Title

One-Way Electric Vehicle Carsharing in San Diego: An Exploration of the Behavioral Impacts of Pricing Incentives on Operational Efficiency

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One-Way Electric Vehicle Carsharing in San Diego: An Exploration of the Behavioral Impacts of Pricing Incentives on Operational Efficiency

REPORT TO THE: UNITED STATES DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION SUBMITTED BY: THE CALIFORNIA DEPARTMENT OF TRANSPORTATION





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1 Executive Summary

Operating an electric vehicle (EV) carsharing system is a unique and ambitious undertaking. EV carsharing has a number of challenges that make it more difficult to manage over similarly designed carsharing services with conventional vehicles. Among those challenges include the fact that the vehicles have restricted driving ranges, can become stranded, and require extended time to refuel and to conduct participant training. These logistical challenges come on top of the fact that EVs are generally more expensive than their conventional counterparts. Hence, most carsharing systems in operation today use mainly conventional vehicles, and the impacts of those systems are derived more from the behavioral change of reducing automobile travel than from a reduced emissions-intensity per mile traveled. While EV carsharing systems have been shown to be technically feasible; very few have been able to engage in economically sustainable operations for a long period of time.

For these reasons, the car2go experiment with EV carsharing in San Diego was highly novel, and it is the subject of investigation in this report. One of the key problems faced with respect to the car2go system was maintaining sufficient charge in the EVs, as well as preventing the accumulation of vehicles in low demand areas. The incentives tested in this study sought to counter these problems, by incentivizing vehicle movements of consumers instead of entirely delegating them to staff. The study tested two incentives, each structured to achieve these independent goals. Car2go operated a centralized charging depot to charge their vehicles. When a vehicle became depleted, car2go staff would regularly have to jockey such vehicles from their location back to the charging depot for refueling, and then back to the service region.

The objective of the first incentive (to support the EV charging depot zone) was structured to entice members to take vehicles to a region that was close to the central charging station. This was designed to reduce the deadheading for staff, in that they would have to retrieve fewer vehicles, and then only redistribute them back to the service region. The first incentive was delivered in the form of car2go driving credits. Members would have to drive the vehicle a minimum of 15 minutes, but they could receive 10 minutes in credit if they parked the vehicle within a 3-block by 3-block zone. As some minimum amount of driving was required to obtain the credit, this incentive was designed to entice customers to deviate their destination slightly to defray the cost of an existing trip, rather than elicit the customer to make a new one.

The objective of the second incentive (to prevent over-supply in low-demand zones) was to move vehicles away from regions of heavy vehicle accumulation. This incentive was similarly structured in terms of the credit after the member did some driving. Members would receive a 10-minute credit, if they drove a vehicle starting within two predefined regions for at least 10 minutes and parked it outside the zone. This incentive was again designed to defray user costs as opposed to allowing the member to earn (or accumulate) credits. A member could only receive a credit for an amount of driving that was equivalent to or less than what they had done. In this sense, the incentive was not designed to induce new trips just to move vehicles but rather to influence where the vehicles were parked.

The first incentive had a relative advantage over the second in that any vehicle in the system could be used to earn the credit, if it was driven to the charging depot zone. Since the second incentive only applied to vehicles starting in low-travel demand zones, it had far fewer vehicles eligible at any given time that could earn the incentive.

We conducted this study using carsharing operator surveys and car2go focus groups, member survey data analysis, and activity data analysis. The carsharing operator survey asked operators to identify the key distinctions between one-way carsharing and roundtrip carsharing as well as identify limitations, obstacles to adoption, as well as technological innovations that would advance one-way carsharing. The survey found that the operators felt that the flexibility for the consumer was a key benefit of one-way carsharing. At the same time, operators reported the lack of reservations for this system reduced the certainty that users would have a vehicle available. Operators felt that parking management and system rebalancing were the key barriers for one-way carsharing. They reported that the top innovations for roundtrip carsharing are: 1) integration with public transit, 2) smartcard usage, and 3) EV use. One-way operators mentioned the same top three innovations.

Two focus groups were held in downtown San Diego to probe response to incentive structures designed to entice car2go members to return vehicles to a zone near an EV charging depot. Each focus group consisted of ten individuals. The focus groups covered the following topics: 1) experience with car2go; 2) car2go as contrasted to roundtrip carsharing services; 3) impact on travel patterns as a result of car2go; and 4) proposed incentive structures. Focus group participants generally agreed that the main benefit of car2go was convenience, while the top three major challenges were the restricted home area, the damage-reporting process, and the check-in and check-out process. The focus groups also reported that recharging was confusing and inconvenient; however, most were interested in the proposed pilot incentive programs.

Besides free minutes as incentives, participants also proposed establishing a point-based membership rewards program in which premier members would receive benefits such as: 1) discounted rates per minute, 2) customer appreciation events, and 3) the ability to reserve a car 24 hours in advance. Participants also suggested promoting some friendly competition through a “high ecodriving score of the week” game. Overall, there was a high interest in participating in an incentive program, but the incentive structures would have an important influence on the impact.

A survey was developed to evaluate how car2go impacts travel behavior and how the members would respond to the incentives. We deployed three surveys, one before the start of the incentives, one after the first incentive was retired, and one at the end of the study when the second incentive was retired. The first survey had 1,081 respondents, while the second and third survey had 448 and 473 respondents, respectively. We sent the second and third survey to respondents of the first survey, as well as to those who had received one of the credits. The survey found that members of car2go in San Diego had demographics that are distinct from the general population of the city. The gender balance of the sample was tilted toward males (62%)

and the sample was younger than the general population. The most common age group within the sample was 25 to 34 years of age (45%) versus 19% within the population. The next most common age group was 35 to 44 years of age (28%) versus 13% within the population. The sample was also predominantly Caucasian (73%) relative to the San Diego population (43%), and it was more educated. Over 70% of the sample had a bachelor's degree or higher versus about 45% within the San Diego population. Only income within the sample was distributed similar to that of the population. The sample was more middle income relative to the population in that households with incomes below $25,000, as well incomes over $200,000 were underrepresented. Relative to the population, the sample was overrepresented by incomes between $75,000 and $150,000. With the exception of the gender balance towards males, these characteristics are pretty typical of carsharing users overall.

The survey found that respondents most often used car2go for recreational activities or errands. Only 9% of the sample reported using car2go for commuting to work. About 27% of the sample reported a modal shift reducing overall driving as a result of car2go, and of those reducing their driving, over 80% stated that car2go was somewhat or very important in this reduction. At the same time, 12% of the sample reported driving more than they did before (the rest reporting no major change in driving as a result of car2go). Similarly, car2go was found to reduce the use of public transportation among 24% of the sample, while 12% reported using public transportation more as a result of car2go. In contrast, 34% of the sample reported walking more as a result of car2go in San Diego, while only 9% reported walking less.

The presence of car2go also resulted in a significant number of respondents using taxis less often, with 59% of the sample reporting that they used taxis less; only about 2% reported using them more. Interestingly, more respondents reported using ridesourcing/transportation network companies, such as Uber and Lyft, more often (22%) as a result of car2go, than those reporting using them less often (16%). One possible explanation for this result is derived from the trip purposes. Car2go members may have been using car2go to access bars and restaurants, and then using Lyft and Uber to return home to avoid drinking and driving.

The survey asked questions about respondent travel to the downtown area where the zone was located and about their typical duration of driving a car2go vehicle. Almost two-thirds of respondents reported that they drove car2go vehicles for more than 15 minutes at a frequency of once a month or less. In addition, another challenge revealed by the survey was that travel to this downtown area via car2go was relatively infrequent, as 46% of respondents reported driving through the downtown area at a frequency of less than once a month.

In the first survey (before incentives were implemented), respondents overwhelmingly (85%) reported that if they were driving for 15 minutes and were expecting that they would be in the region of incentive zone that they would park within it to earn the credit. The second survey sought to understand the degree to which the incentive was used by respondents. In the second survey, 72% of the sample was aware of the incentive prior to taking the survey. Of those, 22% (~16% of the total sample) had received the driving credit. Respondents who had not taken advantage of the incentive, but had known about it, were asked why they had not

used the incentive. Forty-three percent of respondents receiving this question stated that their final destination was rarely within this zone. Notably, 26% of respondents also believed that they would use this incentive in the future. Of the 71 survey respondents that reported receiving the credit in the second survey, over 85% were satisfied or very satisfied with it. Among all respondents to the second survey, 30% reported noticing the vehicles having more charge than average since the incentive took effect, while 11% reported observing less charge, and the remaining respondents (59%) reported no change in perceived charge.

The second and third surveys probed response to the second incentive, which focused on removing vehicles from regions of low use. This incentive was found to be at a disadvantage relative to the first incentive, since only vehicles within a confined zone could move in ways that triggered the incentive. The first incentive, being a destination-based incentive, had all vehicles eligible regardless of where they started. The second incentive, being an origin-based incentive could be used by far fewer people. The second and third surveys probed willingness to act among respondents at different incentive levels. At the offered incentive level of 10 minutes of driving credit, only 7% stated that they definitely would position a vehicle outside the zone, and 12% noted that they probably would at that level. At a credit of 30 minutes, 65% stated that they would reposition the vehicles. In the final survey, 14% of respondents had received the credit from the second incentive. Those that had not received the credit were asked why, and not surprisingly, 72% stated that their trips never involved those zones.

The final survey had questions on both the first and second incentive. Respondents were asked to indicate at what levels of car2go credit they would be willing to drive a vehicle to the charging zone. They were asked to report their willingness to respond to credits both in the form or minutes and cash credits. Surprisingly, minutes were deemed to be a more effective incentive in contrast to the equivalent amount of cash. Eighty-two percent of respondents reported that they definitely or probably would have driven a vehicle to the charging zone in downtown in exchange for a 30-minute driving credit. At the cash equivalent of $12, only 67% of respondents indicated that they would definitely or probably do the same. This suggests that, at least in the case of car2go, minutes of usage credits were deemed more valuable than the equivalent amount of cash.

The activity data analysis evaluated the trends in incentivizing qualifying trips and the customers using them. The analysis found that with the first incentive, there was an increase in the number of trips to the charging incentive zone. This increase was driven by a minority of users who increased their activity to the incentive zone during the period in which it was active. The increased activity was measured against the typical amount of travel that was occurring to the zone without the incentive. This permitted an estimation of the cost effectiveness of the first incentive in terms of incentivizing additional trips to the zone, which was estimated to be about $34.81 per new trip. Notably, this was larger than the monetary value of the incentive of $4.10 because a considerable amount of typical activity already existed to the charging incentive zone. Overall, the activity data analysis confirmed that the first incentive was effective in bringing additional vehicles closer to the incentive. The activity data were also used to evaluate whether the second incentive was effective in removing vehicles from the zones of

oversupply. While the survey indicated that some respondents took advantage of this second incentive, the activity was not large enough to be seen within the activity data.

The survey and activity data found that a limited number of respondents could effectively use both incentives. The incentives did change behavior for some respondents, but the amount offered through the credits may not have been enough to cause considerable changes in behavior large enough to significantly impact operations. Lessons learned related to these results suggest that incentives should be structured to include a large number of vehicles to be eligible, as found in the first incentive, while the second incentive involved a more limited number of vehicles eligible at any given time. However, the results of the study did find that given the right value, members would change their travel behavior to meet the objectives of the incentive policy (i.e., an incentive policy structured to offset staff activity).

There were also several suggestions provided by respondents in the free-response section of the survey that supported these conclusions. Most people indicated that simply increasing the amount of credit offered as an incentive would make the program more effective. Others suggested extending the date when the credits expire, as it appears that they expired too soon for some users to take advantage of them. Another common suggestion was to base the program on where users ended trips rather than started them and to charge a higher rate for users ending trips in areas that do not need more vehicles. Finally, users suggested better advertising of the incentive program.

At any credit level, operators would need to determine whether the level of participation and reduced costs would be worth the lost revenue. In the end, the incentive programs were about trade-offs. User participation in these programs would have reduced the burden of redistribution on the operator and ensured greater availability of vehicles for all other users. The results suggest that there are ways to improve the incentive program to enhance operational efficiency. For example, the results suggest that the incentive program would benefit from a combination of greater incentives offered, improved communication of those incentives, and a structuring of the incentive zone locations in ways that entice members to alter their travel plans. Additional experimentation and study of similar programs may lead to longer-term operational efficiency improvements within shared mobility systems.

2 Introduction

Since its first establishment in Montreal in 1994, carsharing has undergone a steady expansion throughout North America. For about the first 15 years of its growth, it remained under the traditional model of roundtrip carsharing, where users accessed a vehicle at a fixed and dedicated location and then finished their session with a return of the vehicle to that same location. Beginning in 2010, a new phase in the evolution of carsharing had emerged in North America, this time in the City of Austin with the launch of car2go. Car2go was established as a one-way carsharing system that was designed around an urban zone that exclusively used one type of vehicle, the two-seated Smart Fortwo. To access the vehicles, members did not require a reservation, but they could access a vehicle anywhere in the zone and pay for use while driving. The session would end when the member parked the vehicle anywhere within the urban zone. Members could take the vehicle out of the zone, but the session would not close until the vehicle was parked back in the zone.

From Austin, car2go continued to expand to other cities under a similar operational model. In 2011, car2go established an all-electric version of its zonal one-way carsharing system. This system operated the same, but with electric Smart Fortwo vehicles. The zonal design of car2go operations faced unique logistical challenges keeping vehicles appropriately distributed for access by members across the zone. This posed an additional challenge associated with maintaining sufficient vehicle charge on the vehicles, while at the same time keeping vehicles positioned throughout the urban region. Car2go in San Diego was an ambitious project that had not been attempted at this scale within the United States. Car2go faced higher costs and greater infrastructure challenges as a result of this experiment, and this called for the testing of novel approaches to maintain operational efficiency.

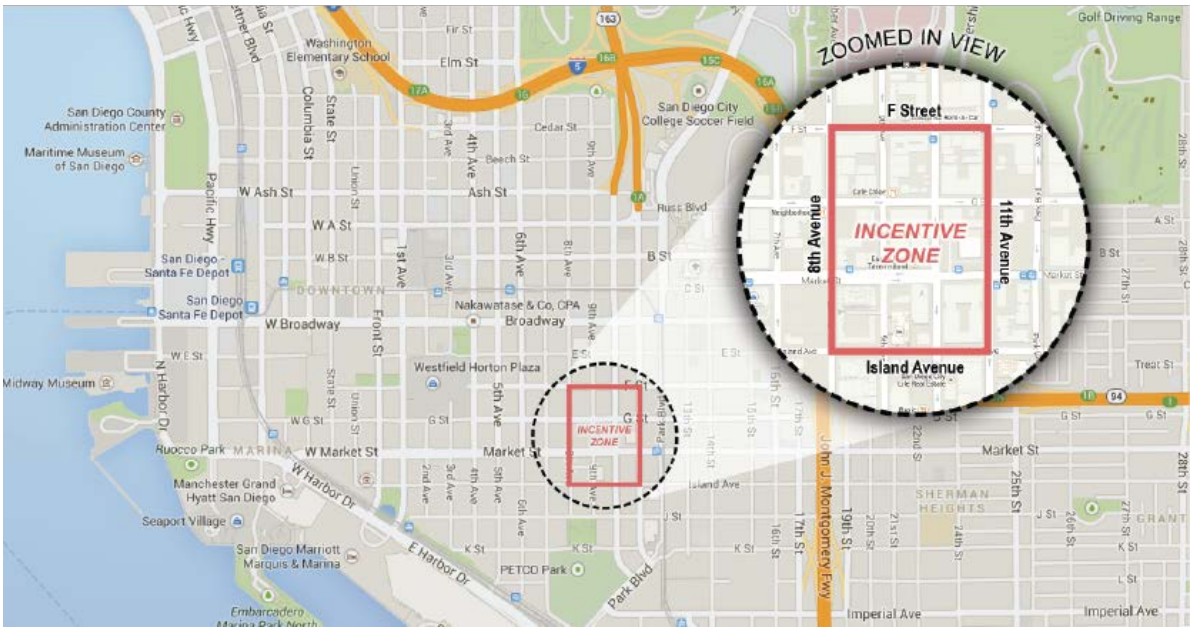
This project was conducted to evaluate whether simple, low-cost pricing incentives could improve the refueling operations of charge-depleted vehicles as well as vehicle distribution. It was implemented as part of the Federal Highway Administration's (FHWA) Value Pricing Pilot (VPP) grant program as a two-year evaluation of pricing/incentives applied to the one-way all electric carsharing system. The project involved developing and studying pricing/incentive structures that could induce certain travel patterns among car2go users that would improve the level of vehicle charge and distribution throughout the vehicle fleet. We implemented surveys and focus groups with car2go San Diego users, as well as conducted interviews with experts in shared mobility. Finally, this study also evaluated the impact of car2go San Diego on the travel behavior of its members.

We employed three longitudinal surveys to evaluate the impacts of two incentive programs on car2go use. At the time of the project implementation, the car2go San Diego fleet was all-electric, which required charging infrastructure to refuel a large number of electric vehicles. To handle this load, car2go established a central depot to manage the charging of multiple vehicles simultaneously. This presented a logistical challenge in that vehicles needed to be brought to this depot to be recharged at regular intervals. These redistribution efforts were costly to the operator, and resulted in additional staff trips over what would have normally been required

for the management of conventional vehicles. In addition, one-way carsharing systems can suffer from an aggregation of vehicles in low-demand areas with a high number of one-way trips.

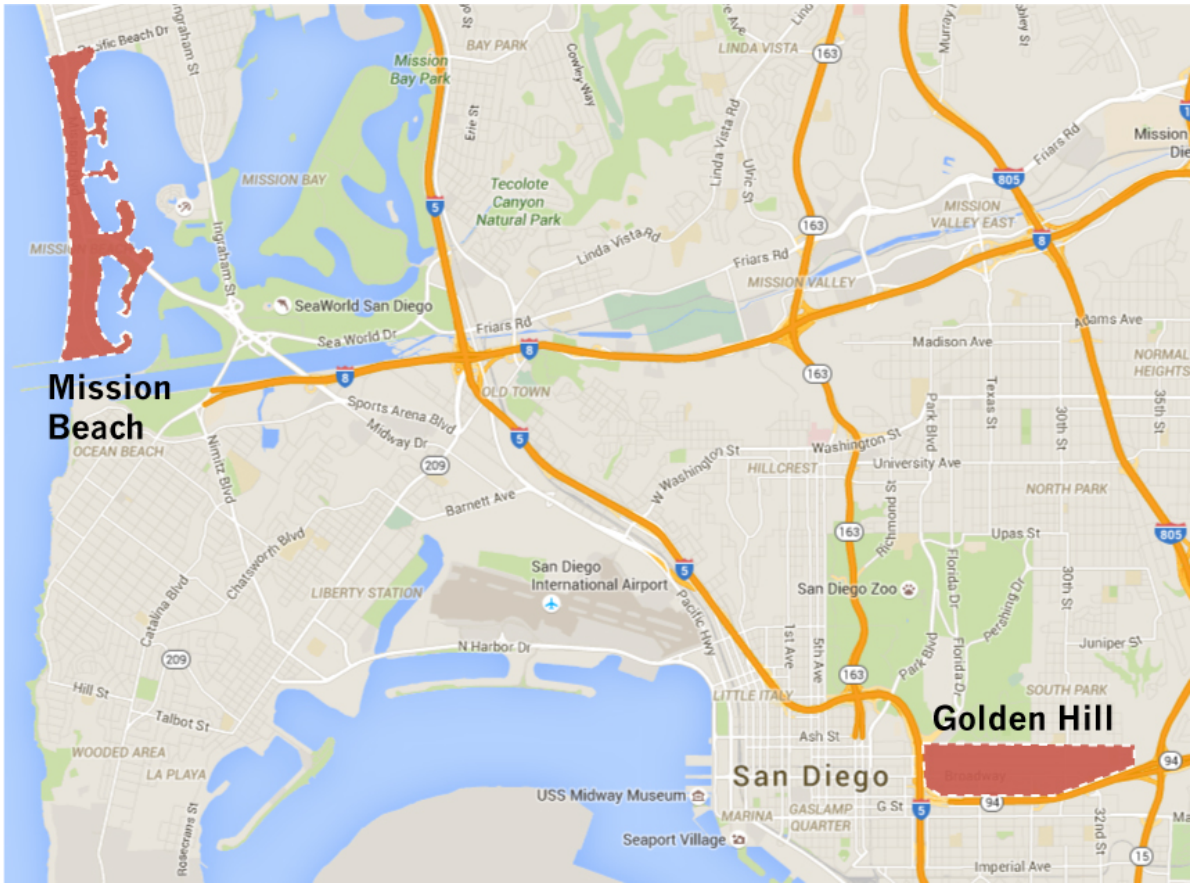
The project tested two incentive structures to address these logistical programs within the car2go system. The first incentive aimed to induce car2go trips that would end near the electric vehicle EV charging depot in downtown San Diego, shown as a region within Figure 1. To qualify for the incentive, a user would have to begin a trip outside of the incentive zone, drive the vehicle for at least 10 minutes, and park the vehicle inside the zone. The user would get 10 minutes of free car2go driving time credited to their account, if they met these conditions. The first incentive was implemented from October 2014 to early-April 2015.

Figure 1: EV Charging Depot Incentive Zone in Downtown San Diego



The second incentive was aimed at generating increased demand for car2go trips in areas with a low demand. This goal was to help stimulate use within low-demand areas and redistribute cars away from them. To receive the incentive, a user would have to start a trip inside a designated low-demand zone, drive the car for at least 10 minutes, and then end the trip outside of one of the zones. The second incentive ran from early April 2015 to early October 2015. The two zones chosen for this study were Mission Beach and Golden Hill, both shown on the map in Figure 2.

Figure 2: Two Incentive Zones for the Redistribution Incentive



We begin this report by outlining the project history and overview. Next, we summarize the literature that exists in the field relating to either one-way carsharing or pricing incentives for operational efficiency. A summary of the expert interviews as well as the focus groups follow. The analysis section presents the results from the longitudinal surveys. These include a demographic overview of respondents, a baseline travel behavior assessment, and an evaluation of the response to the two incentive programs. Finally, we present some lessons learned, as well as a conclusion.

