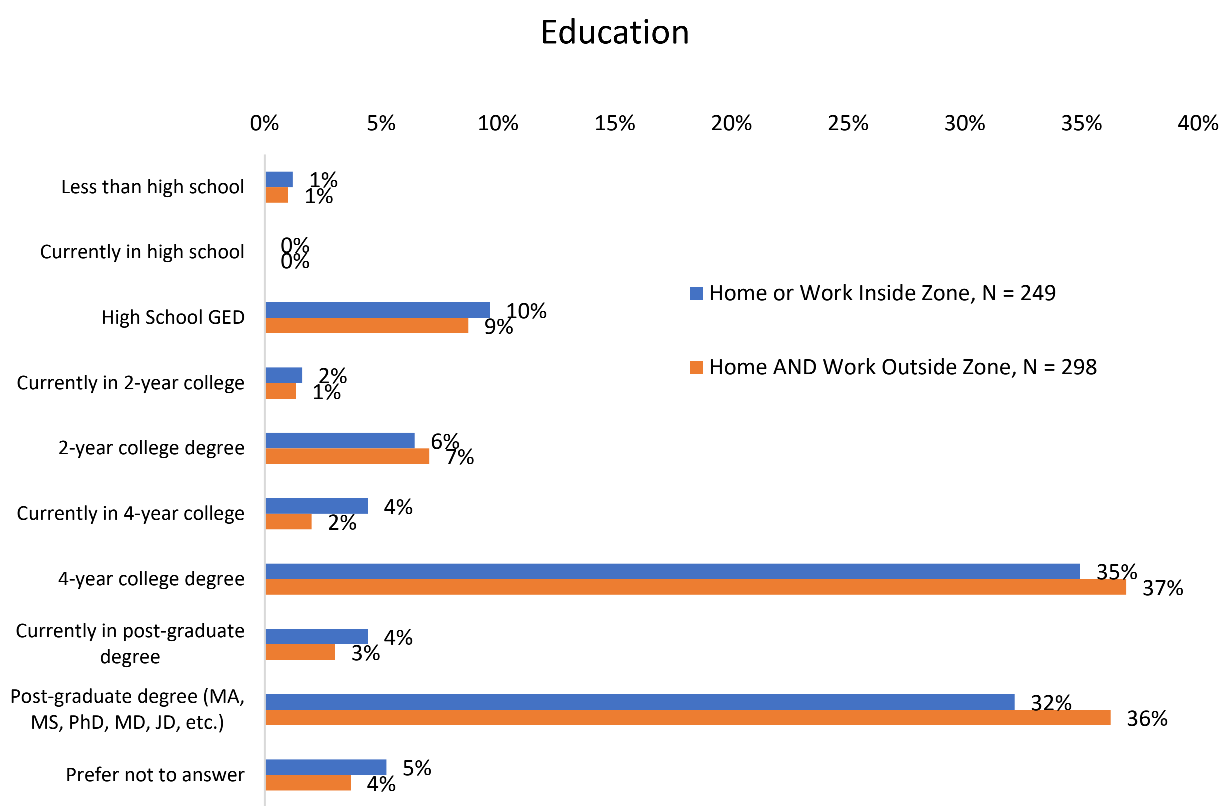
In Figure 14, the age distribution between the two sample populations shows that slightly younger users exist inside the zones as compared to outside the zones. The distributions between the two populations match closely, with the exception that a slightly greater proportion of 25 to 34 year-olds have home or work locations inside compared to outside the zone. Conversely, a slightly greater portion of 45 to 54 year-olds have home and work locations outside the buffer zones when compared to the portion with locations inside the zone.

Figure 14: Age by Home and Work Locations Inside versus Outside Buffer Zones



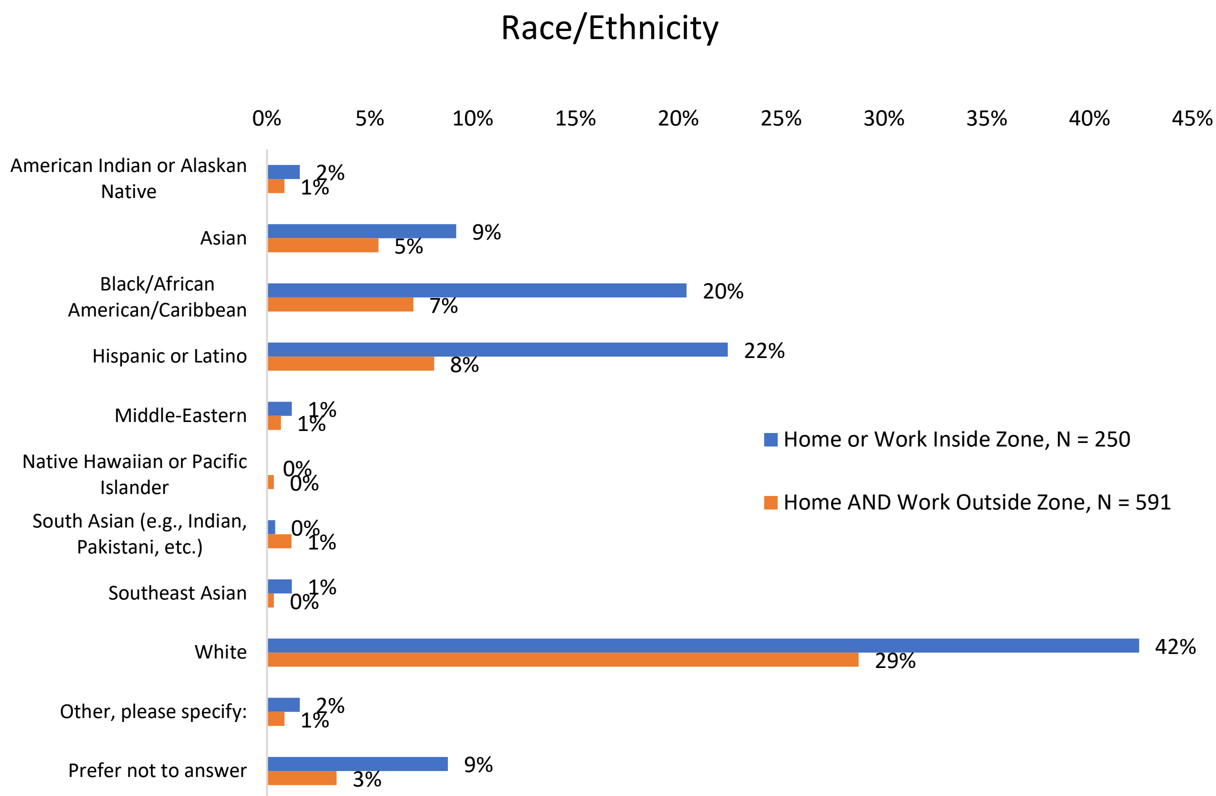
The education distributions between those who live or work inside versus outside the buffer zones also match up fairly closely. Shown in Figure 15, this suggests that the parking pilot program serves a similar, mostly college educated population found among the overall user base. However, slight differences exist in the higher education categories, where those that live or work near or inside pilot zones are slightly less educated than those who have no association with the pilot zones.