3 Background

This section presents a review of the literature about one-way carsharing and incentive pricing in transportation. We conclude with a summary of the expert interviews among carsharing operators, who were interviewed to gain industry perspective on the distinctions between one-way and roundtrip carsharing.

3.1 Literature Review

At present, one-way carsharing generally reflects two main models: 1) free-floating carsharing and 2) station-based carsharing. These types of systems have been deployed in different areas with varying degrees of success. Recent research has sought to document these impacts of one-way carsharing systems across the globe through a number of evaluation and modeling efforts.

3.1.1 Free-Floating Carsharing

Free-floating carsharing services enable shared-use vehicles to be picked up and dropped off anywhere within a designated operating area. The first free-floating carsharing service began in October 2008 in Ulm, Germany as car2go. Car2go later expanded to Western Europe, the U.S., and Canada. By January 2018, car2go was reported to have over 2,970,000 members, making it the largest carsharing operator in the world (car2go, 2017).

BMW and Sixt, a rental car company, also launched a free-floating carsharing system in 2011 in Munich, known as DriveNow. It expanded to six countries including: Austria, Denmark, Germany, Sweden, the United Kingdom, and the United States. DriveNow (now ReachNow) left San Francisco in late-2015, and relaunched in Seattle, Washington. Both operators have worked with cities to prepay for parking spaces for their free-floating vehicles. Free-floating services currently dominate North American one-way carsharing service operations (in contrast to station based). North America's first carsharing operator, Communauto, also launched Auto-mobile —a free-floating carsharing pilot project, in June 2013. The project consisted of a fleet of EVs shared in Le Plateau-Mont-Royal, a neighborhood of Montréal, Canada and expanded to another neighborhood in October 2013 (Communauto, 2013).

3.1.2 Station-Based One-Way Carsharing

Several one-way carsharing systems operate a station-based model. In contrast to free-floating carsharing, station-based systems require users to return the vehicle to a designated station but not necessarily the same one that they started from. Although this model may be perceived as less flexible to the user, station-based carsharing provides more certainty to the locations in which vehicles can be found and deposited.

In December 2011, the Autolib' one-way carsharing service was launched by Bolloré in Paris, France. The fleet was comprised exclusively of electric vehicle (EV) Bluecars provided by

Bolloré. A joint commission was created in July 2009 to supervise the entire network, which includes the center of Paris and nearby municipalities (a total of 54 municipalities by May 2013). By April 2013, Autolib' had 30,000 members accessing 1,800 EVs at 800 stations throughout the city and its suburbs. At that time, the system had provided over two million trips (Fairley 2013). By July 2014, Autolib in Paris had grown to 2,500 vehicles with 155,000 subscribers and 4,000 EV charging locations (Henley, 2014). By July 2016, Autolib was reportedly operating nearly 4,000 cars with about 126,000 subscribers (Autolib, 2016).

One variation on station-based carsharing is the airport-based model. This service facilitates one-way trips between the airport (i.e., the "station") and destinations, such as the central business district (CBD). Hertz 24/7 launched a one-way service in New York between airports and the city in 2011, and they later expanded to offer one-way carsharing in Hoboken, New Jersey; New York City; and Washington, D.C. However, Hertz 24/7 ultimately shut down its North American operations in late-2015 due to insufficient demand (Morgan, 2015). Its European operations, however, remained active. In June 2012, Volkswagen's Quicar in Hanover, Germany launched a one-way trip service between the airport and Brunswick. Additionally, Carrot launched in July 2013, offering one-way trips between Mexico City's CBD and the Santa Fe business district. Indianapolis later announced that it planned to deploy 500 EVs through a new station-based program called, BlueIndy (operated by Bolloré), which then launched in December 2014 (Swiatek, 2014).

3.1.3 One-Way Carsharing: The Present

By July 2014, there were approximately 18 one-way carsharing operators with programs in 10 countries (Austria, Canada, China, France, Germany, Italy, Japan, Mexico, Spain, and the U.S.). A program launched in Hangzhou, China at the end of 2013. It employed EVs that were accessed at and returned to automated garages (Rogowsky 2013). Daimler launched car2go in London and Birmingham in 2012, but they halted UK operations in May 2014 (car2go UK Ltd, 2014). Today, automakers from Europe are the dominant players in the one-way carsharing industry. BMW-Sixt, Bolloré, Citroën, Daimler, and Renault are among the prominent one-way carsharing operators (Fairley, 2013).

One-way carsharing has continued to expand in large part due to ever improving communication technologies (e.g., vehicle access technologies, smartcards, mobile applications, GPS) (Shaheen and Cohen 2007; Shaheen and Cohen 2012), as well as public policies that enable private firms to reserve on-street parking (Shaheen and Cohen 2007; Firnkorn and Müller 2012). Many worldwide experts anticipate growth in one-way carsharing to continue (Shaheen and Cohen 2012).

3.1.4 Recent Research and Modeling Findings

While one-way carsharing provides a flexible service, its operational management is more complex. There is a need to guarantee a level of vehicle availability in the face of constant

spatial supply challenges, which can lead to an oversized fleet and underused vehicles (Firnkorn, 2012). Nakayama et al. (2002) suggested one-way systems need around twice as many reserved parking spaces as vehicles to function optimally.

In the last few years, researchers have proposed many models to assist decision makers and minimize costs while maintaining member satisfaction. Models have been developed to determine the: 1) optimum fleet size, station location, size and number (Cepolina and Farina 2012; Correia and Antunes 2012); 2) best strategy when demand changes (Fassi et al. 2012); and 3) most efficient vehicle relocation systems. Simulation models serve as tools for comparing one-way and various carsharing services (i.e., trip type, driving duration, relocation, destination). Yoon and Lee (2013) conducted simulation models that revealed that one-way offers a higher usage ratio for cars compared to roundtrip carsharing. Barrios (2012) developed a simulation-based approach, using agent-based modeling, to measure and predict vehicle accessibility in one-way carsharing.

System rebalancing (i.e., shuffling vehicles to balance vehicle supply and user demand) is a major research area in one-way carsharing operations and logistics, but it remains a complex problem of supply and demand that each depends on the other (Jorge and Correia 2013). Weikl and Bogenberger (2012) introduced and categorized several rebalancing strategies. Relocation strategies are commonly grouped into two different approaches: 1) user-based relocation and 2) operator-based strategies.

Barth et al. (2004) introduced two user-based rebalancing systems: 1) trip-joining (or ridesharing) and 2) trip-splitting. Whereas the former incentivizes members to share a ride from a low-vehicle-quantity station to a high-vehicle-quantity station, the latter encourages a group of users, departing from a high-vehicle-quantity station, to split into different cars and park at a low-vehicle-quantity station. Di Febbraro et al. (2012) proposed the discrete events system (or DES) model, which provides the optimum drop off station to limit station imbalances. If a member agrees to leave a car at the station suggested by the operator, he or she will receive a trip discount. Although the model determines the optimum drop off station, it does not take into account the fare discount, which depends on the distance between the user-chosen station and the operator-suggested station and the member's willingness to accept it (Di Febbraro et al. 2012). Papanikolaou (2011) addressed the issue of incentive pricing to bring one-way systems into balance exclusively by users. He developed a pricing model where users “buy a car at a station” and then “sell” it at another one. Prices of drop-off and pick-up points are strategically chosen to keep the network balanced.

Kek (2006) introduced two operator-based strategies: the shortest time technique (i.e., vehicles were moved in the shortest possible time) and the inventory balancing technique (i.e., a station with a vehicle shortage was filled with vehicles from a station with an oversupply). Fan et al. (2008) studied the trip allocation approach in which the operator directly accepts or refuses trips to maintain the station balance.

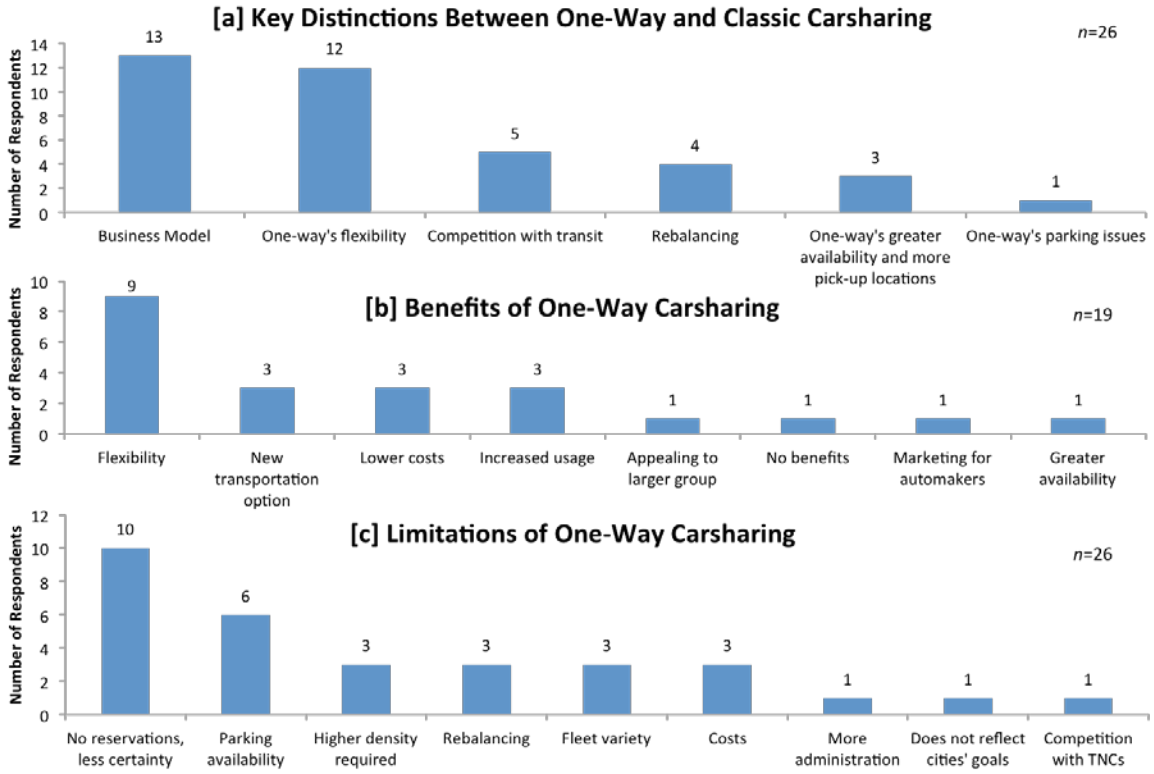
Recently, multi-task models have been developed that can consider simultaneous, strategic decisions (i.e., location, number, and size of stations); tactical decisions (i.e., fleet size); and operational decisions (i.e., vehicle relocation) (Jorge et al. 2012; Boyacı et al. 2013). These advanced simulation models optimize highly complex problems by integrating a large number of variables (Kek 2006).

Despite a growing body of research into one-way carsharing modeling and logistics, the impacts of one-way systems have just recently begun to be documented. In a study on car2go in Ulm, Germany, Firnkorn (2012) found that more than a quarter of survey respondents were willing to abandon their personal car for a car2go membership. Trepanier et al. (2013) evaluated impacts of Auto-mobile in Montréal, Canada through a series of user surveys. Initial results found the program enables many users to make short and spontaneous trips, with median average trips of 2.0 km and 13 minutes. Le Vine et al. (2014) conducted a survey of (n=72) one-way carsharing users to determine impacts to travel behavior associated with grocery shopping. One-way carsharing allowed respondents who did not own a vehicle to shop for groceries less frequently, with less travel time and at fewer stores. A 2014 study of (n=1,169) Autolib' and Mobizen users compared one-way and classic carsharing travel behavior, respectively. It found that Mobizen users reduced vehicle miles traveled and vehicle kilometers traveled (VMT/VKT) and vehicle ownership more than Autolib' users, but the study noted that one-way carsharing is still new and its benefits may be more evident in the future (6t, 2014). Martin and Shaheen (2016) studied the impacts of car2go in five North American cities, including San Diego, and found that on balance car2go reduced vehicles on the road, VMT/VKT, and associated greenhouse gas emissions. Further research is needed to understand the impacts and demand for one-way carsharing including member attitudes, travel behavior, and system operations.

3.2 Carsharing Operator Survey

This section briefly discusses the results of a carsharing operator survey conducted in Fall 2013 in the Americas (U.S., Canada, Mexico, and Brazil), which compares and contrasts one-way carsharing and roundtrip carsharing. Five one-way operators and 26 roundtrip carsharing operators completed the operator survey online (out of 46 operators in the Americas). Operators were asked to identify the key distinctions between one-way carsharing and roundtrip carsharing (see Figure 3). Half (50%) of the roundtip operators (n=13/26) mentioned fundamental differences (e.g., point-to-point vs. roundtrip), and 46% (n=12/26) noted one-way's more flexible use as the key difference. Sixty-nine percent (n=18/26) viewed one-way carsharing as a complement to roundtrip carsharing. Of these, six operators believed it was a complement by providing another alternative transportation mode, and four believed one-way carsharing served a different trip purpose.

Figure 3: Operator responses on distinctions [a], benefits [b], and limitations [c] of one-way carsharing



The authors asked operators about the differences between early adopters of one-way carsharing and members of roundtrip carsharing. One key difference cited by 19% (n=5/26) was that one-way users reside in denser city centers. Operators identified service flexibility as a main benefit of one-way carsharing. Specifically, one-way is beneficial for trips that involve arriving at a location and staying there for an extended time. This results in cheaper trips for one-way users who will not incur charges when the vehicle is parked. Respondents stated that spontaneous, short trips were best suited for one-way carsharing. Figure 3b shows the distribution of all one-way carsharing benefits identified by respondents.

Several limitations of one-way operations were also given (see Figure 3c). Roundtrip operators felt the largest limitation was the reservation-less model (n=10/26), which gives the user less certainty that a vehicle is available at the desired time and location. Similarly, one-way operators stated that users must learn to “trust” that a vehicle will be available at the desired time and location, particularly at airports.

When asked about the greatest obstacles to the widespread adoption of one-way carsharing, the majority cited parking management (n=20/26) and system rebalancing (n=18/26). Operators believe that one-way carsharing will continue to grow over the next decade, but it will focus on major metropolitan areas, similar to the proliferation of roundtrip carsharing.

Moreover, respondents pointed to growing investment from auto manufacturers, which may further spur innovation and growth. When asked about profitability within ten years, 37% (n=7/19) were uncertain.

To capture potential growth opportunities for one-way carsharing, operators were asked what technological innovations they envision. The top three innovations mentioned by roundtrip carsharing operators were: 1) integration with public transit (n=6/26), 2) smartcard usage (n=4/26), and 3) EV use (n=4/26). One-way operators mentioned the same three innovations: integration with public transit (n=1/5), 2) smartcard usage (n=2/5), and 3) EV use (n=1/5). The results of these interviews are discussed further in Shaheen et al. (2015).

4 Focus Group Summary

On May 22 and 23, 2014, two focus groups were held in downtown San Diego to evaluate pricing structures designed to incentivize car2go members to return vehicles near an EV charging depot. The focus groups were led by two researchers from the University of California's Transportation Sustainability Research Center (TSRC). Each focus group consisted of ten individuals, ranging in age, level of educational attainment, ethnicity, and income level. There were six men and four women in each focus group. All of the participants were from San Diego, although a few individuals had only moved there recently.

The duration of the focus groups was two hours each and covered an array of topics including: 1) overall experience with car2go; 2) comparison of car2go to traditional roundtrip carsharing services; 3) change in travel patterns as a result of car2go membership; and 4) proposed pilot programs designed to increase the density of vehicles near the EV charging depot.

Both focus group participants agreed that the primary benefit of car2go was the convenience, while the top three major challenges were the restriction of the home area, the damage-reporting process, and the check-in and check-out process.

Both focus groups agreed that the recharging process was confusing and inconvenient; however, most people were also eager to participate in the proposed pilot programs. The first incentive structure that was proposed (ten free minutes for trips longer than 15 minutes that ended inside the incentive zone) received mixed reviews. The overwhelming majority of individuals in both groups would have effectively been "ruled-out" of this incentive because they either do not take trips to the area or their trips are not 15 minutes or longer. Conversely, the second proposed incentive, which did not have a 15 minute requirement and would award more minutes for returning cars with low states of charge to the Incentive Zone was received much more positively by both groups.

Besides free minutes as incentives, participants also proposed establishing a point-based membership rewards program in which premier members would receive benefits such as: 1) discounted rates per minute, 2) customer appreciation events, and 3) features including the ability to reserve a car 24 hours in advance. Participants also suggested promoting some friendly competition through a "high ecodriving score of the week" game. Based on feedback from the focus groups, there was a high interest in participating in an incentive program, but the incentive structures would have an important influence on the impact.

5 Survey Methodology

This section outlines the methodological design, implementation, and the research results of this study. The analysis relied on two data sources. One of the primary data sources was a longitudinal online survey, which was administered three times over the course of one and a half years. It was administered to members of car2go in San Diego. The other data source was activity data and incentive provided by car2go. The activity data consisted of trip-by-trip activity of vehicles in the system. The incentive data consisted of incentives dispensed by car2go for meeting the conditions of receiving the incentive.

5.1 Survey Design

We developed three surveys primarily aimed at evaluating user perceptions and response to pricing incentive programs implemented by car2go during the survey period with input from our project partners including FHWA, Caltrans, the San Diego Association of Governments (SANDAG), and car2go. The surveys also captured car2go's effect on travel behavior, as well as how users were interacting with the system. Finally, the survey asked for general demographic information of users.

The first survey, also referred to as the "before" survey in this report, asked questions on the respondents' current mobility profile as well as their vehicle holdings and the amount they drive those vehicles. It evaluated car2go's causality on any measurable changes in the user's travel behavior between the time of taking the survey and the year before he or she joined car2go. The survey then switched to asking questions that tried to predict user response to the first incentive that car2go was about to implement. The first incentive was designed to encourage members to bring charge-depleted vehicles to an EV charging depot located in downtown San Diego. It asked users how often they drove car2go vehicles for more than 15 minutes (as this was the minimum driving time required to qualify for the incentive), how often they drove near the incentive zone that included the EV charging depot, and how often they expected to take advantage of the incentive.

In the second survey, referred to as the "interim" survey in this report, we asked about current travel behavior and the effect of car2go on travel behavior in a similar fashion to the first survey. We then asked questions to evaluate the response to and impact of the then recently ended EV charging depot incentive. We first ascertained whether the respondent had been aware of the incentive program and had taken part in it. Those who had not taken advantage of the incentive were asked why, and those who had were asked about their most recent trip to the incentive zone, as well as their general travel patterns. While the interim survey asked follow up questions regarding the EV charging depot incentive program, it also served as a "before" survey for the soon-to-be launched "low-demand zone" incentive program, as described earlier in this report. At the time of the survey launch, this incentive program was targeted at generating demand in two low-demand zones in San Diego: Mission Beach and Golden Hill. We asked questions to gauge how often respondents would take advantage of the

zone redistribution incentive program and how much this willingness to participate changed with increasing hypothetical levels of the car2go credit incentive.

The third survey in this longitudinal study, referred to as the "after" survey in this report, served as the follow up survey to the second incentive program, as well as a final opportunity to understand respondent thinking when it came to pricing strategies that incentivize certain behaviors. We asked questions that would shed light on the revealed actions of the respondents, as compared to the stated preference questions that were asked in the interim survey. For those respondents who had taken advantage of the incentive program through either of the two zones, we asked questions regarding the trips they took to earn credit and their overall opinion of the program. Respondents who had not yet taken advantage of the incentive program were asked why they had not participated. We also asked questions pertaining to the first incentive with the EV charging depot and asked respondents to indicate at which levels of both car2go credits as well as cash incentives they would have been likely to participate in the incentive program. We ended this survey with basic demographic questions.

5.2 Survey Implementation

We implemented the first two surveys associated with this study on QuestionPro and the final survey on Qualtrics. Given that this was a longitudinal study, in which the same population was surveyed multiple times over the course of several months, respondent attrition was a concern. A survey incentive was offered for the completion of the survey: the first 500 unique respondents who gave their email address were given a $25 Amazon gift card, while respondents 501 and up were entered into a drawing for one of ten $50 Amazon gift cards. After the survey link was emailed out to the car2go San Diego population, a reminder email was sent either one or two weeks afterward, after which the survey was closed.

We opened the before-survey on September 23, 2014 and closed it on October 6, 2014. We opened the interim survey on June 16, 2015 and closed it on July 12, 2015. The after-survey opened on February 19, 2016 and closed on March 3, 2016.

6 Results and Analysis

In this section, we present an analysis of the survey data collected through the three longitudinal surveys. The before survey was completed by 1,081 respondents, the interim survey was completed by 448 respondents, and the final survey had 473 complete responses. There were 228 unique respondents who took all three surveys. This section begins with a brief demographic overview of the survey respondents and a baseline travel behavior assessment of these respondents. We then analyze responses to the questions regarding the first and second incentive program. The activity data analysis is presented following the survey analysis.

6.1 Respondent Demographics

We used data from the before survey (n = 1,081) to analyze the demographic breakdown of the respondents. The demographic data collected in the second two surveys is used in cross-tabulations with answer choices pertaining to those respective incentives.

Figure 4 compares the gender and age distribution of car2go user respondents with the overall San Diego population. The data for the San Diego population were derived from the 2014 American Community Survey (ACS). The data show that proportionally more men (62%) use car2go relative to the population (1% preferred not to answer). There is an overrepresentation of those between the ages of 25 and 44 when compared with the San Diego population, especially those between 25 and 34 years of age. Based on the large body of previous research in shared mobility, the results present a consistent finding that younger users are more amenable to shared mobility providers, such as car2go and carsharing in general.

Figure 4: Gender and Age Distribution of Survey Sample Versus Overall Population

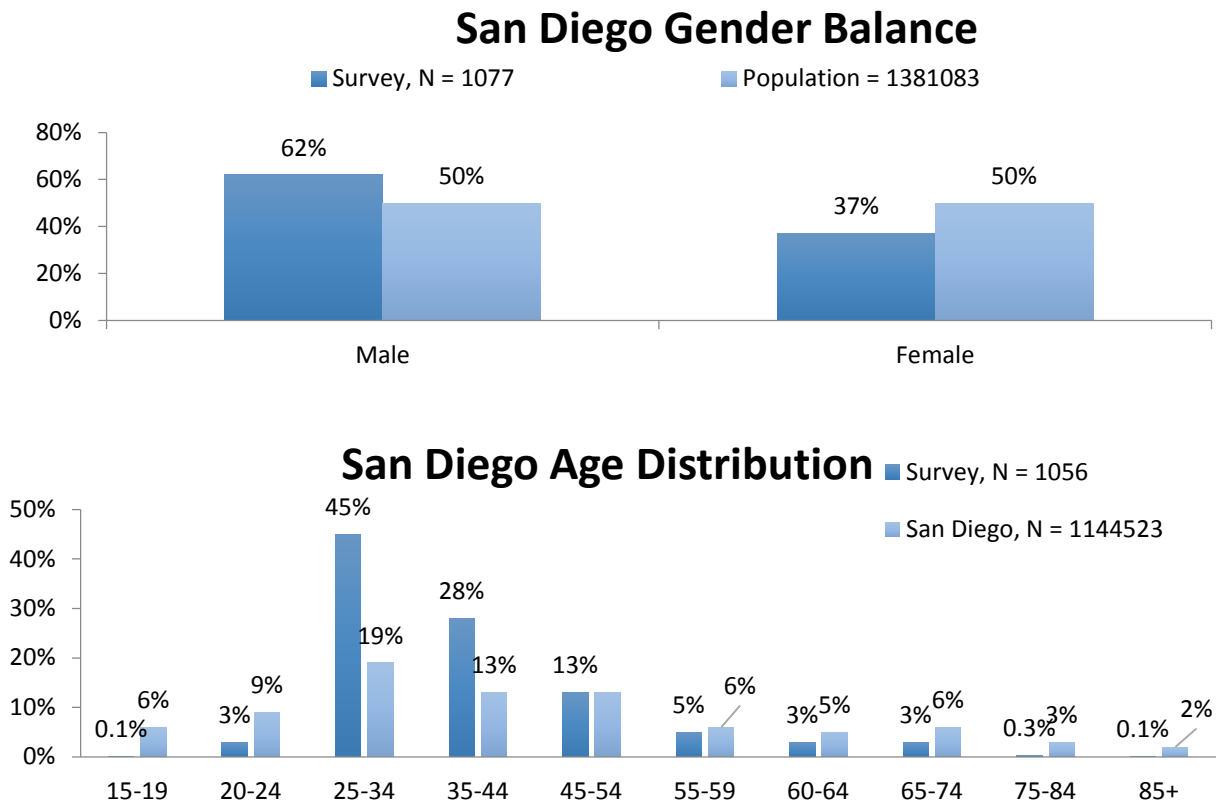
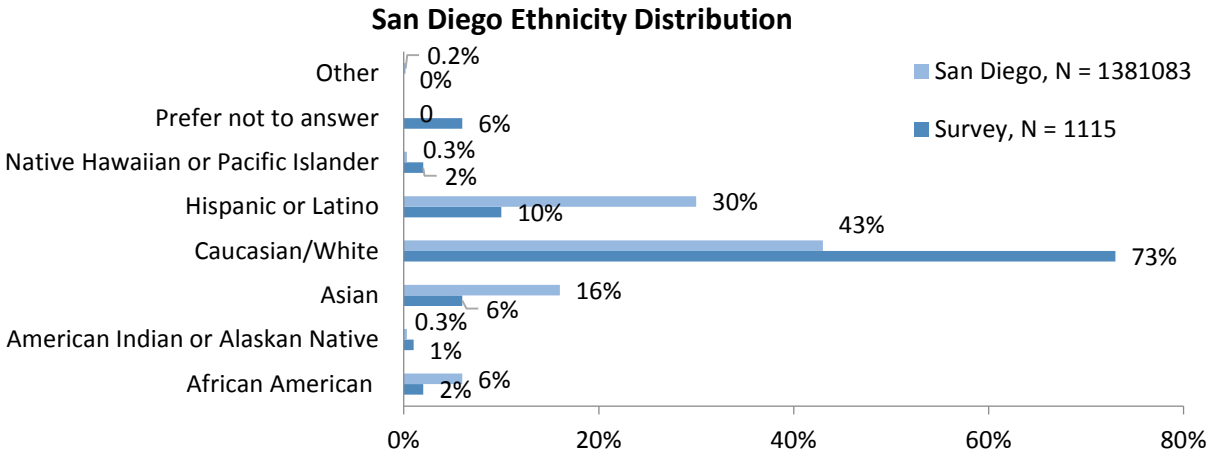
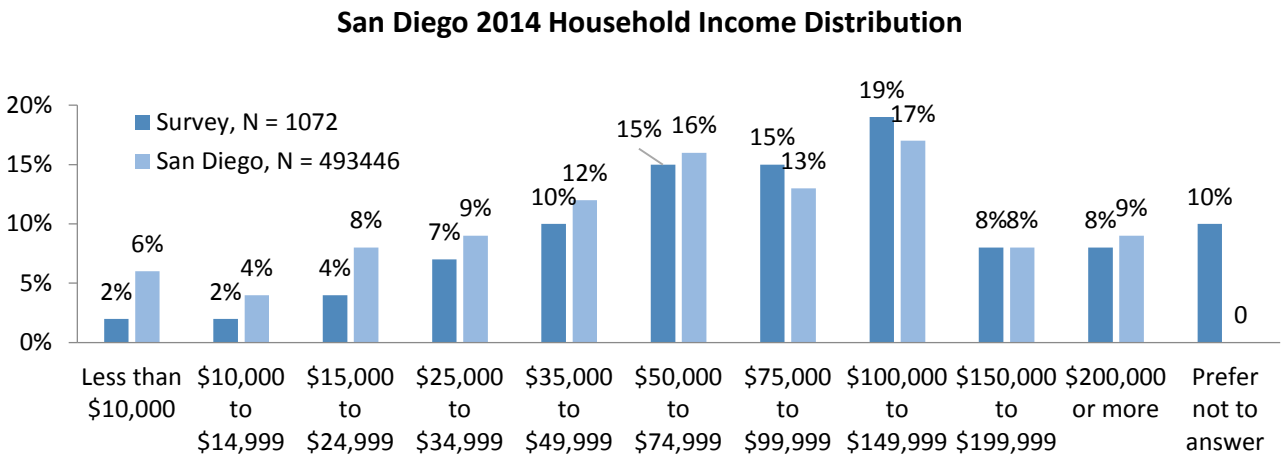
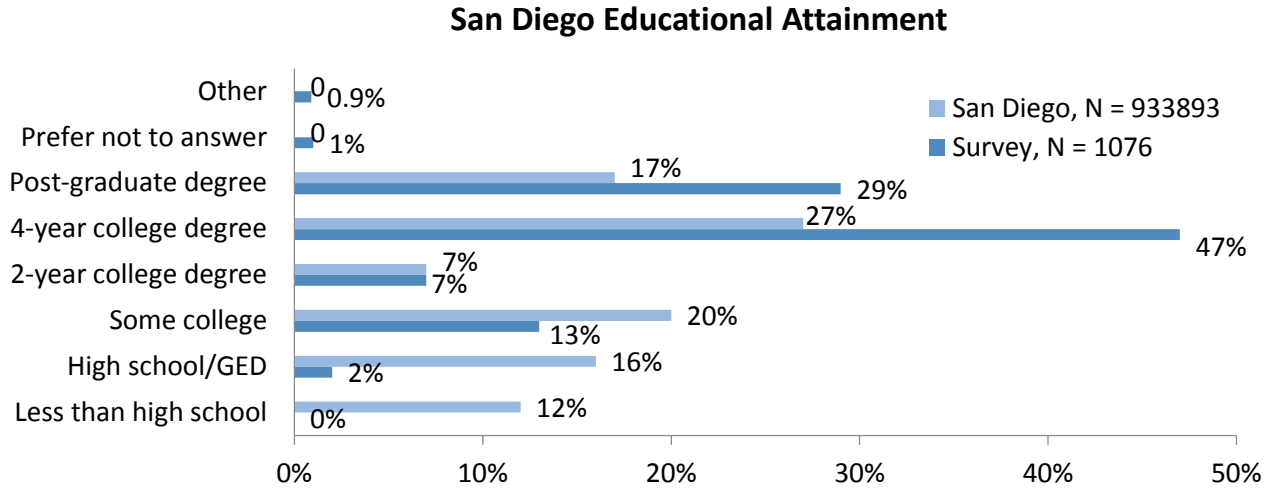


Figure 5 shows the distribution by ethnicity, income, and age of the car2go sample population and the San Diego population. Caucasians are overrepresented by 30% when compared with the overall population. The household income distribution matches relatively closely between the before survey population and San Diego's population, with a slight 4% overrepresentation of those who earn more than $75,000 and less than $150,000. Finally, there were more highly educated respondents in the sample relative to the San Diego population.

Figure 5: Ethnicity, Income, and Education Distribution of Survey Sample Versus Overall Population







6.2 Baseline Travel Behavior Assessment

While a primary purpose of this study was to measure the impact of various pricing incentives on user behavior, the longitudinal surveys also captured information useful for determining how respondents use their membership with car2go and the impact of car2go on their travel behavior. For this, we used data from the first survey to serve as a baseline of behavior before any of the incentive pilot programs were implemented.

Figure 6 shows the shared mobility service profile of the survey respondents for the before survey. The shared services profile demonstrates that in addition to car2go, many respondents were using ridesourcing or transportation network company (TNC) services, such as Lyft and Uber.

Figure 6: Shared Mobility Services Usage Profile of Car2go San Diego Survey Respondents

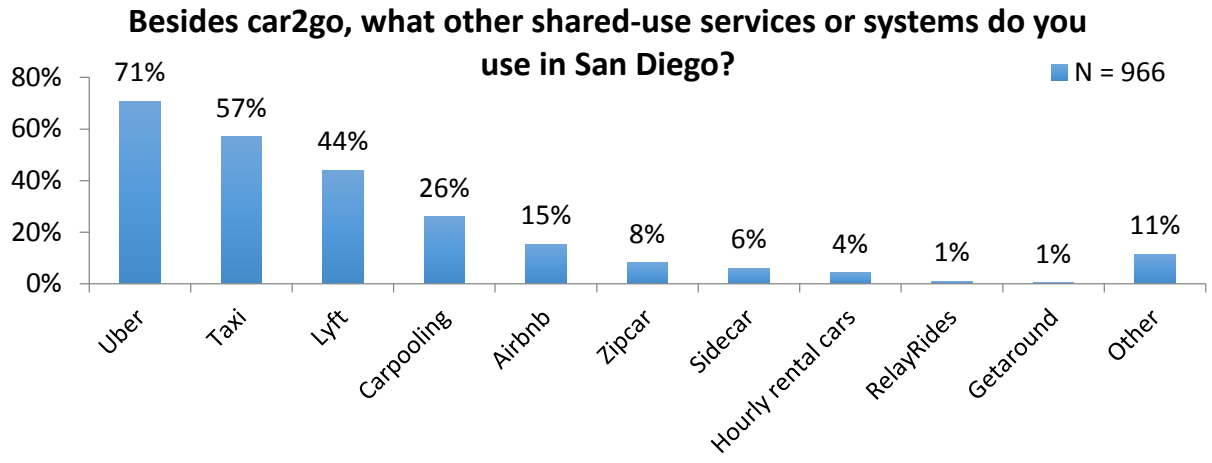


Figure 7: Car2go Trip Purpose Distribution

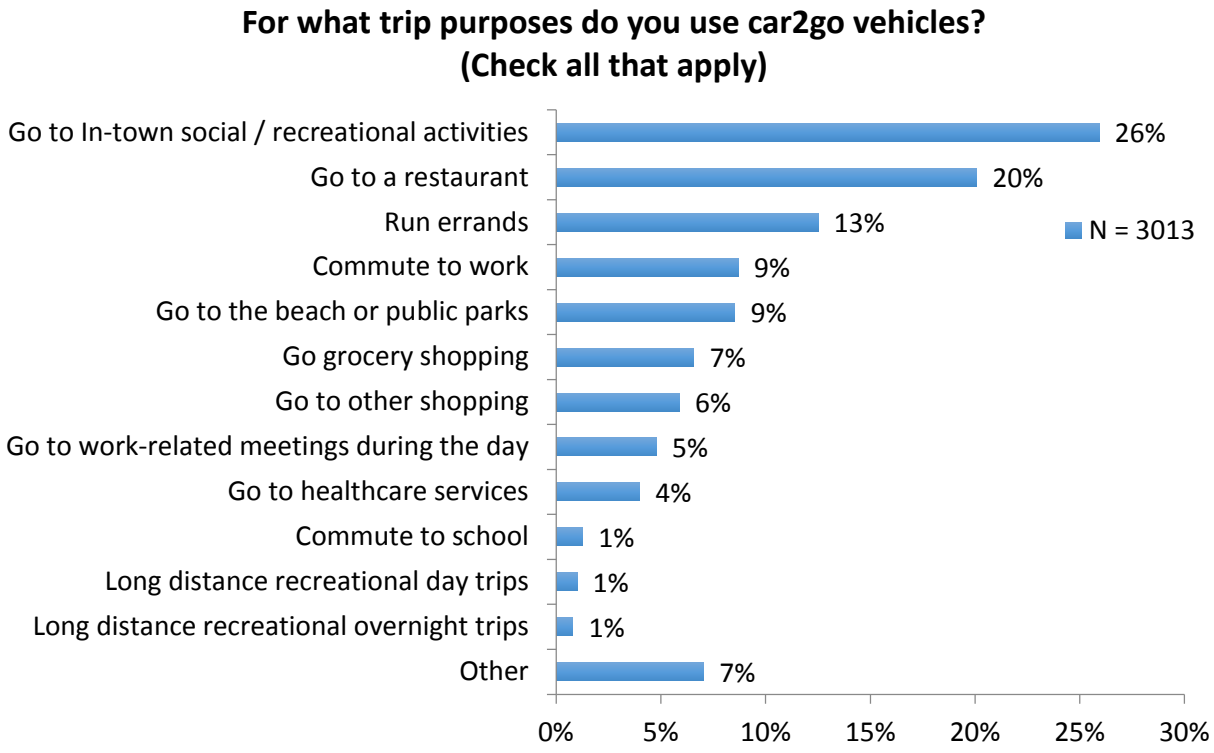
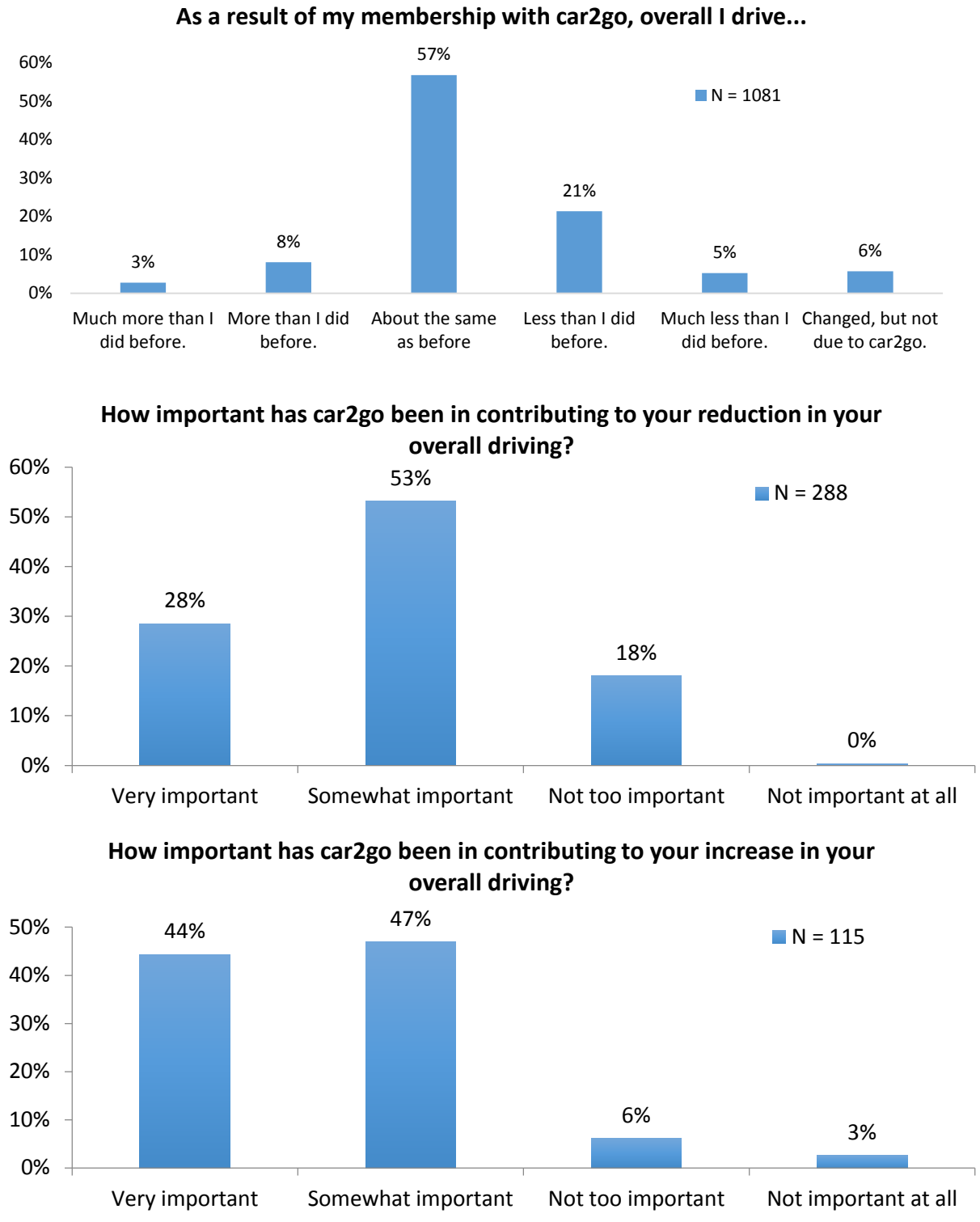


Figure 7 above shows that about one-fourth of car2go San Diego members used car2go for social or recreational activities and an additional 20% use it for the social activity of going to a restaurant. Nine percent used it as a way to commute to work, and another 9% used it to go to the beach or public parks. The remainder of trip purposes consisted of errands, shopping, or other types of recreational trips. The data below in Figure 8 show how car2go is impacting user driving. We asked survey takers how their driving had changed as a result of car2go, and we then asked follow up causal questions to indicate how important car2go was in causing that change.

Figure 8: Car2go Impact on Driving within Sample



Most people reported that overall driving levels had remained unchanged due to car2go. However, the results showed that in the case of San Diego, more respondents had reported a

reduction in driving (~27% due to rounding) due to car2go than an increase in driving (11%). The follow up causality questions indicate that car2go has a fairly important role in causing the changes in respondent driving. Figure 9 shows car2go's impact on respondents' use of public transportation and walking. While 12% of respondents reported using public transportation more as a result of car2go, 24% use it less. For the 39% of people who used public transportation before joining car2go, the service has had no impact. Car2go appears to be having a generally positive impact in shifting people toward more walking, with ~34% (due to rounding) of respondents indicating that they walk more due to the carsharing service versus only 9% of respondents reporting that they walked less.