Figure 15: Education by Home and Work Locations Inside versus Outside Buffer Zones



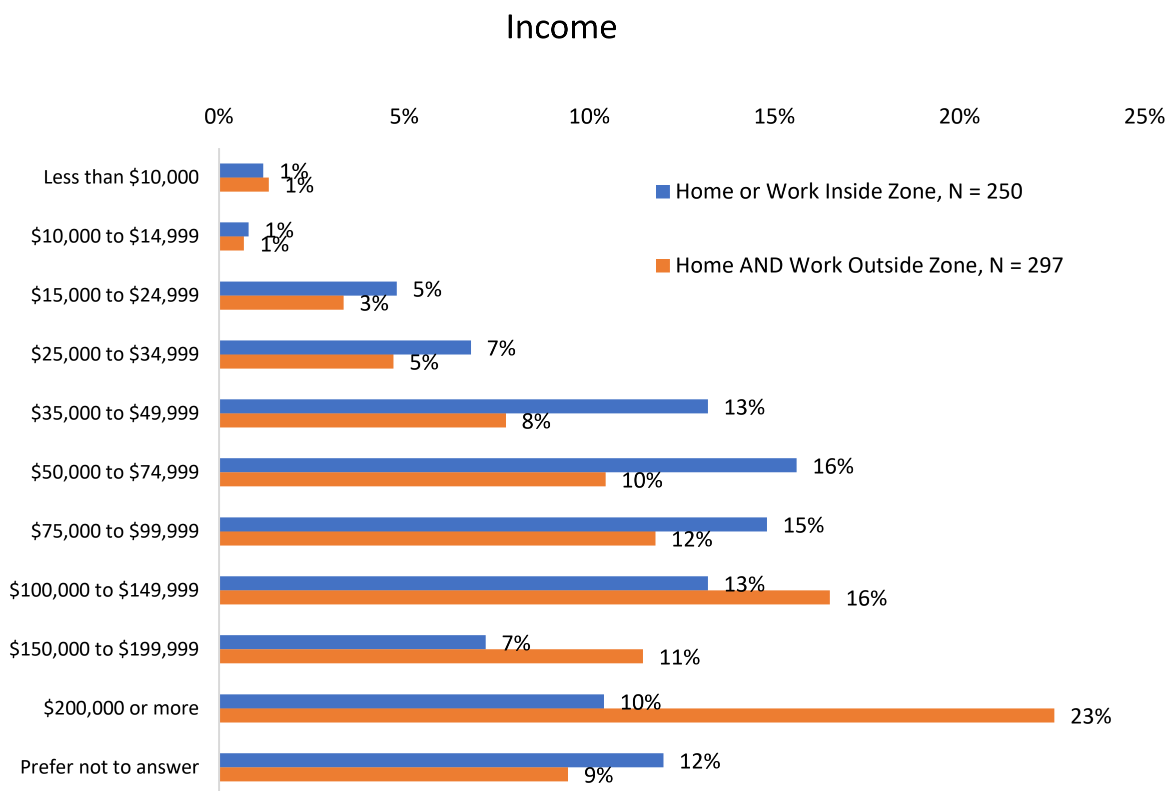
The race/ethnicity distributions differ somewhat between the subsamples. Shown in Figure 16, there are slightly higher proportions of Hispanic or Latino and Black/African American/Caribbean respondents with home or work locations associated with the pilot zones. These findings suggest that the parking pilot program made carsharing available to a more racially diverse population as compared to the general carsharing user population.

Figure 16: Race/Ethnicity by Home and Work Locations Inside versus Outside Buffer Zones



The income distributions differ substantively between the subsamples. As shown in Figure 17, respondents inside the zones have lower incomes than those outside the zones. The portion of respondents who work and reside outside of the buffer zones making $200,000 or more is greater than double the portion of respondents making the same income who work or reside inside the zones. Additionally, 58% of respondents who live or work inside the zones make less than $100,000 annually, while only 36% of respondents outside the zones make less than $100,000. This finding shows that income is the largest demographic differentiator between those residing and/or working inside versus outside the buffer zones. More broadly, the differences suggests that the parking pilot program expanded access of carsharing to lower-income users as compared to the general carsharing population in NYC.

Figure 17: Income by Home and Work Locations Inside versus Outside Buffer Zones



Overall, these results suggest that the pilot program provided carsharing access to users with lower-incomes and greater racially diversity relative to the traditional carsharing user population.

NYC Carsharing Impacts on Vehicle Ownership

The availability of carsharing services in New York City can impact personal vehicle ownership decisions among users. Carsharing can affect personal vehicle holdings in three ways: 1) by allowing members to get rid of a vehicle (shedding), 2) by keeping members from acquiring a vehicle that they otherwise would have (suppression), and 3) by encouraging users to purchase a personal vehicle after exposure to the potential benefits brought on by automobile use (acquisition). The combination of these three effects allows for measurement of the net personal vehicle change due to carsharing and also enables the assessment of VMT and GHG emission impacts (discussed further in the next section). These impacts are important for cities and policymakers to consider when determining the effects that carsharing has on its members, city roadways, and the environment.

Vehicle shedding and suppression both reduce the number of private vehicles on the road, but are different in how they manifest and require different measurement approaches. Personal vehicle shedding is linked to a distinct and measurable event, where a member decides to dispose of a personal vehicle, at least in part, due to the mobility benefits of carsharing. Meanwhile, personal vehicle suppression measures something that did not happen, as opposed to a distinct event that did happen. While it is easier for someone not to acquire a vehicle through inaction than to take action and get rid of vehicle, vehicle suppression plays a key role in reducing private vehicle ownership among carsharing users.

In this section, we discuss the weighting methodology used to scale surveyed impacts to better reflect population-level impacts and the measurement of vehicle shedding, suppression, and acquisition.

Frequency of Use and Weighting

Since those that take a survey about carsharing may be more frequent users of the services, and therefore could exhibit more substantial vehicle ownership impacts than the average user, we weighted impacts based on respondents' frequency of carsharing use.

These weighting factors were derived by combining frequency of use of both Zipcar and Enterprise CarShare carsharing services from activity data provided by the operators and the surveys. We collaborated with Zipcar and Enterprise CarShare to create a common de-identified ID (De-ID) that matched across members, using a uniquely encrypted common ID for each user. This allowed a common ID to exist across users of each service, and allowed us to match frequency of use across respondents and members, including one aggregate usage frequency for those that had used both services. The weighting factors reflect the population percentage divided by the sample percentage within the same frequency category. We considered respondents as active if they used carsharing with a frequency of more than once a month and respondents using the services once a month or less frequently were not considered in the vehicle ownership impacts analysis. Weights greater than 1 indicate that the frequency-of-use category was underrepresented in the sample, whereas weights of less than 1 indicate that the category was overrepresented in the sample. Most of the weighting factors for each frequency category were less than 1, which means that the survey samples were skewed toward higher frequency carsharing users relative to the general carsharing population. In the following sections, we use these frequency-of-use factors to weight the personal vehicle ownership impacts of shedding, suppression, and acquisition.

Vehicle Shedding

A major impact of carsharing services is that they allow a portion of users to sell a previously owned vehicle due to the mobility benefits provided by carsharing. These members decide that they no longer need to own a vehicle and can use carsharing to meet many of the essential mobility needs that were previously provided by the personal vehicle. Those shedding a vehicle constitute a minority of users and the vast majority of carsharing members do not shed a vehicle due to the availability of carsharing.

To measure this effect, survey questions evaluated whether a respondent had shed a vehicle due to carsharing. The survey question flow diagram for determining vehicle shedding is presented in Figure 18. Respondents could indicate whether they had gotten rid of a vehicle(s) because of the increased mobility obtained through carsharing in NYC. If they indicated that they had gotten rid of a vehicle either definitely or partially due to carsharing, additional questions were asked about the number of vehicles shed, the make, model, and year of shed vehicles, and the miles driven on the vehicles during the year they got rid of them. Lastly, survey questions asked whether respondents still would have gotten rid of the vehicle(s) if carsharing were not available. If the respondent indicated that they would probably or definitely still own the vehicle(s) if carsharing were not available, they were considered to have shed a vehicle(s). This last question ensured that the vehicle(s) were shed as a result of carsharing, specifically, and not primarily due to other factors. Vehicle shedding analysis results are displayed in Table 6 below.