Figure 9: Car2go Impact on Public Transportation and Walking Modal Shift within Sample

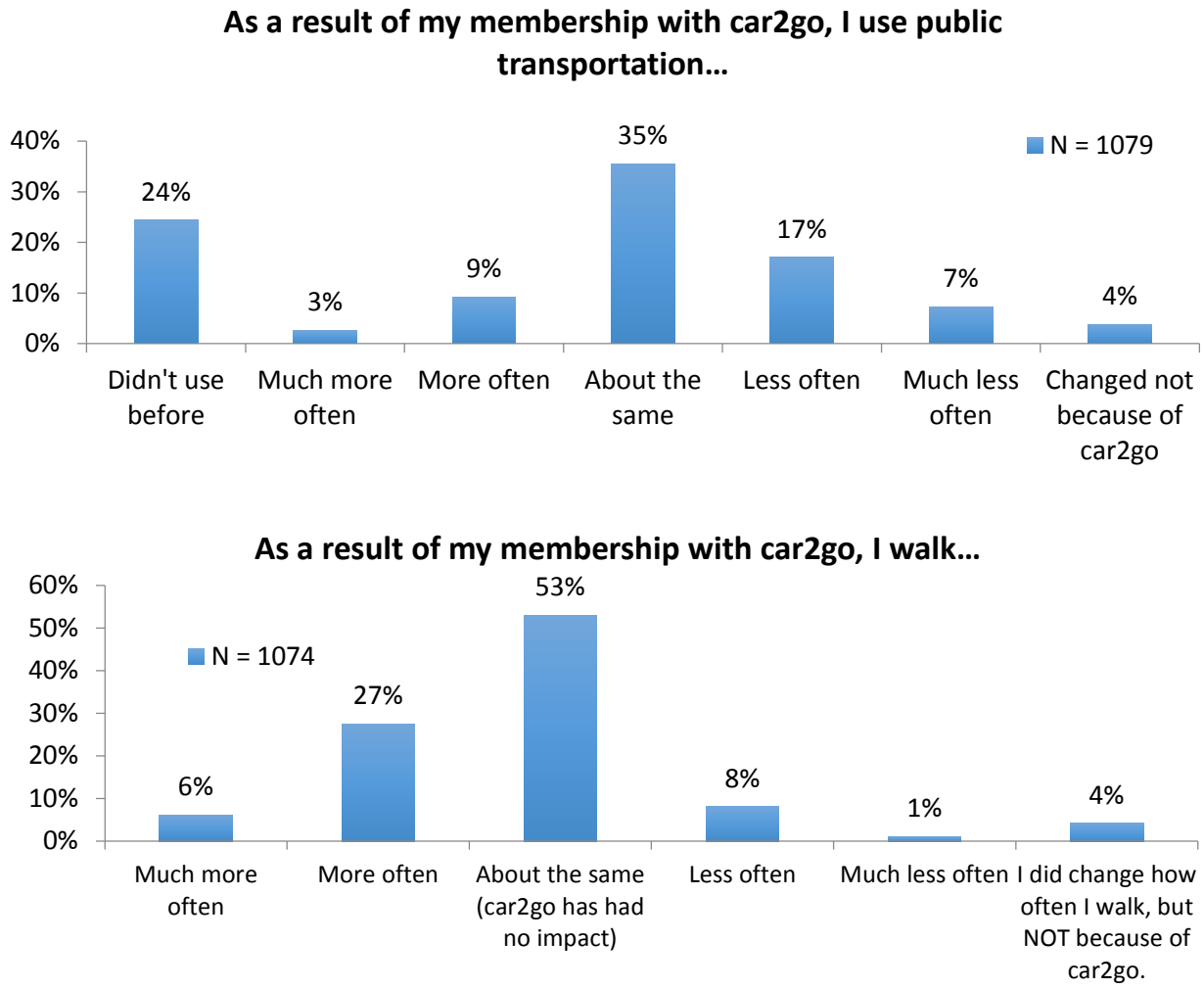
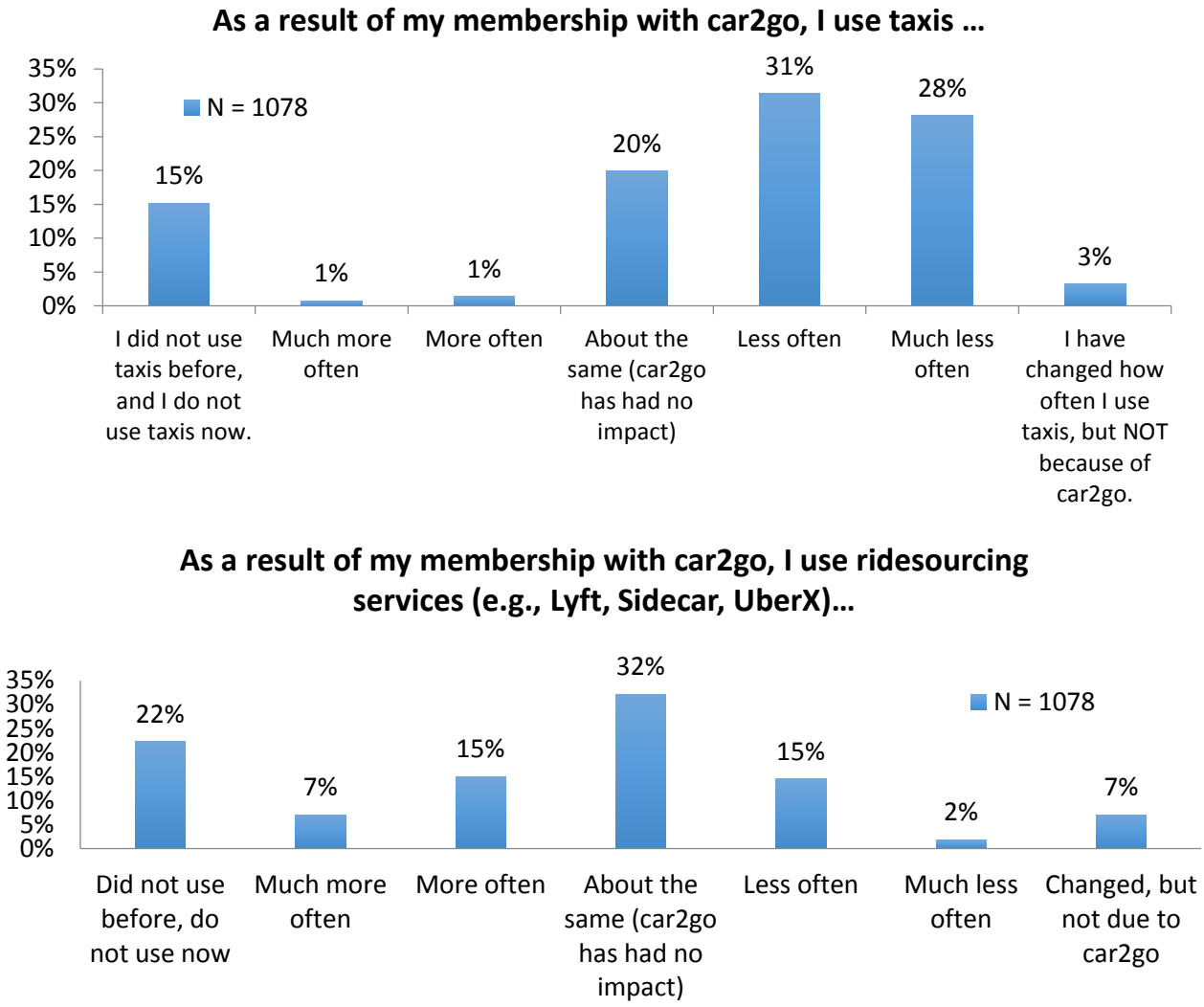


Figure 10 shows that there has been an unequivocal shift away from taxi use due to car2go, as 59% of respondents said they use taxis less as a result of their car2go membership. The shift away is less apparent with ridesourcing/TNC services, such as Lyft and Uber, where ~16% (due to rounding) use these on-demand rides less and 22% use them more. One possible explanation is the complementary role that car2go plays with respect to recreational travel to social events.

Respondents may be using car2go vehicles to drive themselves to restaurants and bars at night, and Lyft and Uber are then used on the return trip to avoid drinking and driving.

Figure 10: Modal Shift in Taxi and Ridesourcing/TNC Use within Sample



Overall, car2go in San Diego was found to have a notable impact on the basic travel patterns of respondents within the context of the key modes presented. In San Diego, car2go seemed to engender an overall shift toward reduced driving, more walking, reduced public transit, reduced taxi use, and increased ridesourcing/TNC use. These ordinal shifts are reported by "count of people" within the sample. They do not consider the measurement of total distance of change. That is, a person shifting travel by a little counts the same as a person shifting travel by a lot in these questions. Still, the response distribution provides insight into the nature of modal shift that is induced by the presence of car2go. In the sections that follow, we discuss the results of questions that evaluate the response to the incentive pilot projects that were implemented in this study.

6.3 First Incentive Analysis: EV Charging Depot

The first incentive program was an experiment designed to improve the efficiency of bringing vehicles close to the EV charging depot where car2go could refuel them. To receive the incentive, members had to drive a car2go vehicle for at least 10 minutes and park it within a three-by-three block radius in downtown San Diego. The response to this incentive was primarily captured by the before and interim survey. We included questions in the before survey that probed the expected responsiveness to the incentive program, while the interim survey provided feedback on whether the respondent had used this incentive program and changed their behavior as a result of it. As mentioned earlier, the before survey was launched in September 2014. In the discussions leading up to that time, car2go and the research team had decided that members would have to drive for 15 minutes before receiving the credit. But before the survey launched in October, car2go proposed changing the minimum to 10 minutes, which was approved by the research team. However, the before survey had already launched, so the questions reflected the 15-minute minimum.

6.3.1 First Survey

Figure 11, Figure 12, and Figure 13 below present data providing insight as to the potential of the incentive that was identified in the first survey. Figure 11 shows that about two-thirds of survey respondents reported that they drive car2go vehicles for more than 15 minutes at a frequency of once a month or less (not including those that never drive that length of time), while Figure 12 showed that 46% rarely drive through the downtown area.

Figure 11: Frequency Users Drive for More than 15 Minutes or to Downtown

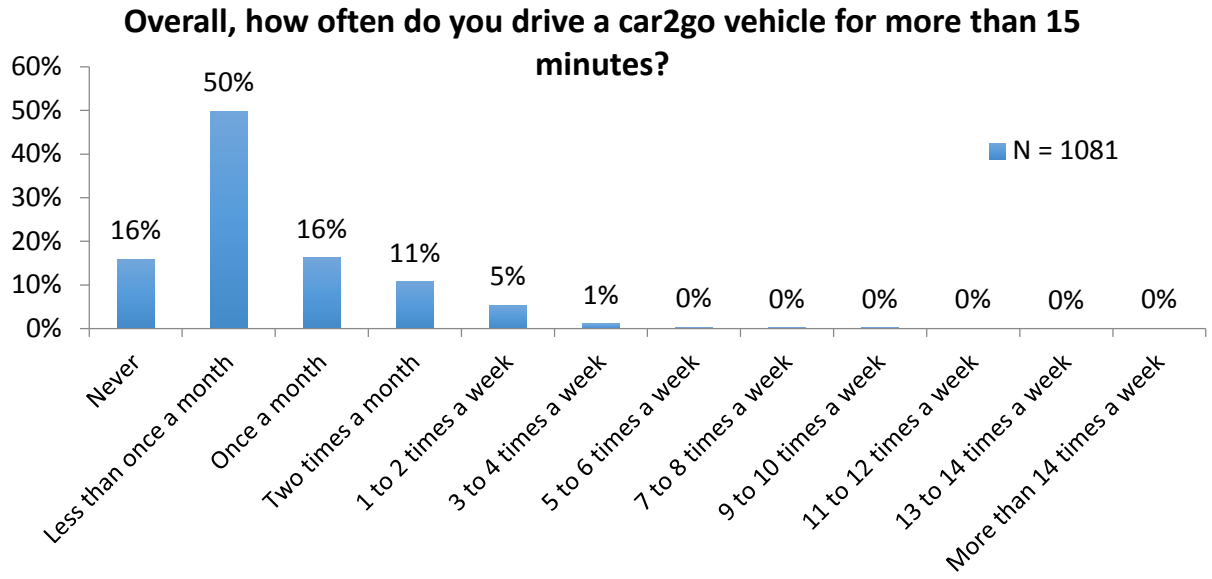


Figure 12: Frequency of Travel to Downtown Region

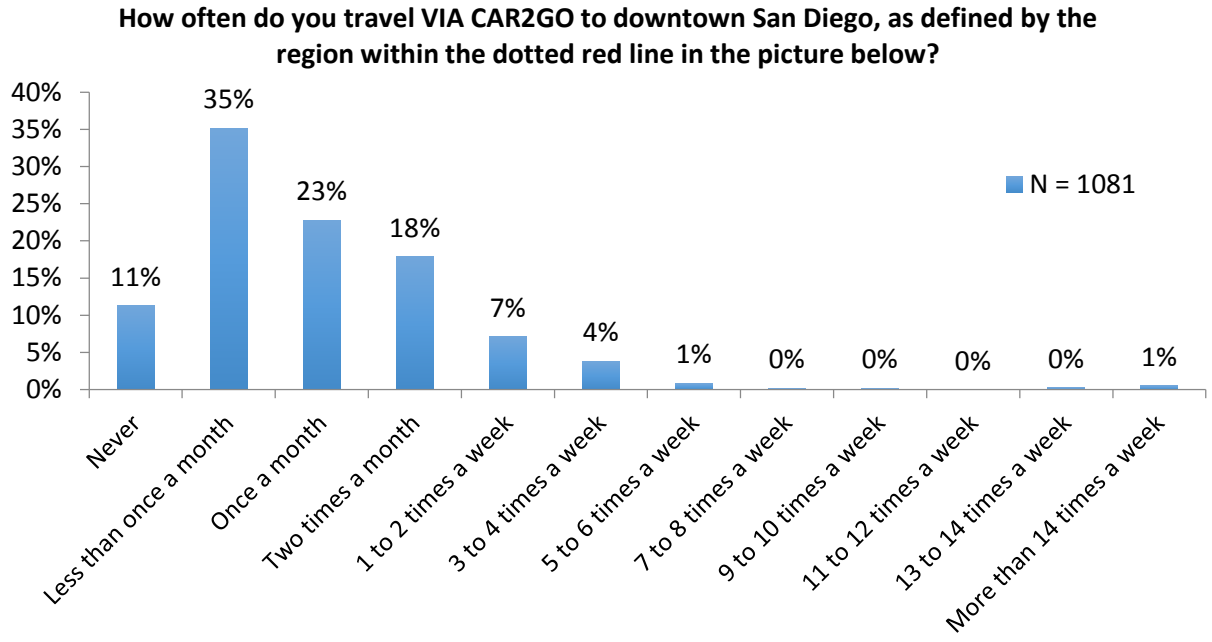


Table 1 shows a cross-tabulation of data from Figure 11 and Figure 12. It shows that travel was expected to be infrequent to the area in which the incentive zone was established. Furthermore, respondents going to this zone reported occasional use of car2go. The cross-tabulation shows that those going to the area of the zone at least once a week and driving the vehicle for more than 15 minutes at a time at least once a week were about 3.6% of the sample. However, those who reported meeting these criteria for once a month rises considerably to 26% of the sample. Overall, the combined data of Table 1 suggests that the users who would be able to regularly take advantage of the incentive would be minority of the user population. This result is perhaps expected, since the small zone in a large city is expected to be the destination of only a small share of the populace. Furthermore, to be successful for the purposes of delivering vehicles, an incentive did not need to engage everyone or even a majority of respondents equally.

Table 1 Cross Tabulation of Driving Car2go for 15 minutes by Driving to Downtown San Diego

Overall, how often do you drive a car2go vehicle for more than 15 minutes?	How often do you travel VIA CAR2GO to downtown San Diego, as defined by the region within the dotted red line in the picture below?												
	Never	Less than once a month	Once a month	Two times a month	1 to 2 times a week	3 to 4 times a week	5 to 6 times a week	7 to 8 times a week	9 to 10 times a week	11 to 12 times a week	13 to 14 times a week	More than 14 times a week	Total
Never	32 (3%)	65 (6%)	42 (4%)	19 (2%)	5 (0%)	8 (1%)		1 (0%)					172 (16%)
Less than once a month	63 (6%)	253 (23%)	114 (11%)	77 (7%)	19 (2%)	10 (1%)	2 (0%)					1 (0%)	539 (50%)
Once a month	16 (1%)	31 (3%)	57 (5%)	42 (4%)	22 (2%)	4 (0%)	2 (0%)					1 (0%)	175 (16%)
Two times a month	5 (0%)	21 (2%)	24 (2%)	40 (4%)	12 (1%)	9 (1%)	1 (0%)				1 (0%)	3 (0%)	116 (11%)
1 to 2 times a week	5 (0%)	8 (1%)	7 (1%)	11 (1%)	15 (1%)	6 (1%)	2 (0%)	1 (0%)	1 (0%)		1 (0%)	1 (0%)	58 (5%)
3 to 4 times a week	1 (0%)	2 (0%)		2 (0%)	2 (0%)	3 (0%)	2 (0%)						12 (1%)
5 to 6 times a week					1 (0%)	1 (0%)					1 (0%)		3 (0%)
7 to 8 times a week				2 (0%)									2 (0%)
9 to 10 times a week			2 (0%)										2 (0%)
11 to 12 times a week					1 (0%)								1 (0%)
13 to 14 times a week													
More than 14 times a week									1 (0%)				1 (0%)
Total	122 (11%)	380 (35%)	246 (23%)	193 (18%)	77 (7%)	41 (4%)	9 (1%)	2 (0%)	2 (0%)		3 (0%)	6 (1%)	1081 (100%)

The data in Table 1 provide important context to expected behavior. In responses shown in Figure 13, 51% of respondents believed that they would use the incentive once a month or more. This might have reflected some exuberance among the responding population. Analysis of activity data presented in the section that follows suggests that the incentive increased activity mostly among members that were already going to the region.

Figure 13: Frequency Users State They Would Use the Incentive

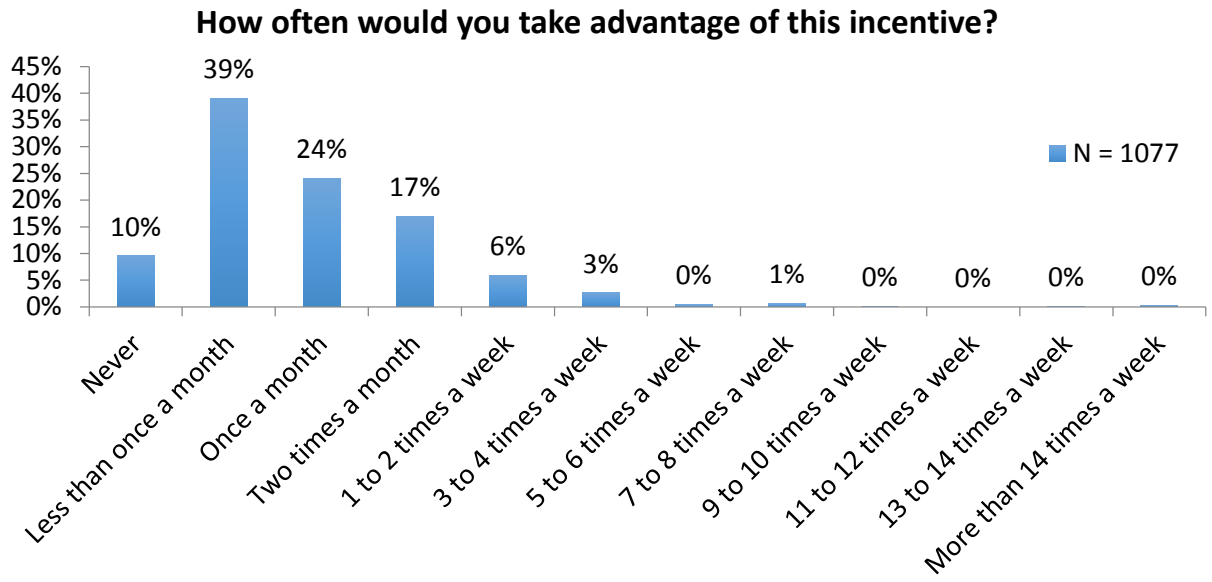
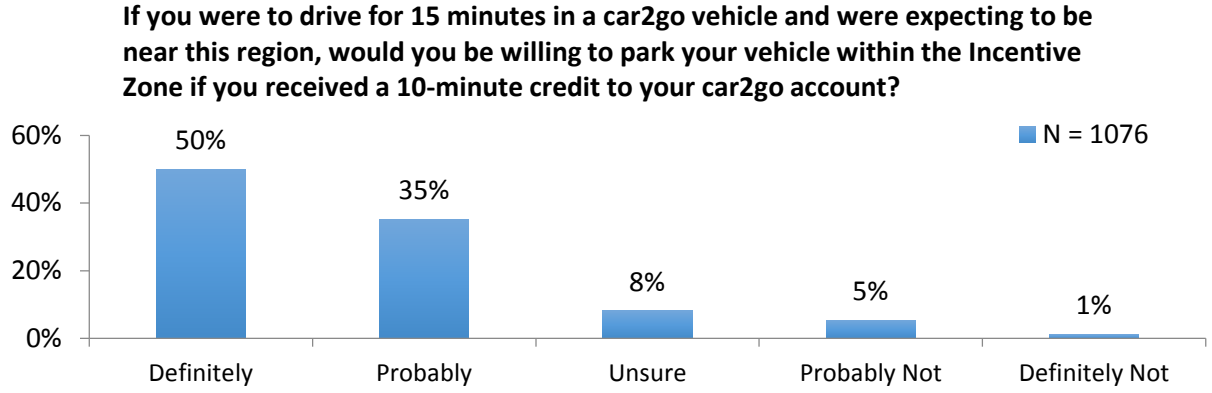


Figure 14 below shows the response breakdown when users were asked whether they would take part in the incentive program, if they expected to be near the EV charging depot. The response in this case was more encouraging, as 85% reported that they would probably or definitely be willing to park the vehicle to receive free credit.

Figure 14: User Willingness to Partake in First Incentive

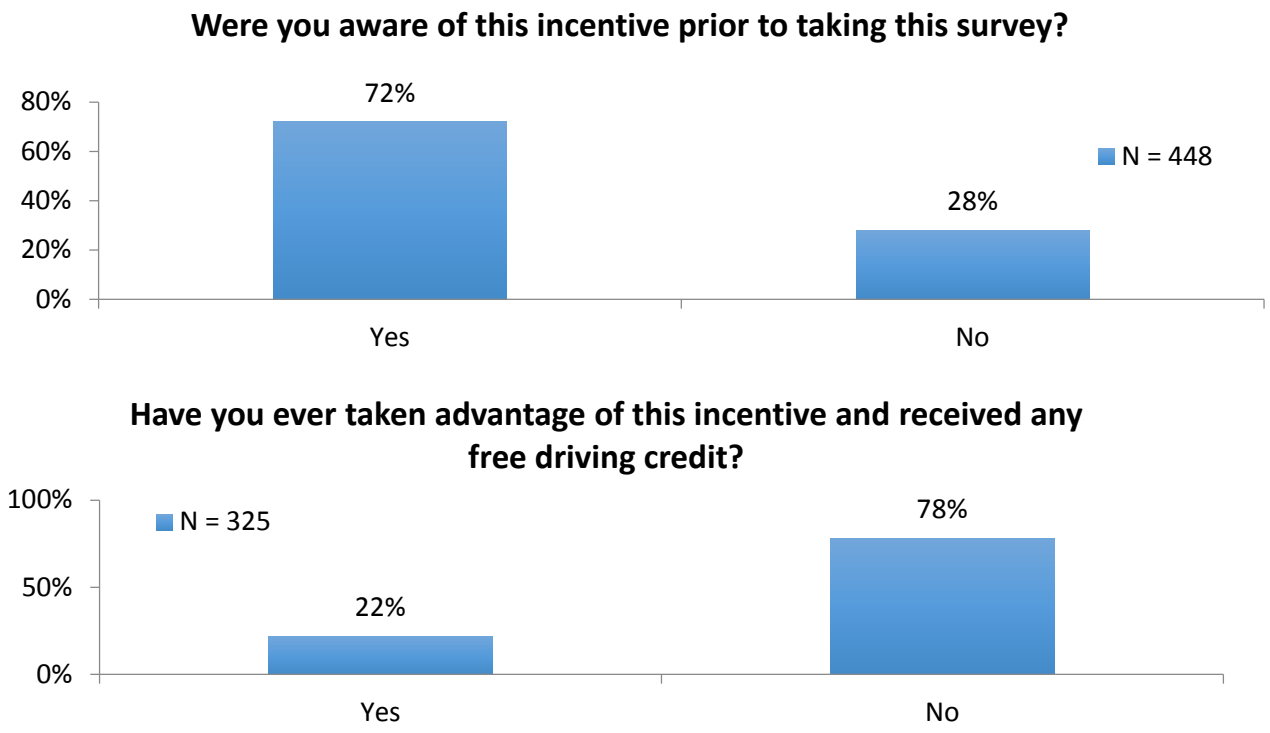


6.3.2 Interim Survey

The interim survey was given to respondents after seven months of operating this incentive and acted as the "after" survey to gain feedback on the response to and use of the EV charging depot incentive. We issued the survey only to those who completed the first survey and received the incentive, and naturally some attrition occurred with the respondents. The survey

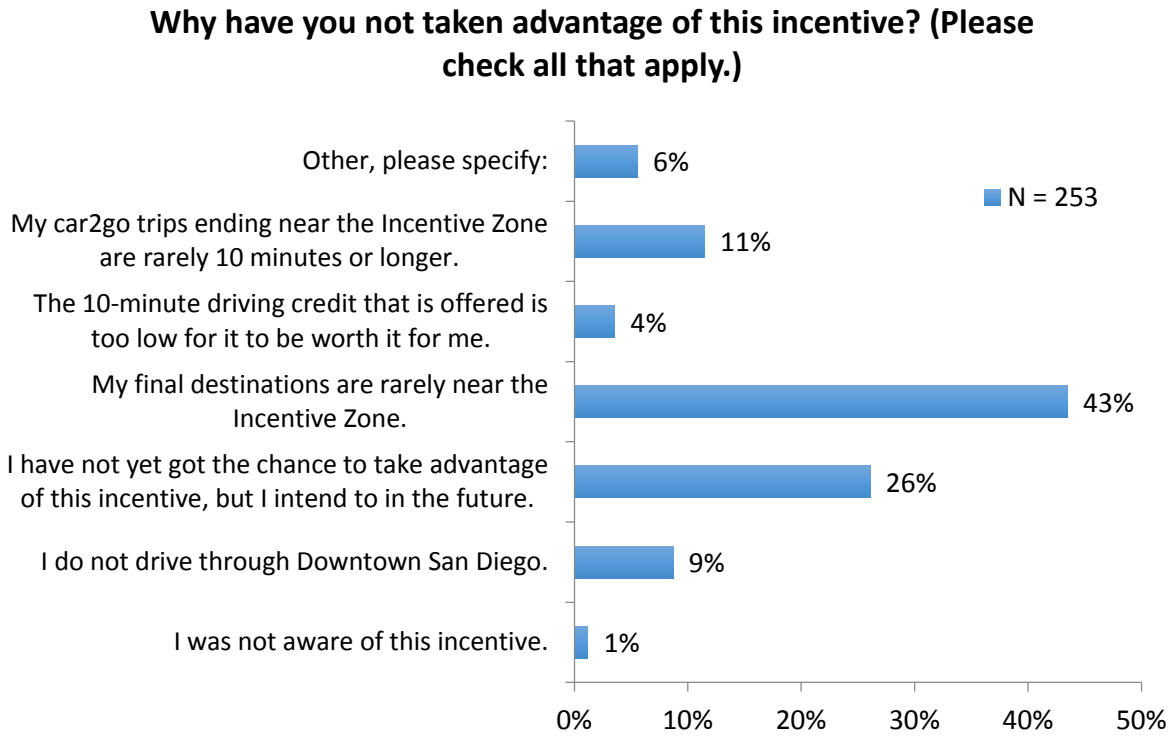
began by asking respondents whether they were aware of the incentive. Then those that were aware of it were then asked whether they had taken advantage of it. The responses are shown below in Figure 15.

Figure 15: Revealed Use of EV Charging Depot Incentive



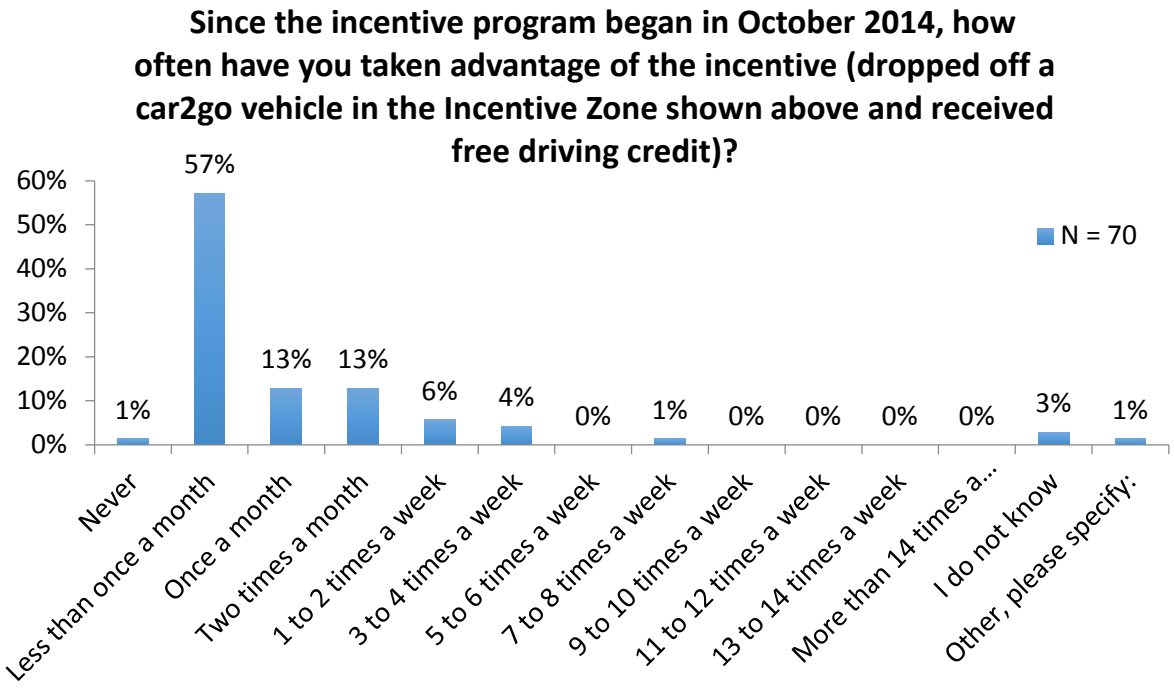
Only 22% of those who had heard of the EV charging depot incentive program had reported taking advantage of it. This comprised 16% of the sample reported taking advantage of this incentive. Those who had not taken advantage of the incentive were asked why, and the responses are shown in Figure 16. The results revealed that many respondents did not use the incentive because their trips did not end in downtown San Diego. One-fourth of the respondents stated that they intended to take advantage of the incentive in the future, while only 4% stated that they had not used the incentive due to the low credit. Overall, the responses suggested that travel patterns, rather than monetary considerations, limited the number of people taking advantage of the incentive program.

Figure 16: Reasons for Not Taking Advantage of EV Charging Depot Incentive



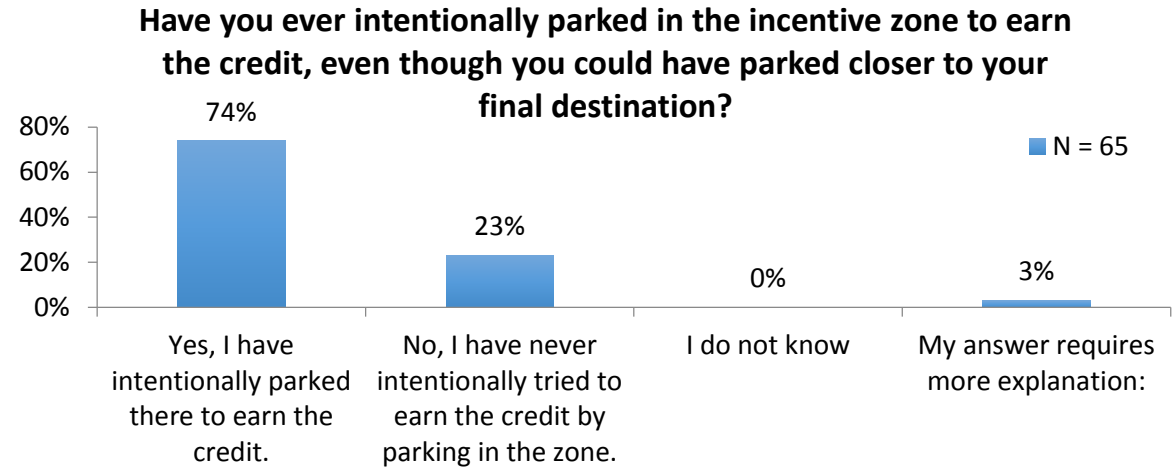
The 16% of the sample population (n = 71) who took advantage of the EV charging depot incentive were asked a series of follow up questions regarding their participation in the incentive. Figure 17 shows how often incentive users took advantage of the program by dropping off a car2go vehicle inside the three-by-three block area in downtown San Diego. Thirty-seven percent participated in the program once a month or more in the eight months since it had started.

Figure 17: Frequency of EV Charging Depot Incentive Use



In the survey, we probed whether the incentive had induced people to change their travel pattern or behavior after the pilot pricing incentive. Figure 18 reveals that about three-fourths of the respondents who had taken advantage of the incentive program deliberately parked closer to the EV charging depot to get the credit.

Figure 18: How Many Respondents Parked Further from Destination for EV Charging Depot Incentive



Although only a minority of respondents participated in the incentive program, it appears that they were satisfied with the program. Figure 19 shows a high level of user satisfaction. Figure 20 shows that out of all the survey respondents, about a third felt that vehicles have been more charged than usual. This is a perception that reflects user sentiment and does not necessarily indicate an actual increase in the level of vehicle charge encountered by users.

Figure 19: User Satisfaction with EV Charging Depot Incentive

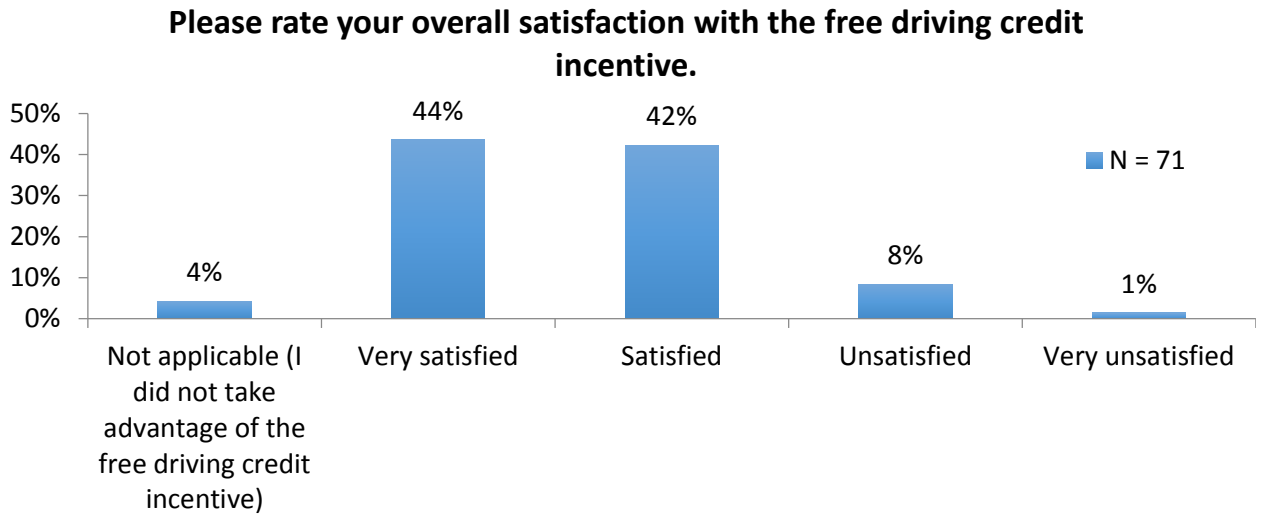
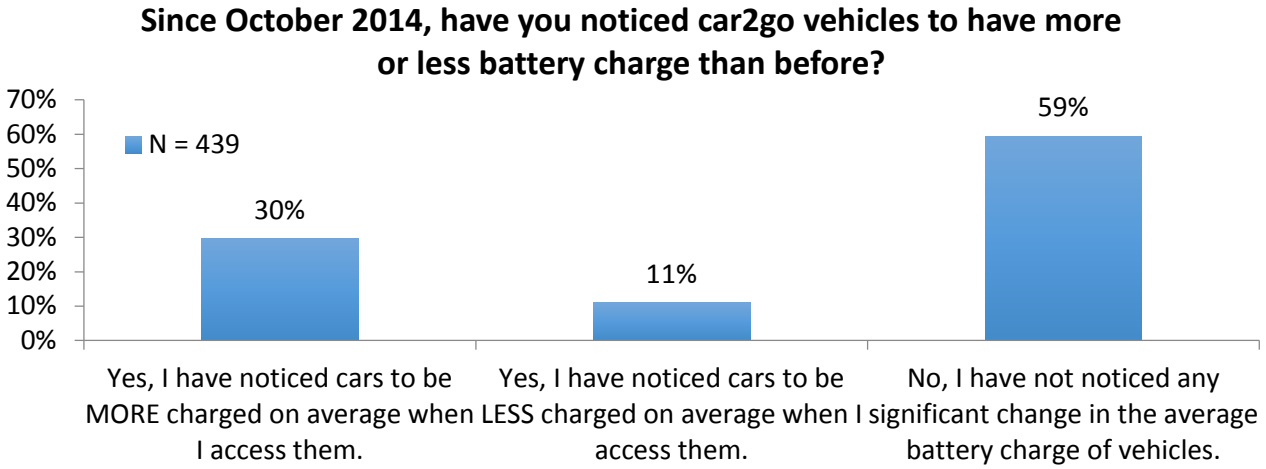


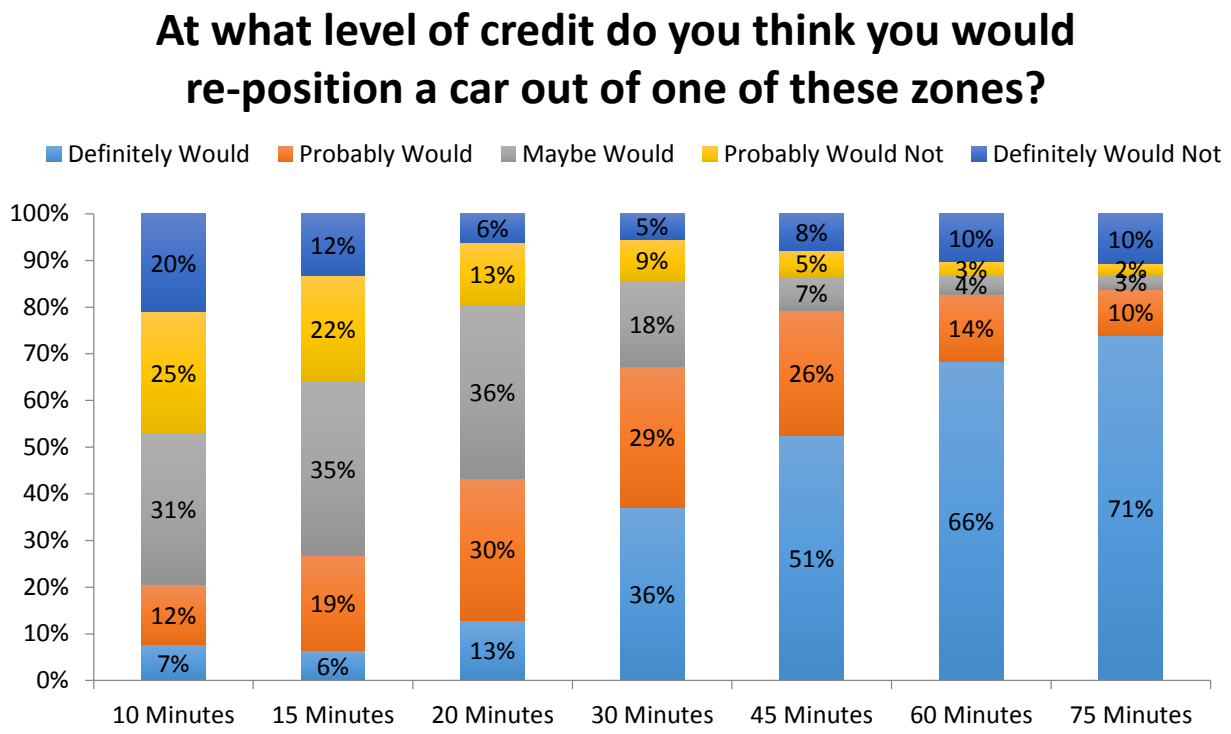
Figure 20: Respondent Views on any Changes in car2go Vehicle Charge



6.4 Second Incentive Analysis: Low-Demand Zones

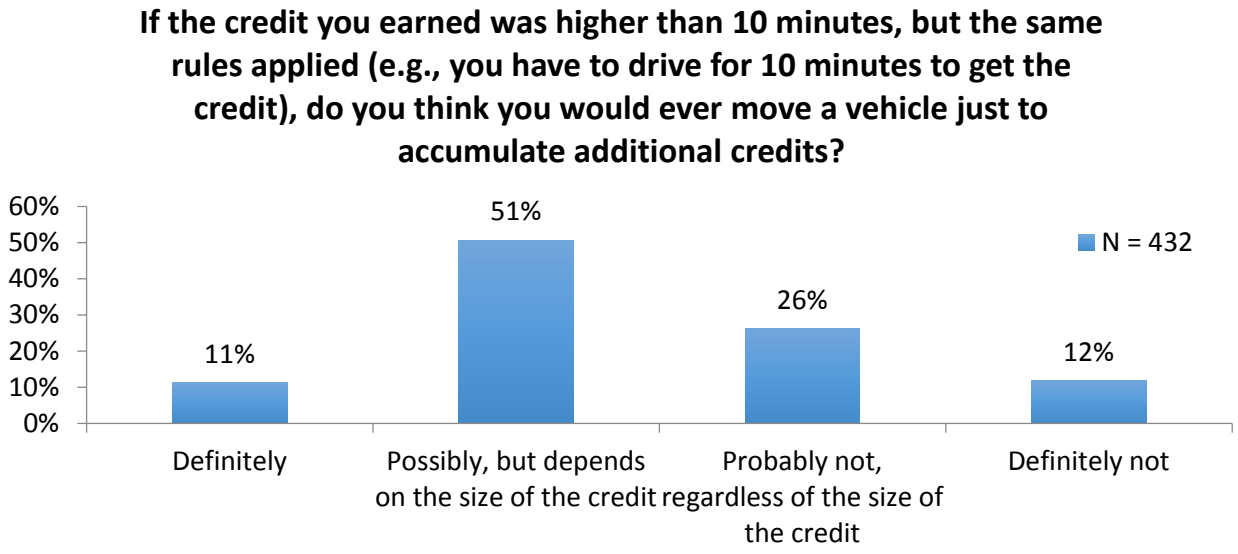
The second incentive pertained to inducing demand for vehicles in low-demand zones. The two zones evaluated were Mission Beach and Golden Hill. The interim survey acted as the precursor to this incentive in which respondents were asked to rate their willingness to re-position car2go vehicles at varying levels of incentive credit. The responses are shown in Figure 21.

Figure 21: Price Response Graph Showing Willingness to Participate at Varying Incentive Levels



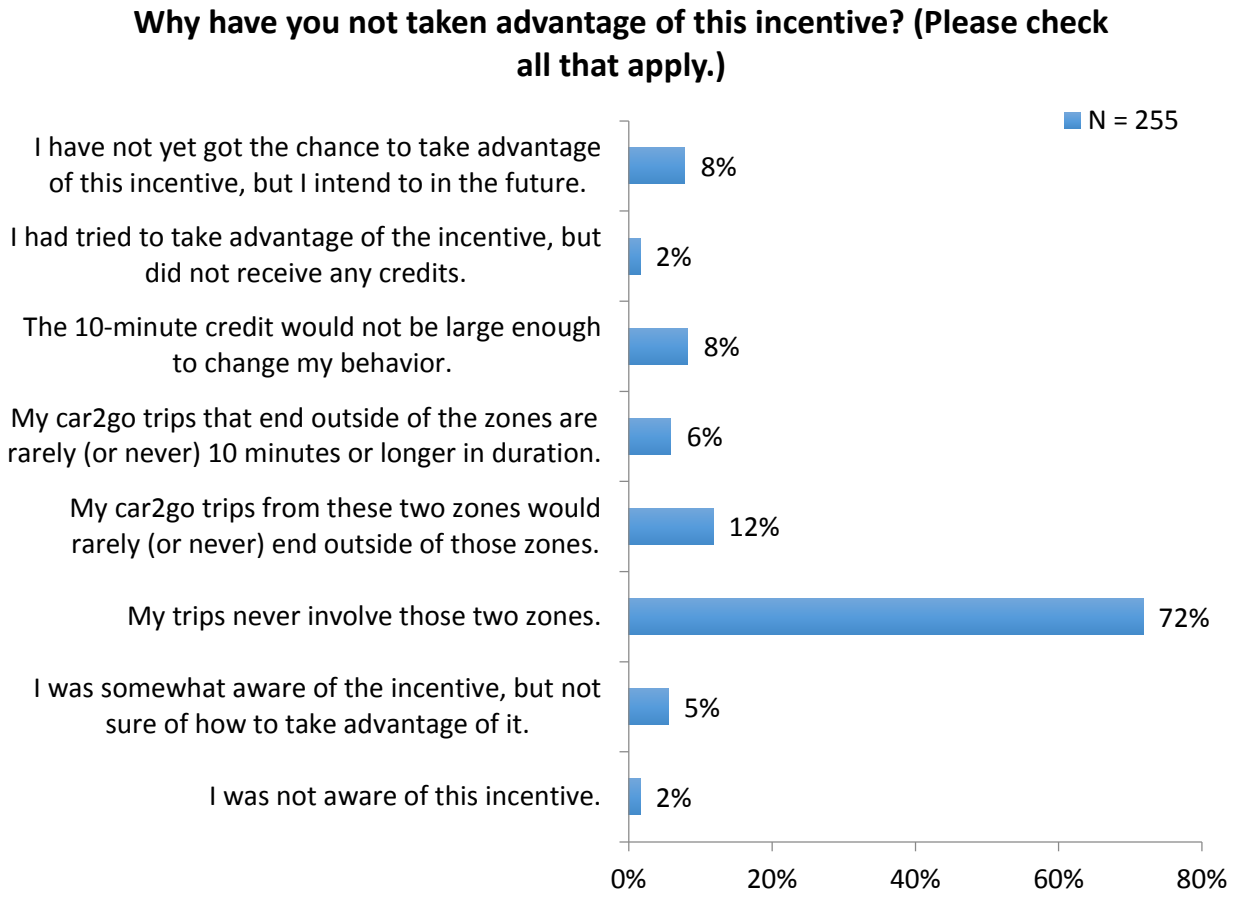
Not surprisingly, Figure 21 shows that member willingness to re-position vehicles increases with a higher credit offered. However, it also shows that there is diminishing return with a higher incentive. For example, the increment from 45 to 60 minutes of credit only yields 3% more respondents who probably or definitely would participate, and the jump from 60 to 75 minutes of credit yields about 1% more respondents. The greatest jump in willingness to participate occurs from 20 to 30 minutes of credit, where there is an increase of 22% in people who probably or definitely would participate. Thus, the response suggested that a 30 minute credit could have been the optimal point at which the largest share of the sample population would participate in the incentive per unit of incentive given. Some respondents would not engage with the second incentive no matter the size. Consistent with the findings in Figure 21, Figure 22 showed 12% of the population was definitely not interested in the incentive program at any credit level.