Figure 18: Personal Vehicle Shedding Question Structure

We find that a very small portion of members shed a vehicle due to carsharing. Less than 1% (0.61%) of members got rid of a vehicle that they had previously owned due to carsharing in NYC. While this effect is small, it has implications for vehicle miles traveled (VMT) impacts, which we discuss further in the VMT analysis section. The small portion of members shedding vehicles due to carsharing may be partly due to relatively low vehicle ownership rates in NYC, in that those without vehicles in the first place have no vehicles to shed. Our surveys found that more than 80% of NYC carsharing respondents do not own a personal vehicle. Next, we discuss the vehicle suppression effects of carsharing in NYC.

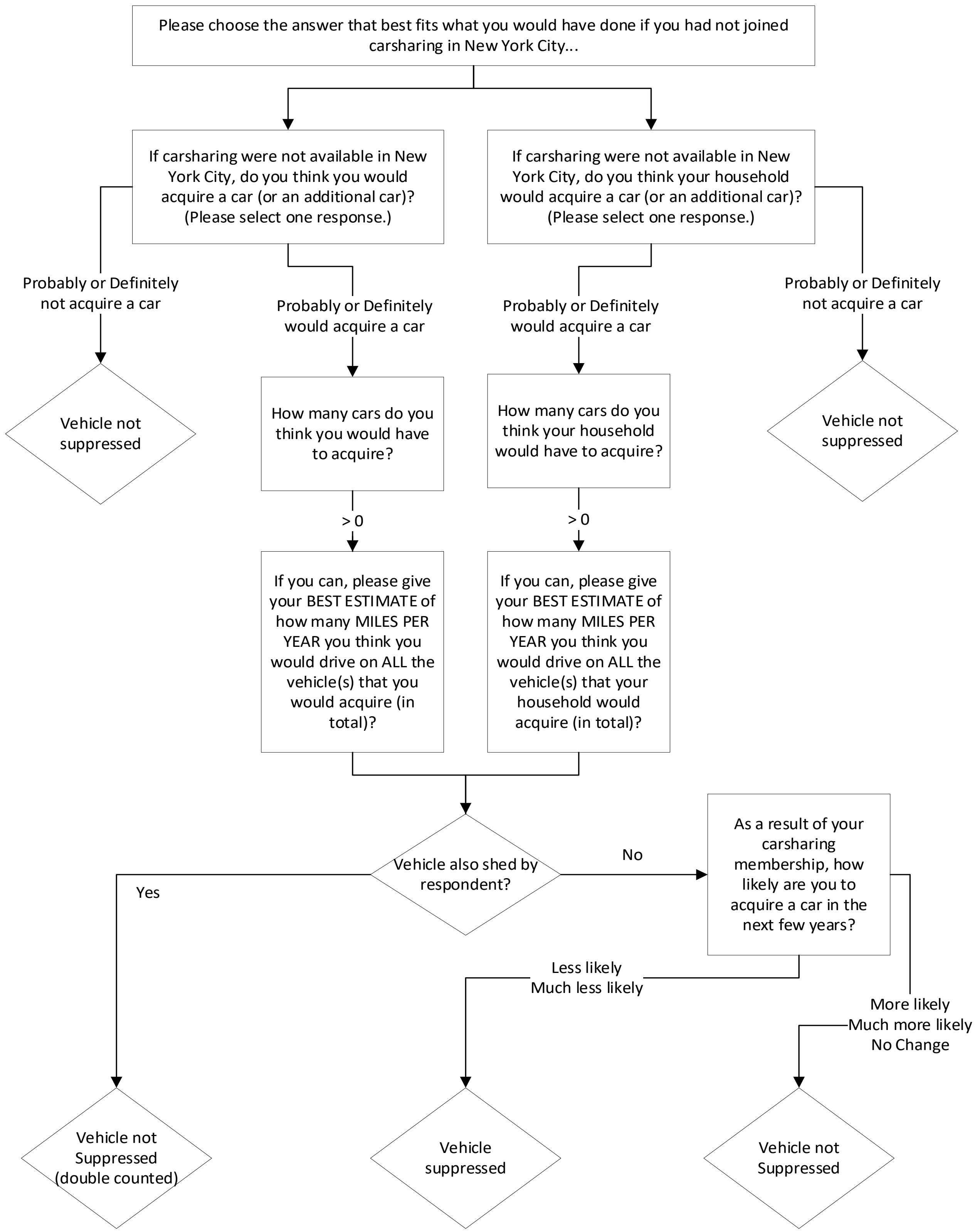
Table 6: Personal Vehicle Shedding From Weighted Sample

Vehicle Shedding Effect	**Number of Weighted Respondents**
Shed a Vehicle Partially Due to Carsharing	6
Shed a Vehicle Definitely Due to Carsharing	6
Total Shed a Vehicle Due to Carsharing	12
Would Still Be Held if Not for Carsharing	5
Percent of Members in Population Shedding a Vehicle	**0.61%**
Vehicles Shed per 1000 Members	**6**

Vehicle Suppression

We assessed vehicle suppression through a similar series of questions. The survey question flow diagram for determining vehicle suppression is presented in Figure 19. First, respondents were asked if they would acquire a personal vehicle had they not joined carsharing. If they replied that they probably or definitely would have acquired a vehicle in the absence of carsharing, respondents were asked about the number of vehicles they would acquire as well as how much they believed they would drive those vehicles. Respondents that already shed a vehicle due to carsharing (and thus would need to re-acquire a vehicle) were removed from the suppression analysis, to avoid double-counting. Lastly, respondents were asked how likely they are to acquire a vehicle in the next few years as a result of their carsharing membership. If they indicated that they are less or much less likely to acquire a vehicle, we considered carsharing to have a sustained vehicle suppression effect and confirmed that these respondents are indeed suppressing a personal vehicle purchase due to carsharing. Vehicle suppression results displaying the number of weighted respondents is shown in Table 7 below.

Figure 19: Personal Vehicle Suppression Question Structure



The suppression results in Table 7 show that 7.3% of NYC carsharing members suppressed a personal vehicle purchase due to the availability of carsharing. Note that this 7.3% is a population value, meaning that it can be applied to the broader population of carsharing membership, as opposed to considering just the impacts within the survey. The larger magnitude of the suppression versus the shedding effect is somewhat expected, since it is easier to not acquire a vehicle than it is to actively get rid of one. This result suggests that carsharing programs in NYC are enabling a small but notable portion of members to avoid acquiring a car (or additional car), meaning that carsharing lowers the dependency on personal vehicle ownership among this portion of members. This prevention of vehicle acquisition has important effects on VMT and emissions, which we explore further in a subsequent section.

Table 7: Personal Vehicle Suppression From Weighted Sample

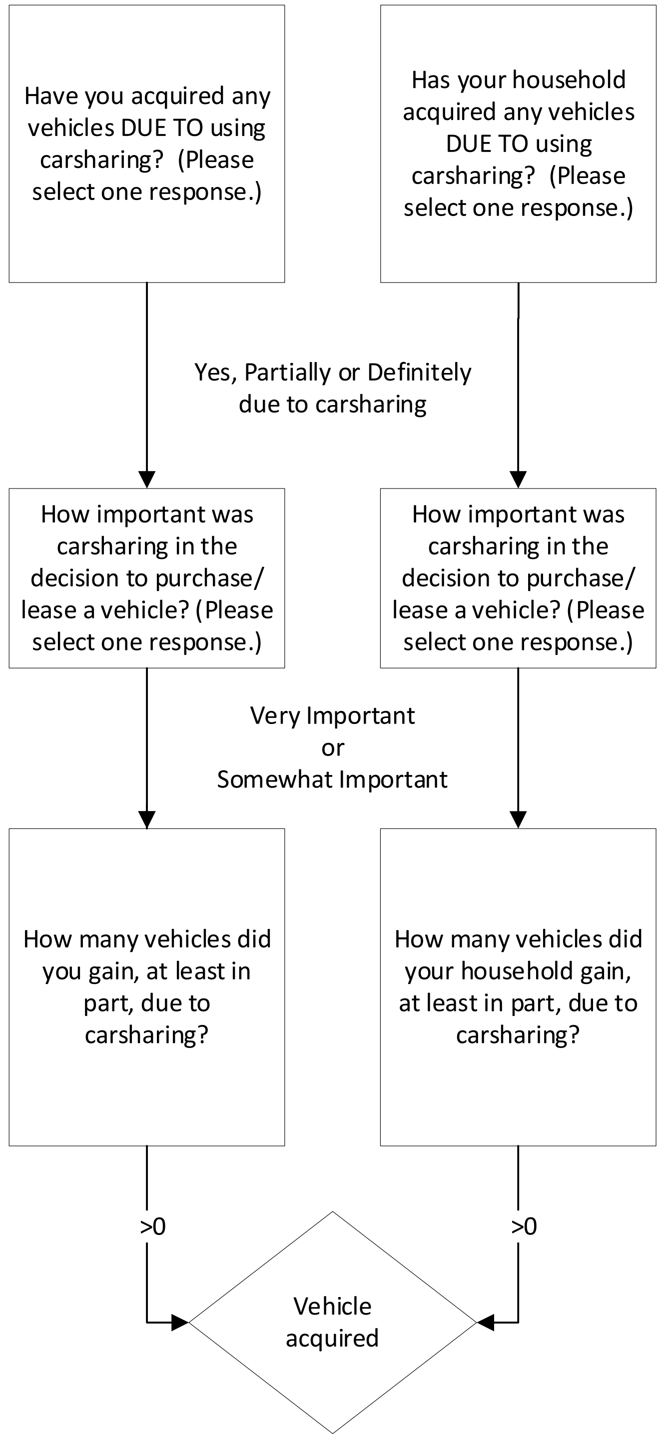
Vehicle Suppression Effect	**Number of Weighted Respondents**
Probably Would Have Acquired a Vehicle	45
Definitely Would Have Acquired a Vehicle	31
Total Due to Carsharing	76
Total Sustained Suppression Due to Carsharing	63
Percent of Members in Population Shedding a Vehicle	**7.30%**
Vehicles Suppressed per 1000 Members	**73**

Vehicle Acquisition

While the impact of carsharing typically reduces the need for personal vehicle ownership among members (via shedding and suppression), a portion of members may acquire vehicles as a result of carsharing. This increase in personal vehicles can occur for a number of reasons. A previously carless member or household may be introduced to automobility through using carsharing vehicles, and ultimately decide to acquire a personal vehicle. Exposure to automobility may motivate some members to purchase a vehicle when they are financially able or other circumstances allow. While vehicle acquisition due to carsharing is somewhat rare, as shown in Table 8, it is considered here for net vehicle ownership impacts.

Vehicle acquisition was explored through a series of survey questions, as outlined in Figure 20. First, respondents were asked whether they or their household acquired any vehicles due to carsharing. If they responded that they acquired a vehicle either partially or definitely because of carsharing, they were also asked how important carsharing was in the decision to purchase or lease the vehicle. If respondents indicated that carsharing was somewhat or very important in their decision to acquire the vehicle, then they were considered to have made a vehicle acquisition due to carsharing. Table 8 displays vehicle acquisition results and the number of weighted respondents.

Figure 20: Personal Vehicle Acquisition Question Structure



As noted previously, a small portion (less than half a percent) of weighted respondents acquired a vehicle due to their exposure to carsharing services. Although this impact is small, it is still considered within the net vehicle impacts analyzed here due to carsharing.

Table 8: Personal Vehicle Acquisition From Weighted Sample

Vehicle Acquisition Effect	**Number of Weighted Respondents**
Partially Due to Carsharing	2
Definitely Due to Carsharing	4
Total Due to Carsharing	6
Carsharing Somewhat or Very Important For Acquisition	4
Percent of Members Acquiring a Vehicle	**0.49%**
Vehicles Acquired per 1000 Members	**4.9**

Net Vehicle Ownership Impacts

With the results in Table 6, Table 7, and Table 8 together in combination, we determined the net personal vehicle ownership changes due to carsharing services in NYC. While the majority of weighted respondents experience no change in vehicle ownership due to carsharing, we find a net personal vehicle ownership change of -7.43% per member, due to the availability of carsharing. These results are shown in Table 9. This includes both negative and positive impacts, with shedding and suppression causing a decrease in personal vehicle ownership, and acquisition causing an increase in vehicle ownership. These net vehicle ownership reduction effects are a key driver of overall changes in VMT and emissions, which we discuss further in the next section.

Table 9: Personal Vehicle Ownership Impacts Within Weighted Sample

Vehicle Ownership Impact	**Number of Weighted Respondents**
Personal Vehicles Shed	-5
Personal Vehicles Suppressed	-63
Personal Vehicles Acquired	4
Net Personal Vehicle Change in Weighted Sample	-64
Net Vehicle Change as a Percent of Members	**-7.43%**
Net Vehicle Reduction per 1000 Members	**74**

With the personal vehicle ownership impacts displayed in Table 9, in combination with member and carsharing vehicle data provided by the operators, we are able to estimate the number of personal vehicles removed per carsharing vehicle. By multiplying the vehicles shed and suppressed rates by the total number of NYC carsharing members, we estimate the total number of personal vehicles shed and suppressed by active members. The number of vehicles shed and suppressed are divided by the total number of carsharing vehicles to produce estimates of how many personal vehicles are shed and suppressed per carsharing vehicle. The number of carsharing vehicles are calculated by taking the average number of monthly active Zipcar and Enterprise CarShare vehicles during the 12-month study period (October 2018 through September 2019). Results are displayed in Table 10.

Table 10: Estimated Personal Vehicles Removed per Carsharing Vehicle

Metric	**Value**
Percent of Members Shedding a Vehicle	0.61%
Percent of Members Suppressed a Vehicle	7.30%
Number of Vehicles Shed by Active Members	783
Number of Vehicles Suppressed by Active Members	9,399
Carsharing Vehicles (Average, Oct ’18 – Sep ’19)	2,526
Vehicles Shed per Carsharing Vehicle	0.3
Vehicles Suppressed per Carsharing Vehicle	3.7
Total Vehicles Estimated Removed per Carsharing Vehicle	**4.0**

The analysis displayed in Table 10 estimates that across the population, 783 personal vehicles were shed due to carsharing, equating to 0.3 personal vehicles shed per carsharing vehicle. Effectively, this means that the presence of about three carsharing vehicles in NYC enables one member to get rid of a personal vehicle. This relatively limited personal vehicle shedding effect is mainly due to the already low vehicle ownership rates in NYC and among the carsharing population in general. We found that less than 20% of members surveyed own a personal vehicle, at present. Thus, NYC carsharing members do not have many personal vehicles to begin with that could be shed due to carsharing.