Figure 22: Willingness to Move a Vehicle if Higher Credit Offered



The after survey, given seven months after the interim survey, sought to evaluate the impact of the second incentive. According to the after survey results, 69% of the 475 respondents were aware of the low-demand zone redistribution incentive, but of those people only 21% had ever received free credit as a result of the program, meaning that 14% of the survey sample had participated in the incentive program. This is similar to the 16% figure of those who had participated in the first incentive program. Of these, 69 respondents who had received free credit through this program, 57% had participated in the Golden Hill incentive zone, 31% in the Mission Beach zone, and 18% were not sure through which zone they had received the free credit. Respondents who did not participate were asked why they had not participated in the incentive, and Figure 23 shows the distribution of responses. By far, the main reason (72%) was simply that most of their car2go trips did not involve the two incentive zones.

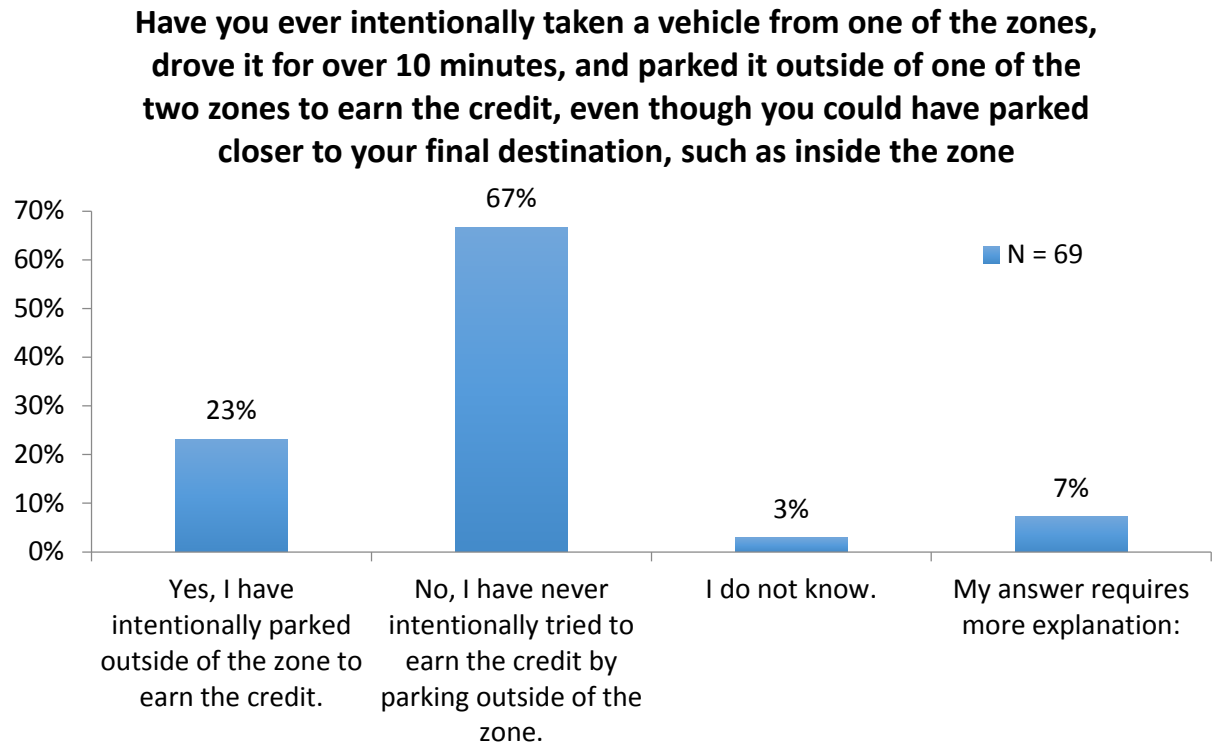
Figure 23: Reasons for Not Taking Part in Low-Demand Zone Incentive



One key difference between the second and first incentive is illustrated in Figure 24. It shows that only 23% of users had intentionally taken a car parked inside the low-demand area and then drove and parked it outside of that area to earn credit. This contrasts with the 71% who had modified their trip to take advantage of the EV charging depot incentive, as was shown in Figure 18 earlier. One of the key differences between the two incentive programs was the location of the incentive zones. The first incentive zone was in a centrally located downtown region, where all vehicles could go to it, while the second incentive program had peripheral zones in which only specific vehicles could leave it. These differences likely influenced the relative impact of the first incentive versus the second incentive.

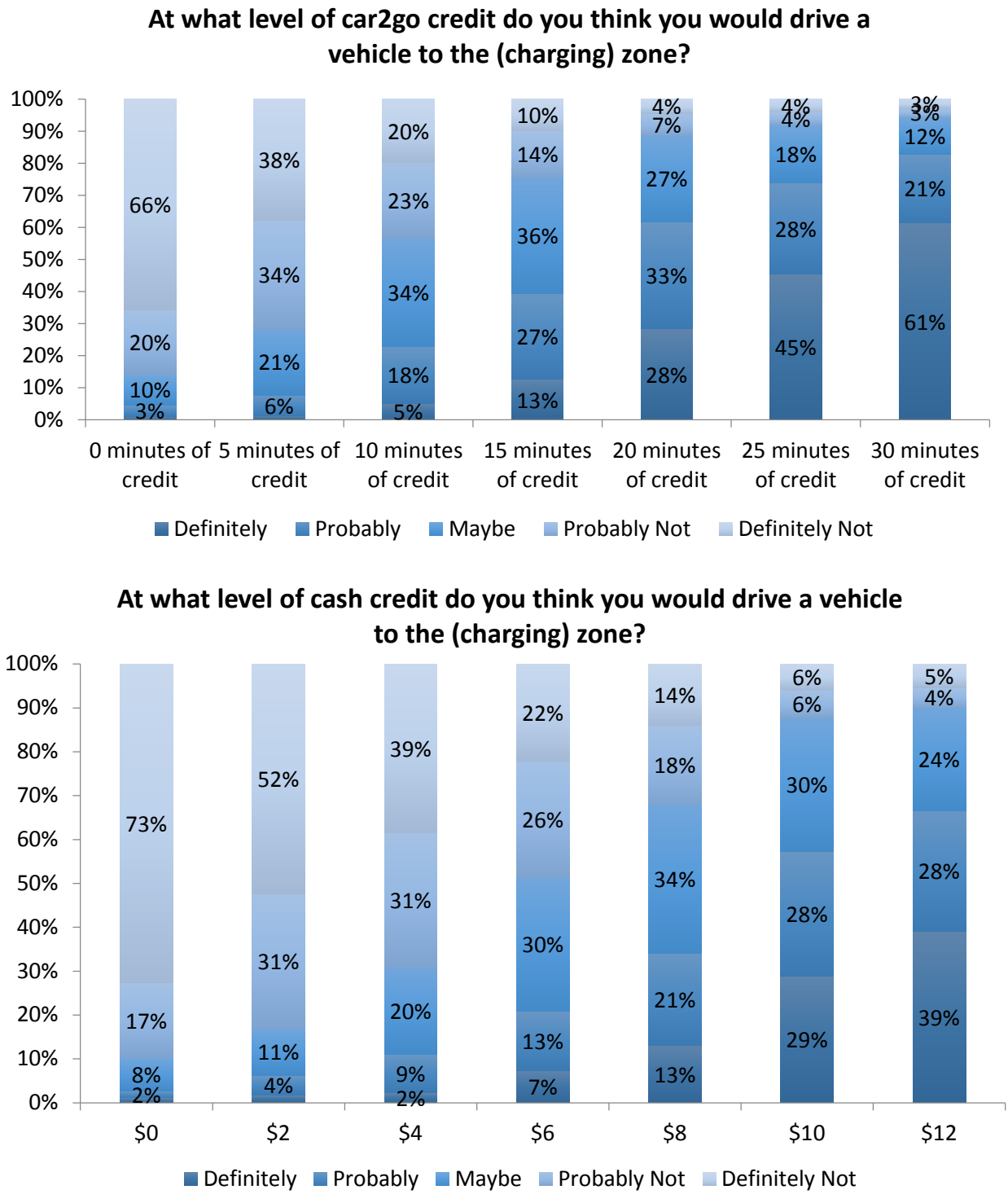
Respondents that reported receiving the second incentive were asked whether they changed their travel patterns as a result of it. The distribution of responses is shown in Figure 24. The responses indicate that only 23% (16 respondents) of those that earned an incentive to drive and park a car out of the low-demand zone did so explicitly to earn a credit. This result, while a limited one, shows that this type of incentive was capable of influencing some travel behavior.

Figure 24: Have Users Intentionally Parked Outside of Incentive Zones to Earn Credit?



The final survey also contained some pricing questions to capture insights related to member valuation of different types of incentives. Similar to the price response graph shown earlier for the second incentive, a price response graph was developed for the EV charging depot incentive using data from the final survey. We wanted to explore how respondents valued car2go credit versus dollars. A price point question comparatively evaluated how these incentives would be received by members and which type would be more effective in motivating changes in behavior. The dollar denominations selected roughly equaled the value of the denominations of the car2go time credit, using the conversion of $0.41 per minute of car2go credit. The results are shown in Figure 25 below.

Figure 25: Price Response Graph Showing Willingness to Participate in EV Charging Depot Incentive at Varying Credit and Cash Amounts



At 30 minutes of car2go credit, 82% of respondents would probably or definitely move a vehicle to an EV charging depot in downtown San Diego. This many minutes of car2go credit translates

to about $12.30. However, when asked what they would do for $12 of cash incentive, only 67% of respondents would probably or definitely move a vehicle into an EV charging depot zone. This contrast is evident for the other denominations as well. Thus, the results suggest that respondents on balance value car2go credit more than an equivalent amount of cash. There are a number of possible reasons for this. It is possible that the users value car2go driving minutes at a higher rate than $0.41 per minute. It is also interesting to note that when the above figure is compared with the price response graph pertaining to the low-demand zone incentive, users appear much more willing to participate in the EV charging depot incentive for a lower rate. For example, the results suggest that for 15 minutes of credit, 25% of respondents would probably or definitely participate in the second incentive. However, for the same amount of credit, 40% of respondents indicated that they would participate in the first incentive, driving a vehicle to an EV charging depot. When asked in the final survey which incentive program they preferred, 37% preferred the first, and 20% preferred the second.

6.5 Activity Data Analysis on Charging Incentive

Researchers evaluated car2go activity data to determine the degree to which the incentives substantively impacted the movement of vehicles toward the incentive zone. The period of data we analyzed for this incentive was from December 2013 to July 2015. The results suggest that the first incentive policy had a limited but detectable impact on overall travel activity to the incentive zone. The trend of user trips taken to the incentive zone is generally flat over the evaluated period. But, there is a distinguishable rise in the number of user trips to the incentive zone during the period in which the incentive was implemented. This rise occurs while overall trip activity in the broader system is generally flat or declining. Recall that in order to qualify for the first incentive, the user had to:

1) Drive a car2go vehicle for at least 10 minutes,
2) Be a user (and not a staff member), and
3) End their trip within the zone surrounding the charging depot.

In the absence of the incentive, a certain level of activity that fit these criteria occurred anyway as part of typical movements of the system. The objective of the before-and-after analysis was to determine how the incentive may have changed the trajectory of this activity while the incentive was offered. Figure 26 below shows a plot of the number of qualifying trips to the incentive zone before, during, and after the incentive deployment. These are trips that met the conditions for the incentive. Each point on the line shows the measurement at the end of the month (September is the activity measured through the end of September). Since the first incentive (we call the “charging” incentive) went into effect at the beginning of October 2013, this point represents the first month in which activity could have been influenced by it. Two vertical lines bracket when the incentive went into effect.

Figure 26: Total Number of Qualifying Trips to the Incentive Zone Before and After Incentive

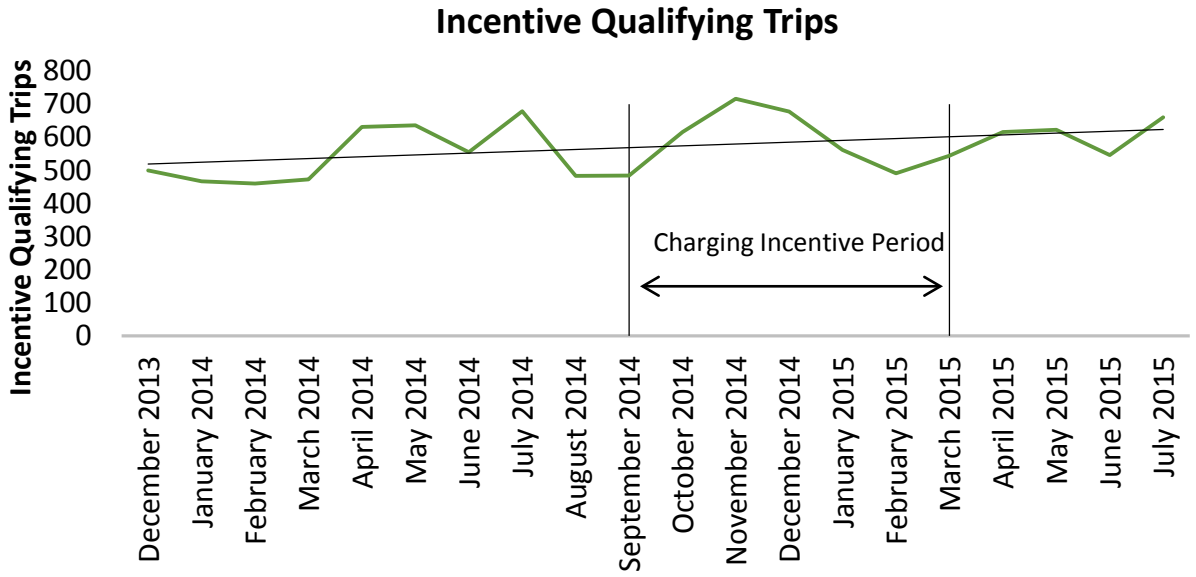


Figure 26 shows a slight upward trend in qualifying trips over the entire series. Immediately after the incentive began there is a noticeable uptick in trips ending in the zone that exceed 10 minutes. The uptick reaches a maximum of 716 qualifying incentive trips, which is also the time series maximum. The surge in activity after the incentive began is a promising result that could be the result of the incentive, but it could also be explained by a surge in broader system activity itself. A plot of the indexed trend in overall user trips system wide is shown in Figure 27 below. This plot shows the total trips divided by the first value of the series (December 2013), and illustrates relative fluctuations from that initial values. The trend generally shows a modest decline in trips over the period.

Figure 27: Count of User Trips System Wide in San Diego

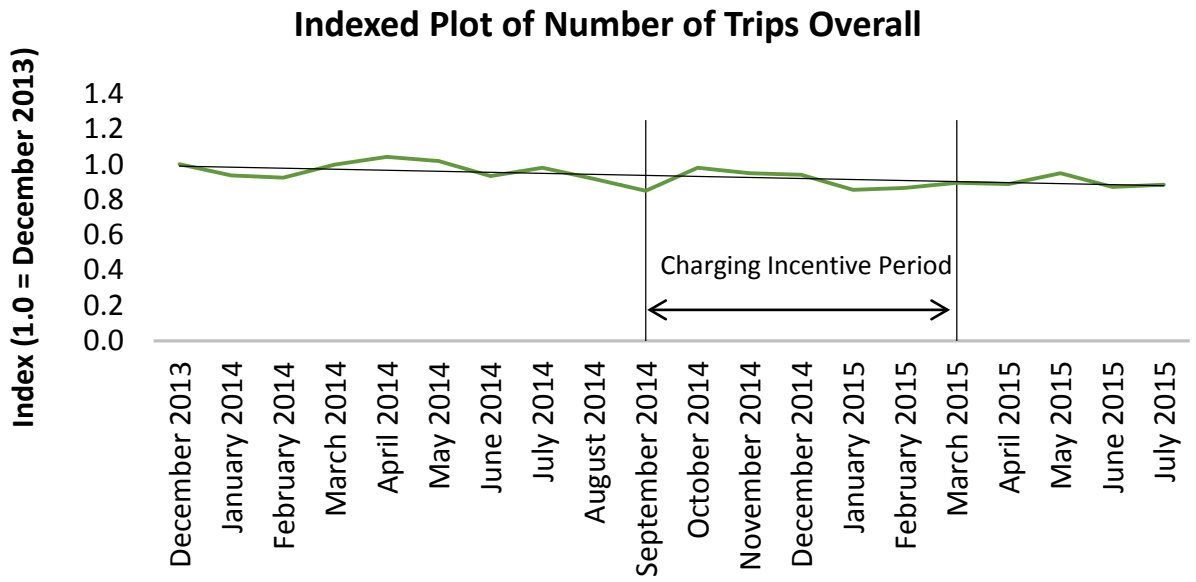
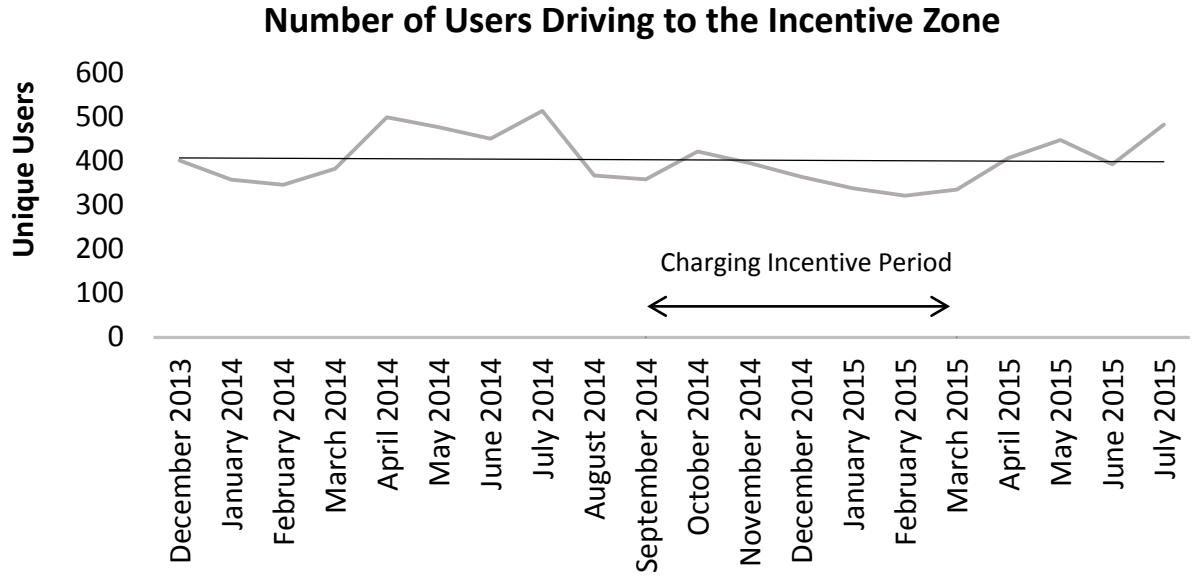


Figure 28 shows that the trends in the number of unique users making trips to the incentive zone stayed relatively flat and even declined over the course of the incentive period. This suggests that the incentive did not induce new people to take trips to the incentive zone. Rather, in combination with the data presented above in Figure 26 the results suggest that existing users traveling to the zone may have made more trips as a result of the incentive.

Figure 28: Number of Unique Users Driving to the Incentive Zone



Taken together, Figure 27 and Figure 28 suggest that the incentive may have induced an increase in traffic to the incentive zone for a relatively stable set of users. This increase in traffic is followed by a recovery of activity to levels preceding the incentive. But because it raises the traffic in the zone to its highest level in the series, and the increase is relatively un-correlated with the number of unique users or system trips, this increased activity is more likely a result of the incentive. Figure 29 (below) shows this comparison very clearly. It presents all three series indexed to a value of 1.0 in December 2013, and it plots the comparative movements together. Effectively, this shows the percentage change over time (relative to December 2013) for each series.