However, the impact of carsharing on vehicle ownership is broader than just the shedding impact. We also find that NYC carsharing enables the suppression of 9,399 personal vehicles, equating to 3.7 personal vehicles suppressed per single carsharing vehicle. The much higher vehicle suppression rate results in an overall personal vehicle removal per carsharing vehicle. In net, combining both the shedding and suppression effects, about 4 personal vehicles are removed from NYC roadways due to the NYC carsharing program. Key analysis takeaways are summarized in the bullet points below:

- NYC carsharing members shed 0.3 personal vehicles per carsharing vehicle.
- NYC carsharing members suppressed the need for 3.7 personal vehicles per carsharing vehicle.
- Overall, when considering both effects together**, each NYC carsharing vehicle removed about 4 personal vehicles from NYC roadways.**

Impacts on Vehicle Miles Traveled and Greenhouse Gas Emissions

The impact that carsharing has on VMT and GHG emissions is important to consider when assessing the impact that carsharing has on cities and the environment. To estimate the impact that carsharing in NYC has on VMT and GHG emissions, we measure a number of behavioral changes among users of the services. These include mileage change estimates related to two of the vehicle ownership impacts described in the preceding section (shedding and suppression), as well as changes in personal vehicle and other shared vehicle use. In order to quantify the direction and magnitude of VMT impact due to NYC carsharing, this analysis measures five main components of carsharing member behavioral change. These components include:

> Change in Personal Vehicle Use: Access to carsharing services may change the amount that a member drives their personal vehicle. For example, carsharing may substitute for driving to an event that would have otherwise been made in a personal vehicle. In this case, vehicle driving (and associated mileage) still would have occurred, even in the absence of carsharing. Therefore, the analysis considers the reduction in personal vehicle driving that respondents report still would have occurred without carsharing. Increases in personal vehicle driving were considered as well as decreases, as described above.

> Change in the Number of Vehicles Owned or Leased (Personal Vehicle Shedding): The availability of carsharing services can make it easier for members to shed a personal vehicle. The surveys collected miles driven on these personal vehicles in the year that they were shed, and these VMT reductions are considered in the analysis.

> Change in the Number of Vehicles That Would Have Been Acquired (Personal Vehicle Suppression): Some carsharing members may be able to avoid the acquisition of a personal vehicle that would have otherwise been purchased in the absence of carsharing. Since a vehicle not acquired is a vehicle not driven, the miles that would have been driven on these suppressed vehicles is an important component that we consider in the VMT analysis. As noted in the previous section, vehicle suppression is more common than shedding, since it entails inaction as opposed to taking the initiative required to sell a vehicle.

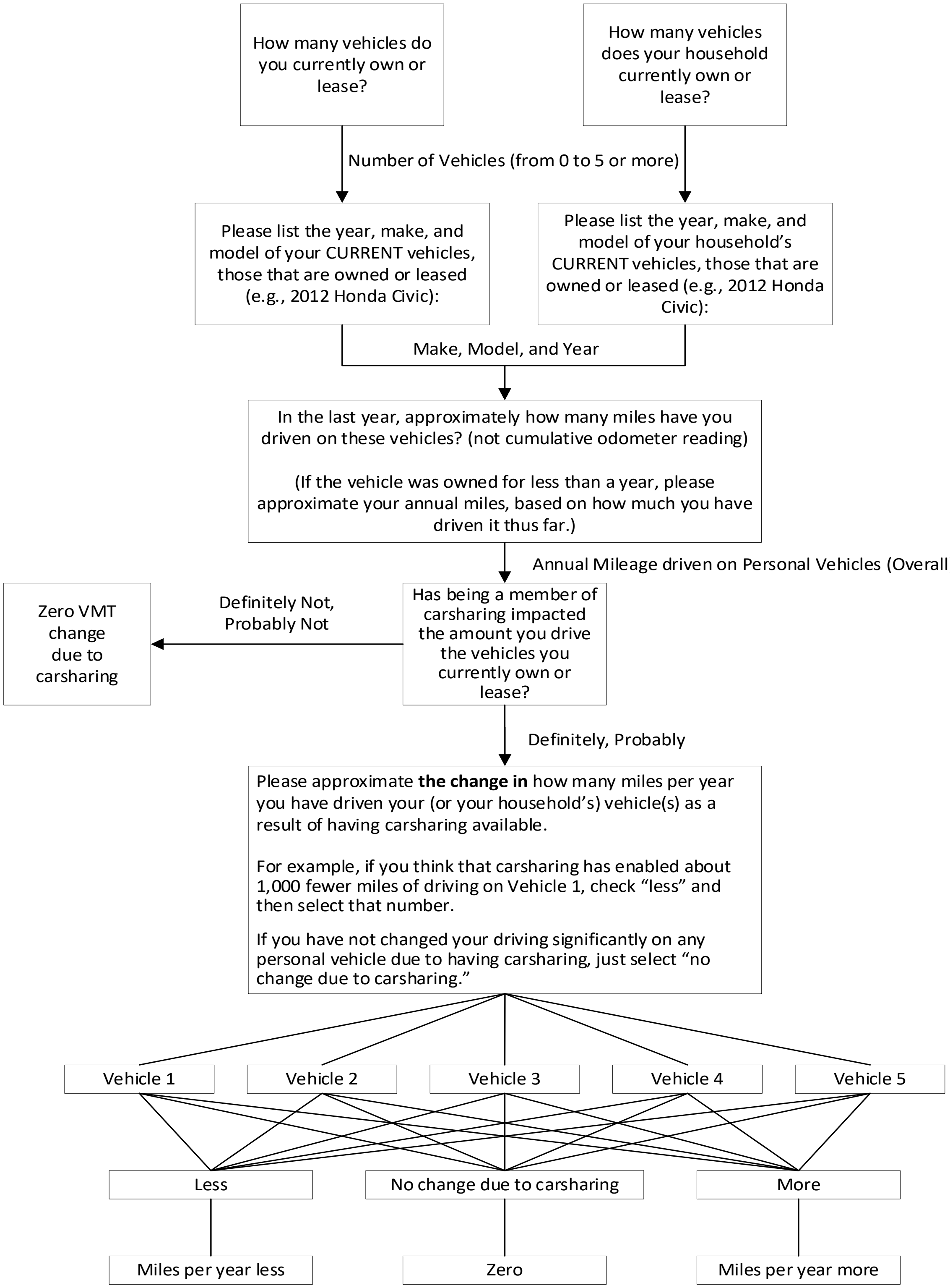
> Change in Use of Other Shared Vehicle Modes (e.g., TNCs, taxi, car rental): Carsharing provides access to a shared mode on a short-term basis, similar to the other shared mobility services. Carsharing users sometimes substitute a carsharing trip for a trip that would have been made using a TNC, taxi, or traditional car rental service. If a trip taken with carsharing would have otherwise been made with one of these similar shared vehicle modes, then the net VMT and GHG emissions impacts for this specific trip are likely negligible. In this case, carsharing is not adding VMT since vehicle activity would have occurred with or without carsharing services to a similar degree.

The measurement of these four changes (personal vehicle use, vehicle shedding, vehicle suppression, and use of other shared modes) drive the VMT change that we measure based on weighted responses from the surveys. In combination with mileage activity data provided by the operators, we use these four components to determine the net VMT impacts, which we outline in this section.

Change in Personal Vehicle Use

To measure the change in personal vehicle use due to carsharing in NYC, a series of questions were asked as displayed in Figure 21. First, we asked respondents that own one or more vehicles whether their use of carsharing had impacted the amount they drive their personal vehicles. If the respondent indicated that carsharing had an impact, we asked whether they now drive each of these vehicles less or more due to carsharing, and queried the change in how many miles per year they are now driving, as a result of their carsharing use. For example, a respondent could indicate that due to carsharing, they now drive 1,000 fewer miles per year on a personal vehicle. For each member changing their personal vehicle miles traveled (PVMT) due to carsharing, we summed PVMT changes across all vehicles that individual members or their household owned that are driven a different amount due to carsharing.

Figure 21: Vehicle Holdings and Driving Change Question Structure



To calculate the VMT impacts due to members changing their use of personal vehicles, we first measured the portion of weighted respondents who either reduced or increased their PVMT as a result of carsharing. Similar to the vehicle ownership impact analysis, the number and percentage of weighted respondents who experienced a reduction or increase in PVMT is displayed in Table 11 below.

Table 11: Personal Vehicle Ownership Impacts Within Weighted Sample

PVMT Change Impact	Number of Weighted Respondents	Percent of Members Experiencing PVMT Change
Reduction in PVMT Due to Carsharing	5	0.61%
Increase in PVMT Due to Carsharing	1	0.12%

As shown in Table 11, the portion of members experiencing a reduction or increase in their amount of personal driving due to carsharing is relatively small. This may be due to multiple factors, including that vehicle ownership rates in NYC (and among carsharing members in NYC specifically) are fairly low, meaning that a good portion of members do not own any vehicles to begin with. This also may be due to NYC carsharing members more commonly substituting carsharing trips for non-driving transportation modes, like public transit or taxis. At any rate, there are a greater portion of members who reduce their PVMT rather than increase their PVMT due to carsharing.

The next step in determining the mileage impacts of these PVMT changes entailed calculating the average changes in PVMT, based on stated mileage reductions and increases by surveyed respondents. For those reducing their PVMT due to carsharing, we found an average reduction of 1,983 miles per year. Among those increasing their PVMT due to carsharing, we found an average increase of just 250 miles per year. This finding shows that the magnitude of the mileage reduction effect is larger than that of the increasing effect, in addition to the larger portion of members reducing rather than increasing PVMT as a result of carsharing services. These results are incorporated into Table 13 which shows the overall VMT impact estimates.

Change in the Number of Vehicles Owned or Leased (Personal Vehicle Shedding)

Members who got rid of (shed) a vehicle due to carsharing are important to consider when calculating VMT impacts. Because these shed vehicles are ultimately not driven as a result of carsharing, the miles driven on these vehicles no longer occurs. Therefore, those who shed a vehicle due to carsharing are reducing their VMT through the shedding of a vehicle.

Survey questions asked those who shed a vehicle to estimate the miles driven on that vehicle during the year prior to getting rid of it. Of the respondents who shed a vehicle due to carsharing, the average miles driven on these shed vehicles was found to be 5,600 miles per year. This means that every vehicle shed due to carsharing removed approximately 5,600 miles per year from the road. By estimating the number of members who shed a vehicle, we find the annual VMT reduced through vehicle shedding to be 4,386,174 miles per year. See Table 13 for detailed calculations.

Change in the Number of Vehicles That Would Have Been Acquired (Personal Vehicle Suppression)
Carsharing users who would have acquired a personal vehicle in the absence of the services also would have driven a certain number of miles on the vehicle that they would have purchased. Although hypothetical in nature, vehicle suppression is a key impact of shared mobility services and the miles that were not driven on these vehicles that were never purchased is important to take into consideration in VMT change calculations.

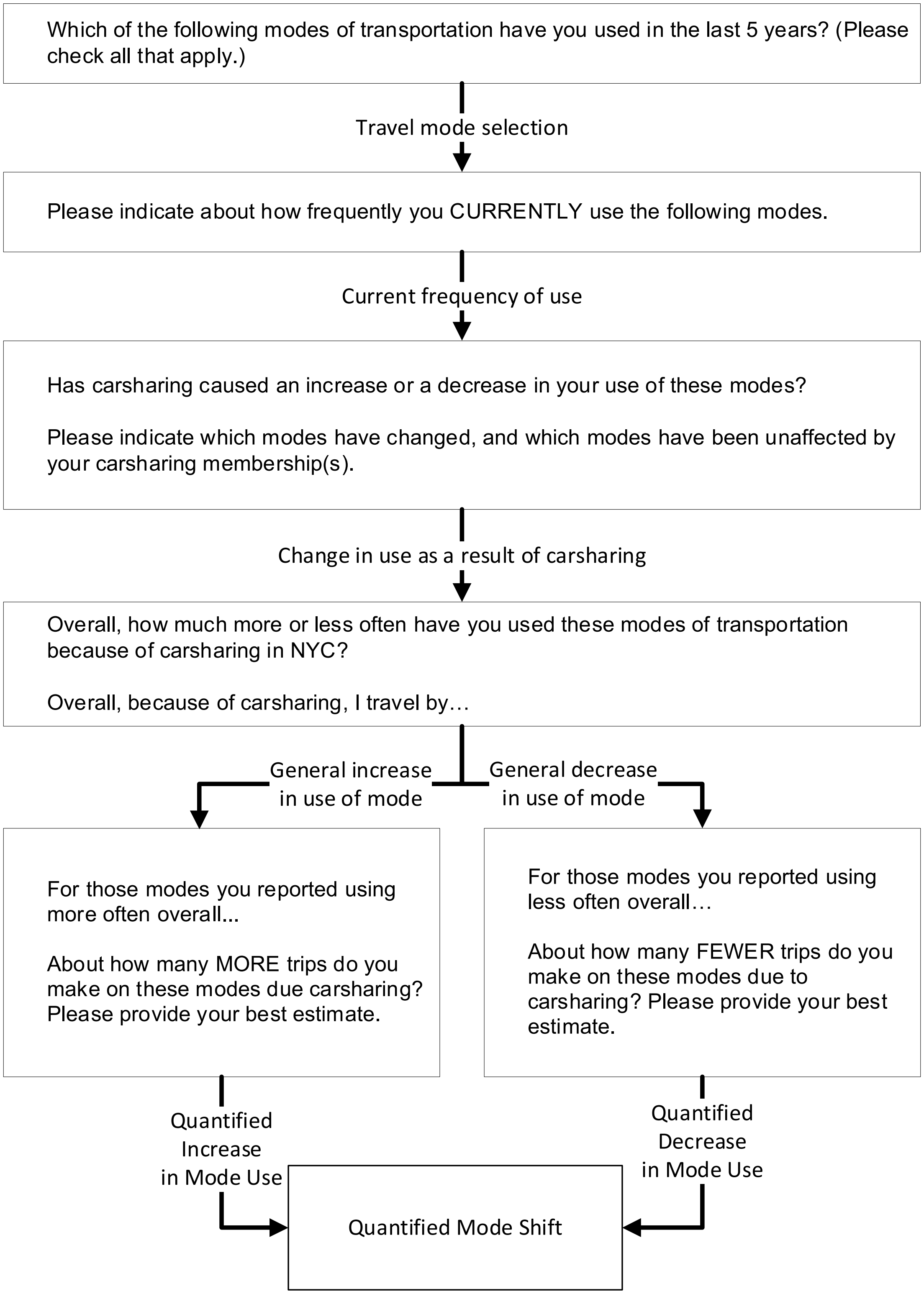
The surveys asked respondents who suppressed a vehicle (or vehicles) to give their best estimate of the number of miles per year they would have driven on these vehicle(s). On average, NYC carsharing respondents would have driven 6,211 miles per year on these suppressed vehicles. In combination with an estimate of the number of vehicles suppressed by active carsharing members, we found that 58,376,251 VMT annually was reduced due to suppression as a result of NYC carsharing (see Table 13). The magnitude of VMT reduction is larger for the suppression effect as compared to the shedding effect, mainly due to the much higher suppression rate of active members (7.3%) versus the shedding rate of active members (0.61%).