Figure 29: Trends Incentive and System Activity Indexed to 1.0

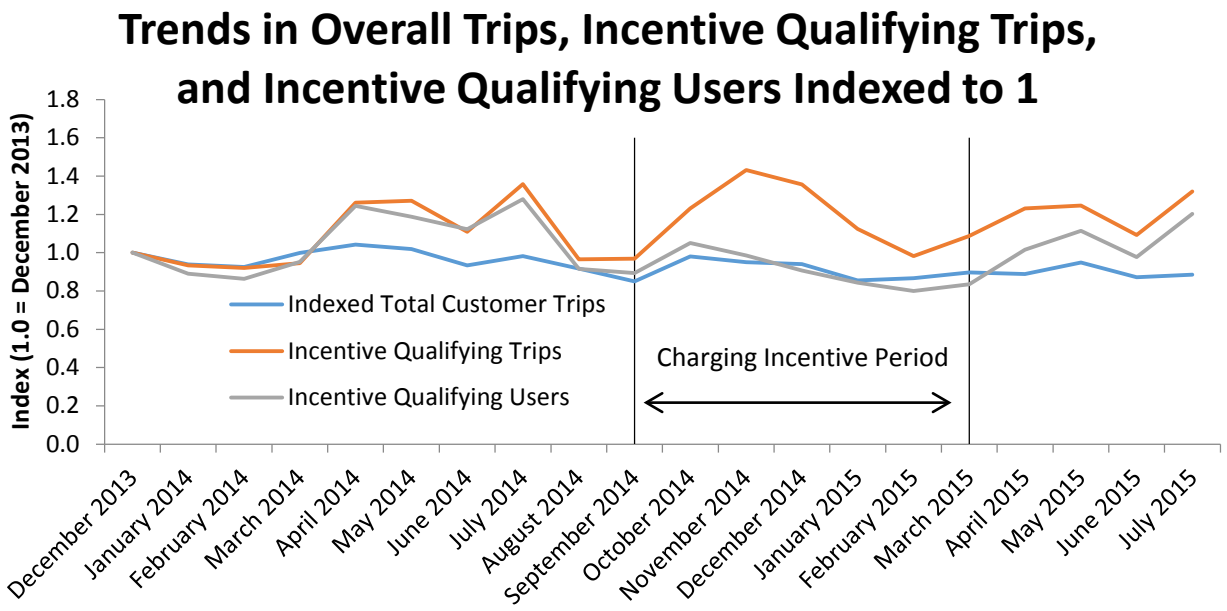


Figure 29 shows a few dynamics at play. First, the indexed plot of *Incentive Qualifying Trips* and *Incentive Qualifying Users* move in a correlated way both before and after the incentive period. The observed correlation between users and qualifying trips that occurred before the incentive explains the increase in trips to the zone in mid-2014, as more users had travel needs in this area. But during the incentive period, this correlation breaks down. The number of unique users traveling to the incentive zone remains relatively flat, whereas the number of trips to the zone increases. Notably, the correlation in movement returns after the incentive expires. All the while, overall activity in the system remains mostly flat.

Many dynamics can influence the movement of vehicles to a 9-by-9 block square, and the dynamics shown in Figure 29 could be numerically explained in a number of ways. However, the notable departure of *Incentive Qualifying Trips* from the series of users and overall trips suggests that the incentive did change the behavior of a select number of users and increased their travel to the region. This enabled easier access for car2go to charge the vehicles.

The presence of this dynamic is supported by a deeper inspection of incentive qualifying trip activity and the frequency of that activity before and during the implementation of the incentive. Table 2 below shows how the user activity is distributed before and during the incentive. The table shows that a total of 2,580 users (across all months) made a trip to the incentive zone at some point (before or during) during the incentive period. The cells of the cross-tabulation present a count of users based on how many trips they made before and during the incentive period. For example, 29 users took one trip to the incentive zone before the incentive period, and between two to five trips during the incentive period. Those cells below the identity cells (diagonal) represent users that traveled to the incentive zone less, while those cells above the identity represent those that increased their travel to the zone. The user count distribution shows that a minority of users increased their travel to zone. In total 671, or 26% of these users, made more incentive qualifying trips during the period than before.

Table 2 User Count by Change in Incentive Qualifying Trips

Users by Trips Before Incentive	Users by Trips During Incentive (the number of customers making the number of trips in the interval)															
	Zero	1 to 1	2 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	56 to 60	> 60	Total
Zero		446	122	15	6	1	1	2	2						1	596
1 to 1	1087	106	29	6	1	2				1	1					1233
2 to 5	427	90	52	11	4	2		2		1						589
6 to 10	39	13	19	4	4	1		2	1	2	1				1	87
11 to 15	12	3	6	7	1										1	30
16 to 20	6	3	3	1			1					1				15
21 to 25	3	2	2	2	3		2									14
26 to 30	1			1		1		1								4
31 to 35	1			1		1	1								1	5
36 to 40																0
41 to 45	1	1		1												3
46 to 50																0
51 to 55																0
56 to 60	1															1
More than 60			2												1	3
Total	1578	664	235	49	19	8	5	7	3	4	2	1	0	0	5	2580

Table 3 shows the balance of incentive qualifying trips before and after the implementation of the incentive. This constitutes the sum of trips to the incentive zone by the users shown in Table 2 during the incentive period. The first column shows all zeros since the sum of trips by all users making no trips to the incentive zone is zero. As with Table 2, the counts in cells above the dark line constitute the number trips made by users that increased their travel to the incentive zone during this incentive. The key point from Table 3 below is that much of the activity taken to the incentive zone is driven by high frequency users that significantly increased their travel to the zone during the incentive period. This supports the finding suggested in the discussion of Figure 29 that a minority of users with light activity before the incentive period increased their travel substantially during the incentive period.

Table 3 Cross-Tabulation of Incentive Qualifying Trips Before and During Incentive

Trips by Users Before Incentive	Trips During Incentive by Users (the total number of trips made by users in the interval)															
	Zero	1 to 1	2 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	56 to 60	> 60	Total
Zero		446	339	112	80	20	25	55	65						72	1214
1 to 1		106	79	41	12	37				39	45					359
2 to 5		90	141	85	48	39		57		38						498
6 to 10		13	53	30	52	16		56	35	72	43				72	442
11 to 15		3	17	57	11										70	158
16 to 20		3	6	10			22					48				89
21 to 25		2	8	15	41		49									115
26 to 30				8		18		28								54
31 to 35				10		17	22								64	113
36 to 40																0
41 to 45		1		7												8
46 to 50																0
51 to 55																0
56 to 60																0
More than 60			4												101	105
Total	0	664	647	375	244	147	118	196	100	149	88	48	0	0	379	3155

6.5.1 Evaluation of Value of the First Incentive

The incentive of 10 minutes of credit reflects a very modest marginal per trip cost to car2go ($4.10 of forgone revenue at $0.41 per minute). But the value of the incentive is a function of the total payout of incentives to the user base. Car2go also had to provide the incentive to those users who were engaged in regular activity to the zone and who needed no other incentive to travel there.

It is not possible to determine precisely how many trips were induced (at the margin) due to the incentive from the activity data. While the survey identified users that did change their behavior due to the incentive, this information was not obtainable on a trip by trip basis. But one way to estimate those marginal trips (that would not have happened without the incentive) is to take the difference between those that exceeded the average level of regular activity of travel to the zone prior to the incentive implementation. Since overall trips remained flat during the incentive period, the fluctuation in travel to the zone would comprise one estimate of the incentive effect on trips.

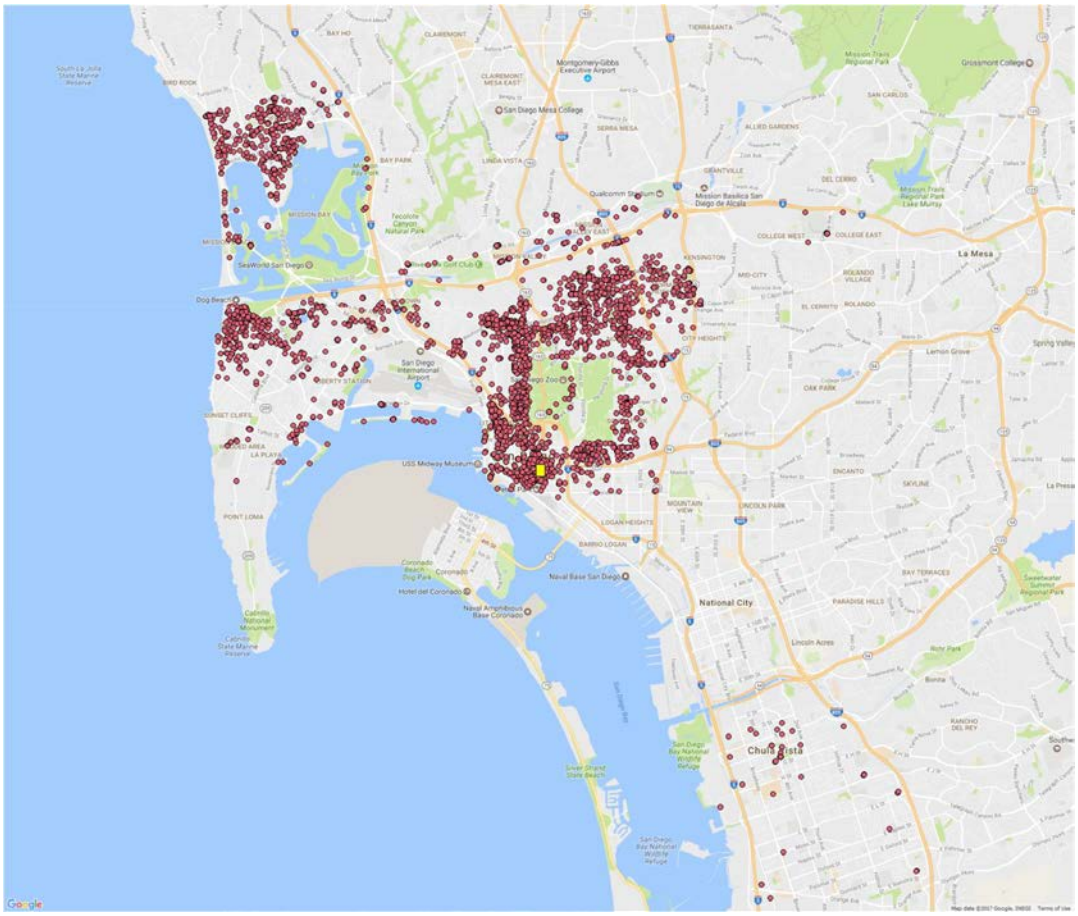
On average, about 537 trips per month were taken to the incentive zone prior to incentive implementation, offering an estimate of the typical level of travel activity to the zone. Prorating for the partial incentive months of October 2014 and April 2015, this average would yield a total typical activity level of about 3,071 trips to the zone during the incentive period, which would have occurred without the incentive.

During the incentive period (including partial months) a total of 3,481 trips were taken to the incentive zone. By this estimate, 410 of those trips were additional trips (about 12%) that were induced to the zone during the incentive period as a result of the incentive. The total forgone revenue from the incentive would have amounted to about $14,272.10. This reflects revenue that car2go had forgone due to the incentive. This was calculated as 3,481 trips multiplied by the $4.10 value in the incentive. Since car2go spent this much in total, the benefit it received from this spending is a function of this total amount. This benefit is also a function of the number of trips that were estimated to be induced by the incentive. This second part is the estimated 410 trips. This is estimated because we do not know exactly how many trips were induced due to the incentive. In contrast, the first part (total spending on the incentive) is known by the number of qualifying trips and the incentive costs to car2go. Given the total spending of $14,272.10, divided by the estimated 410 trips induced by the incentive, we calculate that the incentive cost to car2go was about $34.81 per induced trip.

A logical question that arises is how much does it cost car2go to bring in a vehicle and charge it, and what are the other possible costs avoided as a result of the incentive? Car2go's cost structure was not explored or disclosed as part of this study, so there are limits to the precision of this investigation on the avoided cost side. There are also limits in regards to understanding which specific trips were actually incentivized or induced vs. typical trips to the charging zone. That is, if 12% of trips to the zone occurred as a result of the incentive policy, which trips were they? Were these vehicles far away from the zone or were they very near and easily accessible? While the 10-minute minimum provides some insurance that those qualifying trips had to travel some distance and have some depleted charge, different vehicles would have different retrieval costs for car2go.

The average distance driven of vehicles that qualified for the incentive was about 5.57 miles (8.96 kilometers), and the average driving time of qualified trips during the incentive period was 17.9 minutes. This includes the indirect travel for other trip purposes (e.g., doing something else and then returning the vehicle to the zone). Vehicle trips that qualified for the incentive had origins that were positioned throughout the car2go San Diego operational region (both near to and far from it). This is shown in Figure 30 below, where the origins are comprised of the dots on the map, and the incentive zone is the yellow rectangle in downtown San Diego.

Figure 30 Map of Origins of Vehicles that Qualified for the Charging Incentive



Ultimately, the assessment of the cost effectiveness of the incentive to improving operational efficiency may be an assessment of averages. Since the incentives designed had to be applied system wide, operators would have to make an evaluation as to whether the incentive induces enough of an increase in behavior over typical activity to justify providing the incentive to the entire population of qualifying users.

6.5.2 Fundamentals of Incentive Cost Effectiveness

This investigation shows some fundamentals about the cost effectiveness of incentives. These fundamentals apply to the policy enacted by car2go but also to all policies that provide compensation for some desired behavior (or purchase). For example, the same fundamentals apply to automotive purchase incentives (e.g., government policy or manufacturer discounts) that are given to anyone who purchases a vehicle that is discounted to sell. As long as these policies provide a reward to anyone who conducts the desired behavior (e.g., delivering a vehicle, purchasing a particular model, etc.), there is a fundamental cost effectiveness to any of these policies, which is a function of a very small number of variables.

The following variables are all that is needed to evaluate the cost effectiveness of any incentive policy designed to change behavior. They include:

$A = Total\ activity\ (trips\ to\ the\ incentive\ zone)$
$c = Cost\ of\ the\ incentive\ per\ unit\ (amount\ of\ revenue\ forgone\ or\ paid\ for\ behavior)$
$p = Percentage\ of\ total\ activity\ induced\ by\ the\ policy$
$I = Induced\ activity\ or\ the\ trips\ that\ would\ not\ have\ happened\ without\ the\ policy$
$E = Cost\ effectiveness\ of\ the\ policy\ (\$\ spent\ per\ induced\ activity)$

The cost effectiveness of the policy is, as described earlier, the total cost of the policy divided by the additional activity that the policy caused. This is in units of $ spent per induced trip. Using the terms defined above, this cost effectiveness is defined as follows:

$$E = \frac{A \times c}{I}$$

Consider the fact that the incentive applied in this study was given for each qualifying trip. This induced activity (the 410 trips estimated earlier) could be defined as the percentage of the total activity that occurred because of the incentive. This induced activity, I, is equal to $I = A \times p$. Simple substitution leads to the following reduction:

$$E = \frac{A \times c}{I} = \frac{A \times c}{A \times p}$$

$$E = \frac{c}{p}$$

The term defining the total activity cancels out, and the cost effectiveness of the incentive policy is simply the unit cost of the incentive divided by the percentage of activity that is induced (or caused) by the policy. The function is undefined if $p = 0\%$, since this implies an infinitely bad cost effectiveness, if not a single user changed behavior due to the incentive. In such a case, the operator or policy is paying for a behavior, 100% of which would occur anyway.

This simple relationship reveals an equally simple curve that defines the cost effectiveness at any percentage of induced activity for a given incentive cost. For this analysis, where the cost (c) of the policy is $4.10, Figure 31 shows the cost effectiveness for all percentages of activity induced.

Figure 31 Sensitivity Analysis of Evaluated Policy Cost Effectiveness

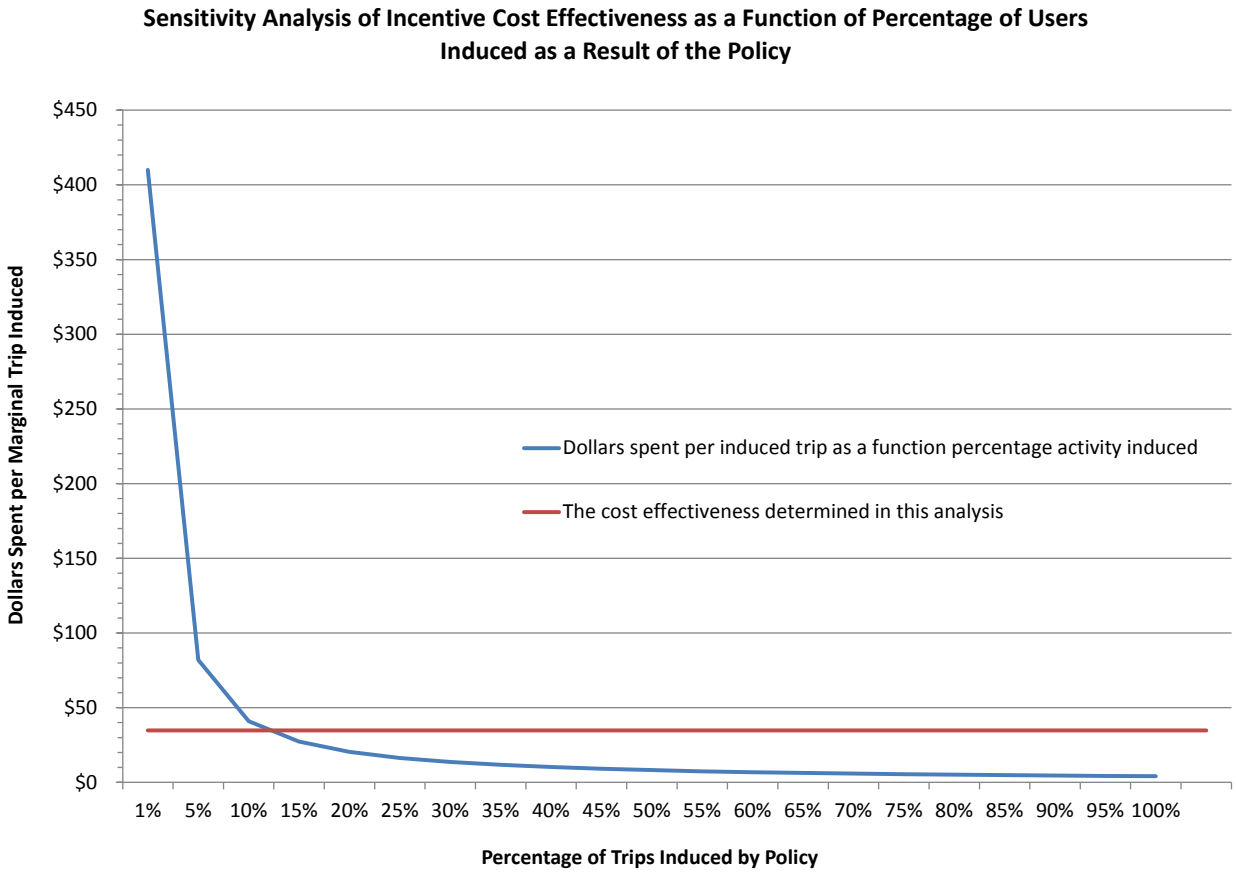


Figure 31 shows the range of cost effectiveness overall for all hypothetical percentages of induced activity. The horizontal line shows the empirically determined value of $34.81 from the estimate derived above. This value crosses at 12% induced trips, which is the percentage of trips estimated to have been induced by the analysis above. As the percentage of activity that is induced by the policy increases, the cost effectiveness improves more marginally at each increment. The final value at 100% is $4.10. That is, if everyone paid by the policy would not have made the trip without it, then the cost per induced trip is exactly the cost of the incentive. It cannot be any lower.

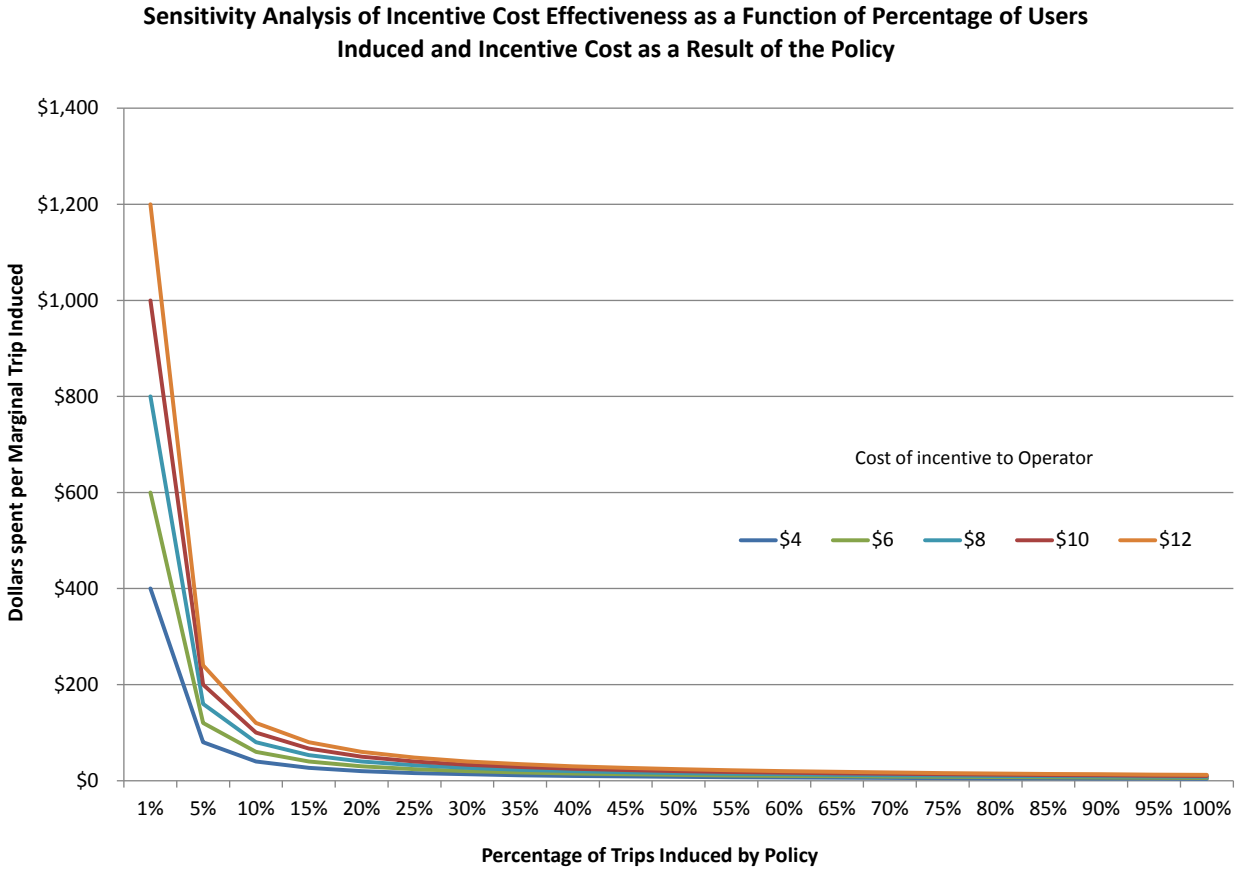
This simple relationship, although shown here for inducing EV carsharing travel activity to a small geographic zone, can apply to a large number of policies and relationships. For example, the cost effective of car manufacturing incentives are governed by the same relationship or government policies, such as the incentives for the purchase of electric vehicles.