Change in Use of Other Shared Vehicle Modes (TNCs, taxis, car rental)

Since some carsharing members change their use of other shared vehicle modes as a result of carsharing, we wish to capture these changes in VMT. Many of these carsharing trips that substituted for other shared vehicle trips using modes like TNCs (both private and pooled), taxis, and car rental services did not substantively contribute to an increase in VMT, since a similar amount of shared vehicle mileage would have been produced.

To measure the change in use of other shared vehicle modes, we asked respondents mode shift questions about whether their use of particular transportation modes had changed due to carsharing. This mode shift question structure is outlined in Figure 22. If respondents indicated that their use of a shared mode had changed, we asked whether carsharing facilitated an increase or a decrease in their use of that mode. Finally, the surveys asked these respondents to estimate how many more or fewer trips they made on these shared vehicle modes, due to carsharing. Respondents were given Likert-scale answer options to indicate the magnitude and direction of mode shift. For example, a respondent using taxis less due to carsharing could indicate that they now use taxis 'about once fewer every month' as a result of carsharing. For each member changing their use of shared vehicle modes due to carsharing, we summed the aggregate VMT changes across the four shared modes that we considered. These shared modes included: 1) TNCs (Uber/Lyft), 2) pooled TNCs (UberPool/Lyft Shared or other shared-ride service, e.g. Via), 3) yellow taxi or green taxi, and 4) car rental (within NYC). We converted stated frequency changes to approximate frequency changes measured as a change in trips per year, then used miles per trip assumptions for each of the four modes to produce an estimate of VMT change per year due to carsharing. We assumed a trip-based mileage of 5.4 miles for TNCs and 3 miles for taxis, with an added 41% TNC deadheading and 45% taxi deadheading, resulting in 7.6 miles per TNC trip and 4.4 miles per taxi trip (Schaller 2017a; Schaller 2018). For car rentals, we assumed trip mileage to be the average carsharing trip length of the respondent, based on activity data provided by both operators. We used the summation of these changes in mileage (both positive and negative) across the four shared vehicle modes as part of the VMT and GHG emissions change analysis.

Figure 22: Mode Shift Question Structure



To calculate the VMT impacts due to members changing their use of other shared vehicle modes, we first measured the portion of weighted respondents who either reduced or increased their mileage on these modes (in aggregate) as a result of carsharing. The number and percentage of weighted respondents who experienced a reduction or increase in shared mode VMT is displayed in Table 12 below.

Table 12: Change in Use of Other Shared Modes Impacts Within Weighted Sample

Change in Use of Other Shared Modes	**Number of Weighted Respondents**	**Percent of Members Experiencing Shared Mode VMT Change**
Reduction in Other Shared Modes VMT	25	2.92%
Increase in Other Shared Modes VMT	2	0.24%

As shown in Table 12, the portion of members experiencing a reduction in their use of other shared mode VMT is much larger than the portion of those experiencing an increase in their used of other shared modes, as a result of carsharing.

The next step in determining the mileage impacts of these shared mode usage changes entailed calculating the average mileage reduction and increase in VMT, based on stated mileage changes by surveyed respondents. For those reducing their use of other shared modes due to carsharing, we found an average reduction of 607 miles per year. Among those increasing their use of other shared modes due to carsharing, we found an average increase of 1,164 miles per year. Although the magnitude of change in average mileage is larger for those increasing their use of other shared modes compared to decreasing, because of carsharing, the larger percentage of members experiencing shared mode VMT change results in a much larger net decrease in VMT rather than an increase. These results are incorporated into Table 13 which shows the overall VMT impact estimates.

Operator Activity Data

In addition to behavioral VMT change data measured through surveys, we also received activity data from both Zipcar and Enterprise CarShare on individual member activity, aggregate numbers of trips taken and mileage driven on carsharing vehicles, and the types of carsharing vehicles that make up their fleets. These data are crucial when weighting survey results to better reflect impacts at the population level, but we also used operator activity data as part of VMT change calculations. In order to determine whether the presence of carsharing results in a net increase or net decrease in VMT, we compared the weighted VMT changes due to behavioral change against the total VMT produced by carsharing vehicles during the study period (October 2018 through September 2019). In addition, the total number of members during this timeframe was also used to estimate the number of members experiencing various behavioral impacts (PVMT change, shedding, suppression, other shared modes change). If the total estimated VMT reduced due to carsharing is greater than the VMT produced by carsharing vehicles, then we conclude that carsharing caused a net reduction in VMT. If the opposite is true, we conclude that carsharing caused a net increase in VMT. Pertinent operator activity data and impact estimates derived using these data are presented in Table 13.

Net Change in VMT Due to NYC Carsharing

When combining changes in VMT resulting from behavioral change with VMT produced by operators, we find a net reduction in miles driven per member of 7% due to carsharing in NYC. This means that if the total net reduction in VMT were spread equally across the population, it would result in a 7% reduction in VMT per member. Table 13 below outlines the VMT reduction calculations in detail.

We use the weighted PVMT change, shedding, and suppression rates and multiply them by the number of NYC carsharing members to estimate the number of active members who reduce or increase their PVMT, shed a vehicle, or suppress a vehicle. Then, in combination with average reductions or increases in VMT for these associated actions, we estimate the annual VMT reduced or added due to these behavioral changes. We are then able to calculate the total estimated VMT eliminated and total VMT added due to behavioral changes brought on by the presence of carsharing. We then combine the VMT eliminated and added due to behavioral changes with the VMT produced due to the NYC carsharing program, and find a net decrease in VMT due to carsharing services of 38,681,463 miles per year. Considering the number of members and average VMT of members before joining carsharing, this equates to an estimated reduction in VMT of 301 per year per member and a percentage reduction of 7% per member.

Table 13: Vehicle Miles Traveled (VMT) Impact Estimates

Percent of Active Members reducing PVMT (weighted)	0.61%
Percent of Active Members increasing PVMT (weighted)	0.12%
Shed Rate Active Members (weighted)	0.61%
Suppressed Rate Active Members (weighted)	7.30%
Percent of Active Members reducing Other Shared Modes VMT (weighted)	2.92%
Percent of Active Members increasing Other Shared Modes VMT (weighted)	0.24%
Number of Active Members reducing PVMT	783
Number of Active Members increasing PVMT	157
Number of Vehicles Shed by Active Members	783
Number of Vehicles Suppressed by Active Members	9,399
Number of Active Members reducing Other Shared Modes VMT	3,760
Number of Active Members increasing Other Shared Modes VMT	313
Average reduction in PVMT	-1,983
Average increase in PVMT	250
Average miles driven on shed vehicles	-5,600
Average miles driven on suppressed vehicles	-6,211
Average reduction in Other Shared Modes VMT	-607
Average increase in Other Shared Modes VMT	1,164
Annual VMT Reduced by PVMT Change (mi/yr)	-1,553,436
Annual VMT Added by PVMT Change (mi/yr)	39,162
Annual VMT Reduced by Vehicles Shed (mi/yr)	-4,386,174
Annual VMT Reduced by Vehicles Suppressed (mi/yr)	-58,376,251
Annual VMT Reduced by Change in Use of Other Shared Modes (mi/yr)	-2,283,198
Annual VMT Added by Change in Use of Other Shared Modes (mi/yr)	364,683
Total Estimated VMT Eliminated due to Carsharing (mi/yr)	-66,599,059
Total Estimated VMT Added due to Carsharing (mi/yr)	403,845
Number of NYC carsharing members	128,668
Estimated NYC carsharing VMT (Oct '18 - Sep '19)	27,513,750
Estimated Total Net VMT Change	-38,681,463
Estimated Change in VMT per member	-301
Average Before VMT per member	4,313
Percent Reduction in VMT per member	**-7%**

These results suggest that carsharing services in NYC have facilitated reductions in VMT among their member base. Additionally, a key follow-up question is whether carsharing services are reducing or increasing GHG emissions as a result of their operations, which we explore further in the following section.

Net Change in GHG Emissions Due to NYC Carsharing

Change in GHG emissions among members due to carsharing is an important metric in assessing the environmental impacts of carsharing in NYC. To calculate emissions changes, we employ a similar methodology to the VMT change calculations outlined in Table 13, and add a fuel consumption component based on the average fuel economies of members' and operators' vehicles.

To derive fuel economy factors for personally owned vehicles, we collected make, model, and year data from surveyed respondents of vehicles that they currently own, as well as of vehicles that they may have shed or acquired. For suppressed vehicles that would have been acquired in the absence of carsharing, we assumed the fuel economy factor to be equal to the average fuel economy of carsharing vehicles of 28 mpg. Additionally, we assumed an average fuel economy of other shared vehicle modes (TNCs, taxis, and rental cars) of 35 mpg. Both operators provided us with make, model, and year data for their carsharing fleets, as well as the amount of driving done on each distinct vehicle. Make, model, and year data were linked to the combined (city/highway) fuel economy ratings as defined by the Environmental Protection Agency database derived from www.fueleconomy.gov. These data allowed us to calculate the fuel consumed (or not consumed) due to the same behavioral changes outlined previously as well as the fuel consumed by carsharing vehicle operations during the study year. To calculate fuel consumed, we assumed all fuel burned was gasoline and applied a factor of 8.887 kg carbon dioxide (CO_2) per gallon to estimate GHG emissions produced or prevented. This factor is based on the latest published EPA methodology (EPA 2020).

Using this methodology, we found the average fuel economy of currently owned vehicles to be 25 mpg. We found a similar average fuel economy of shed vehicles (24 mpg), and an average fuel economy of vehicles owned by members before they joined carsharing of 24 mpg as well. Lastly, we found the average mileage-weighted fuel economy of carsharing fleet vehicles to be 28 mpg. Based on these fuel economy estimates and associated fuel consumption and emissions changes, we found a net reduction in emissions of 6% per member (shown in Table 14). In other words, carsharing members in NYC are reducing their emissions by 6%, on average, as a result of the program.

Table 14: Greenhouse Gas (GHG) Emissions Impact Estimates

Average Fuel Economy of Currently Owned Vehicles (mpg)	25
Fuel Not Consumed due to PVMT reduction (gallons of gasoline)	-62,536
Fuel Consumed due to PVMT increase (gallons of gasoline)	1,577
Annual GHG Emissions Prevented due to PVMT reduction	-555
Annual GHG Emissions Produced due to PVMT increase	14
Average Fuel Economy of Shed Vehicles (mpg)	24
Fuel Not Consumed by Shed Vehicles (gallons of gasoline)	-179,843
Annual GHG Emissions Prevented by Shed Vehicles (t/yr)	-1,598
Fuel Economy Assumption for Suppressed Vehicles (mpg)	28
Fuel Not Consumed by Suppressed Vehicles (gallons of gasoline)	-2,049,148

Annual GHG Emissions Prevented by Suppressed Vehicles (t/yr)	-18,211
Fuel Not Consumed due to reduction in Other Shared Modes (gallons of gasoline)	-65,234
Fuel Not Consumed due to increase in Other Shared Modes (gallons of gasoline)	10,420
Annual GHG Emissions Prevented due to reduction in Other Shared Modes	-580
Annual GHG Emissions Produced due to increase in Other Shared Modes	93
Average Fuel Economy of Carsharing Vehicles (mpg)	28
Fuel Consumed by Carsharing Vehicles (gallons of gasoline)	965,799
Estimated Carsharing Emissions (t/yr)	8,583
Net Annual Emissions Change due to carsharing (t/yr)	-12,255
Estimated Emissions Change per user	-0.095
Average Fuel Economy of Before carsharing private vehicles (mpg)	24
Average Before GHG per user	1.585
Percent Reduction in GHG per Carsharing Member	**-6%**

This modest reduction in GHG emissions is important to consider when taking into account the environmental effects of carsharing services. The slightly smaller magnitude of GHG emissions reduction of 6% (Table 14) compared to the VMT reduction of 7% (Table 13) is due to differences in average fuel economy estimates and assumptions of the vehicles involved in the calculation. Suppression is the largest driver of emissions reductions, and thus the suppressed vehicle mpg assumption has a notable effect on the percent reduction in GHG per carsharing member. For example, if we assumed a relatively efficient fuel economy of suppressed vehicles of 40 mpg, this would result in just a 3% GHG emissions reduction per member. If we assumed a less efficient fuel economy for suppressed vehicles of 20 mpg, there would be a 10% reduction in GHG emissions per member.

The magnitude of reductions in VMT and emissions are not as significant as those found in other similar studies of carsharing emissions. This is likely due in part to the unique land-use and demographic circumstances in NYC. Vehicle ownership rates are notably low in NYC compared to most other North American cities, and thus there is less personal vehicle VMT that can be displaced by carsharing. Overall, the VMT and GHG emissions reductions suggest that carsharing programs in NYC are producing benefits among their member base by reducing net VMT and emissions.

Conclusion

The analysis of the survey results provided a number of key takeaways that can be informative for NYC in planning. The three surveys provided results suggesting that carsharing primarily served as a substitute for car rental services as well as a number of other personal vehicle modes, including personal vehicle driving. The surveys also suggested that the pilot program expanded the membership base of carsharing from its traditional demographics. The survey also found that carsharing was primarily employed for additional mobility rather than as a primary mode of transportation.

The analysis of the impacts of the pilot showed that the locations of the parking locations had a modest impact on behavior according to the after survey results. Two after survey questions provided glimpses that designated parking spaces had an impact on their use of carsharing. A spatial analysis was also performed and showed that proximity of parking locations to home and work locations of respondents did not differentiate carsharing use significantly. This observation suggests that the impact of parking locations on usage levels was not extensive. Nevertheless, the results of the survey questions suggest that the spaces were being used by some carsharing users.

The analysis presents information on the impacts that carsharing had on vehicle ownership and VMT. The analysis of vehicle ownership explored changes as a result of personal vehicle shedding, suppression, and acquisition as a result of carsharing. Consistent with previous studies, the results found that personal vehicle suppression, the avoidance of a car purchase, to be the largest impact at about 7%. Personal vehicle shedding was found to be far smaller, at 0.61%. This difference is larger than has been found in other studies, as was possibly a result of the relatively low car ownership that exists in New York City. The analysis translated these vehicle ownership impacts to VMT and GHG impacts, by estimating changes in driving through a number of different impacts as well as evaluating the driving that occurred through the carsharing vehicles themselves. The findings of the analysis suggest that carsharing is reducing VMT and GHG emissions in New York City. Reductions in VMT measure at about 7% across the membership base, and reductions in GHGs measure at about 6%. The slightly reduced GHG impacts are a function of the assumptions about the fuel economy of vehicles suppressed and other vehicles involved in the GHG calculations. Overall, findings suggest that carsharing activity reduced annual VMT by about 38.7 million miles and produced an annual net reduction of about 12,000 metric tons in GHGs per year within the city. The results of this analysis show that carsharing has had a measurable impact on travel behavior within the city. The findings suggest that carsharing reduced vehicle ownership, VMT, GHG emissions, and appeared to expand the membership of carsharing to a more diverse demographic. Future research building on these findings may explore how additional policy measures could further extend deployments of carsharing into communities with limited transportation options and higher financial burdens of personal automotive ownership.

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