The relationship applies to any incentive policy in which there is a level of activity that would have happened anyway, and the policymaker cannot discriminate between those actors that would have engaged in the behavior anyway and those that are induced to make a certain decisions as a result of the policy. One needs to know the size of the incentive and estimate the

percentage of the people that change their behavior as a result to directly calculate the policy cost effectiveness. While this latter estimation is the more difficult part analytically, the function can be used to predict in advance the potential cost effectiveness of any incentive policy to determine what the reasonable bounds are for cost effectiveness. This can be done to ascertain whether an acceptable level of cost effectiveness is achievable or plausible under forecasted circumstances.

For an additional perspective on the sensitivity analysis of the cost effectiveness of incentive policies, we can vary the policy cost. Figure 32 shows the plot of policy cost effectiveness by the percentage of activity induced and by modest changes in the incentive to the operator (or policymaker). The results show a series of curves that converge to the cost of the incentive in each case. The collection of curves show that the differences in policy cost effectiveness across incentive values declines as the percentage of activity induced by the policy increases. This illustrates a very important dynamic that can favor large incentives over smaller ones. For example, large incentives are more likely to have a higher percentage of activity induced versus smaller incentives. It can be more cost effective to have a larger incentive when the gains in the percentage induced are large. Taken at the extreme, consider a policy that effectively credits $0.01 for an activity versus $100 for the same activity. The smaller incentive does not change behavior, but it still costs the policymaker, effectively yielding a poor effectiveness outcome. The $100 incentive will inevitably cost the operator, manufacturer, or policymaker more money, but in changing some behavior as result will be more cost effective. The cost effectiveness can rise with increasing incentive size relative to smaller incentives as long as the gains in the percentage of the activity induced increase with the increased incentive value.

Figure 32 Sensitivity Analysis of Policy Cost Effectiveness as a Function of Incentive Cost



6.5.3 Linking Activity Data to Survey Data

The ability to link activity data to survey data afforded us an opportunity to conduct some analysis evaluating how respondents reported use and expectations versus actual activity. The results provide some validation to survey responses, but they also show that respondents may misreport information regarding their incentive use. In the cases examined, the majority of respondents generally reported their activity correctly. But the linking of survey data with activity provides additional information on how expectations and use are correlated with responses.

Table 4 below shows a comparative analysis of responses to the first survey, given before the incentive was launched, probing expectations of incentive use among respondents. Recall that at the time of the survey, the research team was planning for a 15-minute minimum drive time before it was lowered to ten minutes just before survey launch. Table 4 shows a cross tabulation of expectation of incentive use, which count the qualified trips made by respondents. About 60% respondents thought that they would “Probably” or “Definitely” use the incentive, but they ended up making zero trips. The question was exploratory, so the mis-match between expectations and manifestation is not surprising. Another 256 respondents

reported that they would “Probably” or “Definitely” use the incentive, and they did, which is far higher than those who stated that would “Probably Not” or “Definitely Not” use the incentive. The results shown in Table 4 reveal that about 25% of respondents expecting to use the incentive did use the incentive at some point. But it also shows that an even larger share indicating expectations of using the incentive did not.

Table 4 Expectations of Using Incentive vs. Activity Data Validating Use

If you were to drive for 15 minutes in a car2go vehicle and were expecting to be near this region (either on the way or as a destination), would you be willing to park your vehicle within the Incentive Zone if you received a 10-minute credit to your car2go account?							
Number of Qualified Trips	Skipped	Definitely	Probably	Unsure	Probably Not	Definitely Not	Total
0	5	328	276	74	42	9	734
1	1	89	51	5	7	2	155
2		37	11	5			53
3		14	4	1			19
4		11	3	1			15
5		9	1	1	1		12
6		4					4
7		1					1
8		2	2		1		5
9							0
10		1	2				3
11		1	1				2
12		1					1
13		1					1
14		1					1
15			1				1
More than 15		8					8
Total	6	508	352	87	51	11	1015

Table 5 below shows a similar analysis for the first incentive within the interim survey. In the table, we present the cross-tabulated results from two questions. Only respondents who reported that they had heard about the incentive were given these questions, so the sample size count is smaller than other questions analyzed from the interim survey.

Respondents who reported that they had heard about the incentive were asked, if they had received a credit. Of the 69 who had reported that they had, there was no qualifying trip in the

activity data for 15 of those respondents identified in the dataset. Of 254 respondents that reported that they had not received a credit, 177 were found to have zero incentive qualifying trips in the activity data, but the balance or 77 had received a credit despite the fact that they made some incentive qualifying trips.

Respondents that reported that they had received a credit were then asked to indicate how often they had received a credit. The distribution shows that a majority of respondents indicate frequency that would correctly approximate their actual use. However, 13 respondents reported some positive frequency, whereas no activity was found in the data.

The results from Table 5 show some discrepancy in survey and activity data responses. A substantial majority of respondents reported their activity in both cases. But a sizeable minority (about 25%) also reported some participation, whereas the activity did not show incentive qualifying activity. There are several possible explanations for this. One is that respondents were unaware of their participation in the incentive. That is, they were unaware that they had earned a credit, despite the fact that they had done so unintentionally. The reverse is true for those that thought that they had earned a credit but apparently had not. A majority of those that falsely thought that they had earned some credit, reported that they earned that credit infrequently. Still other explanations are possible including: errors in the activity data, unknown reasons for credit disqualification, and even misrepresentation by some respondents. Ultimately, Table 5 shows a majority of correct activity representation by respondents, and the reasons for existing discrepancies cannot be known. This analysis motivates further application of this type of data linking, which can in future studies be used to better calibrate responses to existing activity data when available and possible.

Table 5 Reported Use of Incentive vs. Activity Data Identified Use

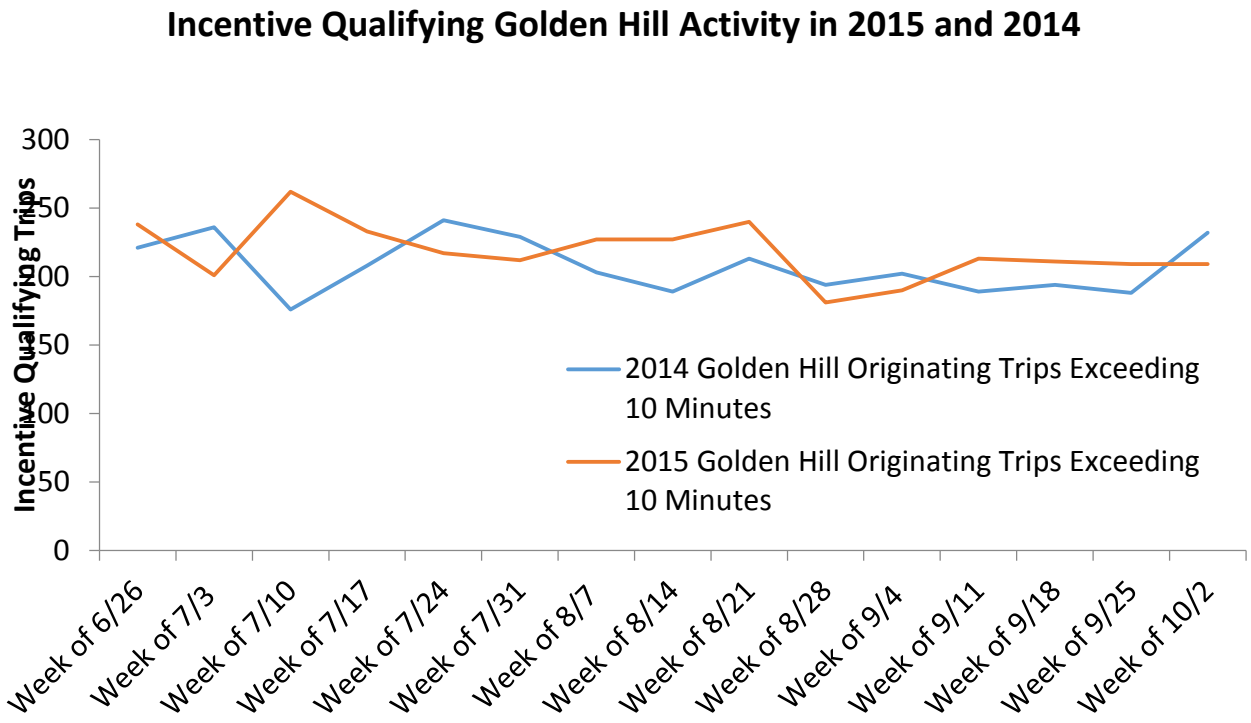
Number of Qualified Trips	Have you ever taken advantage of this incentive and received any free driving credit?			Since the incentive program began in October 2014, how often have you taken advantage of the incentive (dropped off a car2go vehicle in the Incentive Zone shown above and received free driving credit)?														
	Yes	No	Total	Never	Less than once a month	Once a month	Two times a month	1 to 2 times a week	3 to 4 times a week	5 to 6 times a week	7 to 8 times a week	9 to 10 times a week	11 to 12 times a week	13 to 14 times a week	More than 14 times a week	I do not know	Other, please specify:	Total
0	16	181	197	1	8	1	3	1	1									15
1	15	46	61		11	3	1											15
2	12	15	27		11												1	12
3	10	8	18		6	3										1		10
4	4	3	7		3	1												4
5	1	2	3		1													1
6	3		3		1		2											3
7	1	2	3				1											1
8		1	1															0
9		1	1															0
10	1		1				1											1
11	2		2					1			1							2
12	2		2			1	1											2
13			0															0
14	1		1					1										1
15	1		1						1									1
More than 15	1		1						1									1
Total	70	259	329	1	41	9	9	3	3	0	1	0	0	0	0	1	1	69

6.6 Activity Data Analysis on Oversupply Incentive

The other incentive experiment conducted by car2go sought to remove vehicles from oversupplied zones. As presented in Figure 2, the two zones were called Mission Beach and Golden Hill. Both zones were locations in which vehicles were found to accumulate by car2go and were difficult to keep from being oversupplied. The incentive provided 10 minutes of credit to anyone who drove a vehicle for 10 minutes starting in the zone and then finishing the trip outside it.

The surveys indicated that there was limited impact of this incentive on behavior. The activity data analysis also supports this conclusion. Car2go provided researchers with a summary of user trips that started within the zone and exceeded 10 minutes for overlapping periods in 2015 and 2014. The year-over-year comparison, presented in Figure 33, shows the difference between activity in the incentive year and the year preceding the incentive.

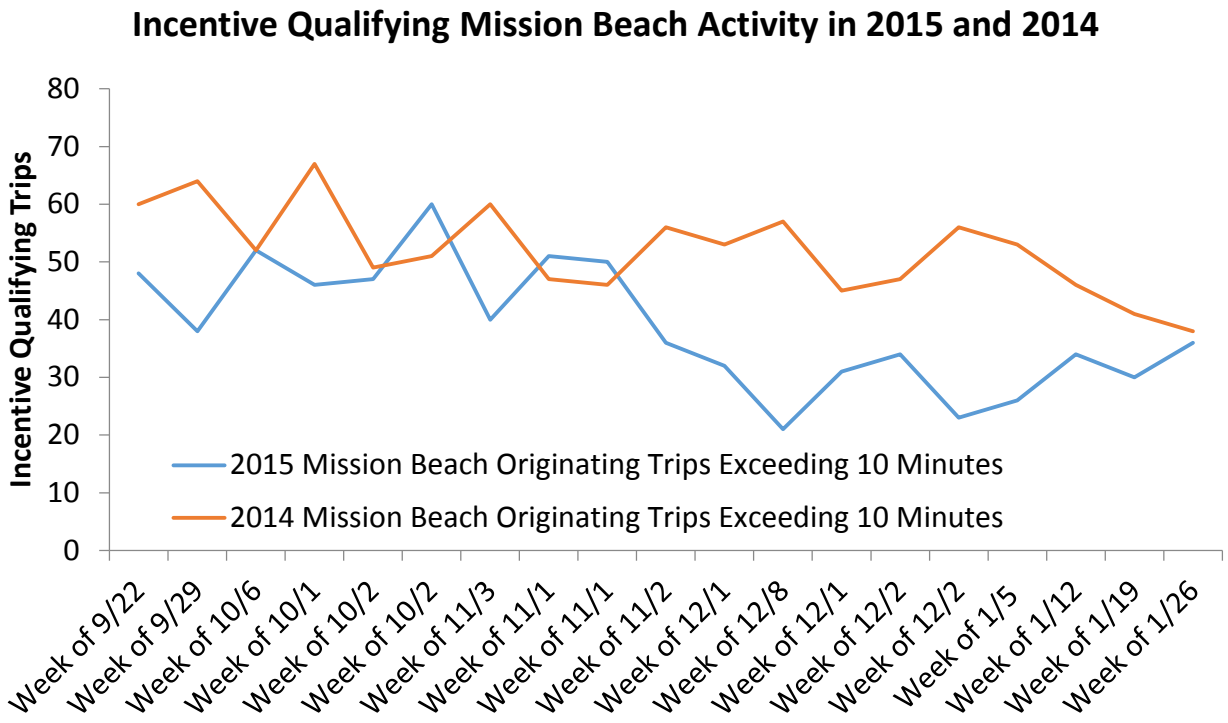
Figure 33 Golden Hill Activity During the Incentive and the Preceding Year



The plot shows a relatively constant level of activity in the Golden Hill area during both years. The average number of incentive qualifying trips per week was 102.5 during 2015 and 110.6 in 2014. This decline may have to do with the overall decline in system activity observed in Figure 27. Nonetheless, no significant departure between the two time series is observed, supporting the general conclusion from the survey that this incentive was not very effective in changing behavior.

A similar conclusion can be reached from the analysis of activity data within the Mission Beach incentive zone. As can be seen in Figure 34 below, incentive qualifying trips out of Mission Beach declined during both years, but activity was even lower in 2015 than in 2014. The average number of trips for the series in 2014 was 52 trips per week, while it was 38.7 in 2015. That is, the incentive did not produce a notable increase in observable activity data that was distinct from the broader trend.

Figure 34 Mission Beach Activity During the Incentive and the Preceding Year



The results shown in Figure 33 and Figure 34 suggest that the incentive was not especially impactful in creating significant movements in vehicles away from the incentive zone. This is not to say the incentive had no influence on vehicle movement. But the activity data suggest that this influence was limited enough so as to not significantly influence overall activity in the two over-supplied regions.

The dynamic of this incentive may lend to its lower level of success. Relative to the charging incentive explored earlier, the oversupply incentive had some disadvantages. One of the main ones was that only a constrained population could take advantage of it. Naturally, they had to be in the region of oversupply, whereas anyone could participate in the charging incentive. Second, the oversupply incentive had another dynamic that required more monitoring than could be afforded by a fixed-rate incentive. Vehicle oversupply can be temporary problem, whereas maintaining vehicle charge is a continuous problem. As vehicle supply declines, there are fewer vehicles to move and perhaps even fewer people to move them. In such a scenario, the incentive is not needed or is in fact successful in eliminating the oversupply. In that case, other measures of incentive performance might be useful, such as monitoring the level of vehicle supply within the region. In the case of this incentive, the activity did not indicate much movement that would suggest an impact on supply. Other factors may have been at play. But because an incentive of this kind is of variable need, a better design might have been to produce a variable incentive that could vary with a measure of oversupply. Overall, the data suggest that the second incentive of this study did not produce much reaction from users relative to the first incentive.

7 Conclusion and Key Takeaways

This project permitted experimentation with pricing to incentivize the rebalancing of vehicles within the car2go San Diego electric vehicle carsharing system. The study employed four methods of measurement including: 1) expert interviews, 2) focus groups, 3) a longitudinal survey of car2go members, and 4) vehicle activity data. Expert interviews were focused on carsharing operators, who stated that they expect one-way carsharing to grow mostly in major metropolitan areas, since most one-way carsharing users reside in dense city centers. The focus groups of car2go members revealed that they are overwhelmingly open to trying incentive programs, but they had apprehensions about the effectiveness of the low-demand zone incentive in particular. The concept of using incentive programs to promote or discourage certain travel behaviors was well received by users, but the structure and amount clearly mattered.

The proportion of survey respondents who reported taking advantage of the incentive programs was relatively low. However, of the respondents that did take advantage of it, there was a high level of satisfaction with the incentive program. Twenty-six percent of those who had not taken advantage of the first incentive said that they had intended to employ it in the future. Thus, there was an indicated openness to the incentive structures, overall. Also, as shown in the activity data analysis, increased incentive activity was driven mainly by a small minority of users making incentive qualifying trips many times. Incentives do not have to engage the entire population, or even a majority of the population, to successfully achieve their operational objectives.

In many cases, incentives designed for specific purposes simply cannot engage everyone due to different travel needs. For example, 43 percent of those who had not taken advantage of the first incentive said it was because their final destinations did not end near the EV charging depot incentive zone. Both the surveys and activity data found that more users preferred the EV charging depot incentive in contrast to the low-demand zone incentive even though the amount of driving credit offered was the same. The EV charging zone incentive was found to have a number of advantages. For instance, any vehicle with a low charge could come to it, whereas in the low-demand incentive, the number of vehicles that could be used for the incentive was more limited. The zone for the EV charging depot incentive was also in a downtown area with a lot of desired destinations.

While the EV charging incentive was the better performing of the two, it also had some weaknesses that are important to consider for future design. Namely, the estimated cost effectiveness of the incentive was $34.81 per marginal trip. This cost is about seven times the value of the incentive given to the user. This cost is estimated because it is difficult, if not impossible, to precisely determine the number of trips that would not have occurred had the incentive not been in place. But to calculate the extra trips that the incentive “caused,” some estimate of the trips that would have occurred anyway must be considered. The incentive program as designed in this study cannot separate those trips that would have happened anyway and those that that were caused by the incentive. If it could, then the cost effectiveness

of the incentive would have been much better. This is a common hindrance to the cost effectiveness of user incentives, and it is seen in a number of situations in both the public and private sector. For example, auto manufacturers regularly discount certain models to motivate their sale (e.g., "$2500 cash back"). This discounting is done because it increases sales, but it is also costly, since it is paid to users who would have bought the vehicle any time during the promotional period. The same can be said for government rebates for items like appliances, vehicles, and home solar installations. These incentives work, and they increase sales that would otherwise not have happened. But the true cost effectiveness of such incentives must be measured by the estimated increase in activity strictly as a result of the incentive. A weak incentive, one that pays too little to make difference, is a give-away, in that it will not change behavior significantly, but it costs the provider considerable resources across all sales. Thus, this dynamic suggests that incentives need to be sized appropriately to be attractive. One possible weakness of the incentives applied in this study is that they may have been too weighted toward cost defrayment versus value accruing. That is, users could only reduce the cost of a trip, but they did not accumulate value to be used later. The design thus lent itself to travelers that were going to the region for other purposes. Had the design permitted incentive values above the cost of the trip, a different set of behaviors may have occurred with increased activity. However, this would have come with increased cost to the operator.

While the survey suggested that 30 minutes of driving credit would yield the greatest marginal increase in the willingness of members to participate in the incentive, operators would have to evaluate how cost effective this would be. Operators would need to determine whether the level of participation would be worth the revenue lost from offering higher levels of credit. It was found that users preferred drive-time incentives over monetary incentives of equal redemption value. The survey questions revealed users' stated preference in some cases, which may not always translate into revealed actions. In the end, the incentive programs were about trade-offs. User participation in these programs would have reduced the burden of redistribution on the operator and ensured greater availability of vehicles for all other users. However, these come at both an economic cost of paying out incentives, as well as a potential environmental cost of induced trips, against staff movements needed to cover existing operations. The results suggest some approaches to ensure a more successful incentive program. Such approaches would entail a combination of greater incentives offered, improved communication of those incentives, and enhanced structuring of the incentive zone locations to better entice members to alter their travel plans. Additional experimentation and study of similar programs may lead to longer-term operational efficiency improvements within shared mobility systems.

There were also several suggestions provided by respondents in the free-response section of the survey. Most people indicated that simply increasing the amount of credit offered as an incentive would have made the program more effective. Others suggested extending the date when the credits expire. Another common suggestion was to base the program on where users ended trips rather than started them and to charge a higher rate for users ending trips in areas that do not need more vehicles. This additional revenue could then be used in the redistribution effort. One possible design of this would be to consider varying the credit based

on the number of vehicles located in low demand areas that the operator would like moved. Surcharges could be paired with credits, where the operator surcharges vehicle trips ending in low demand areas, while offering a comparable credit for taking vehicles out of those same low demand areas. The surcharge/credit level could be set to balance supply and demand. Finally, awareness matters too, as users suggested better advertising of the incentive program.

Overall, the incentives evaluated in this study showed some success in changing behavior. The more successful incentive (i.e., the EV charging zone) was able to increase user activity to the incentive zone over and above what was already occurring. The cost of this incentive per induced trip was probably higher than what would have occurred with a more optimal design. Optimality of design and magnitude was not tested in this study, but findings of this research suggest that user incentives can be used to improve operational efficiency, and insights gained may inform the implementation of improved designs in the future.

8 References

6t (2014) One-way carsharing: which alternative to private cars? 6t, Agence de l'Environnement et de la Maîtrise de l'Energie. http://6t.fr/download/AD_ExecutiveSummary_140523.pdf.

Autolib' Métropole (2016) Tableu de Bord Autolib'. July 3, 2016.

Barrios JA (2012) On the performance of flexible carsharing - a simulation-based approach. http://iceusa.org/GS1%20J%20A%20Barrios_On%20the%20Performance%20of%20Flexible%20Carsharing.pdf.

Barth M, Todd M, Xue L (2004) User based vehicle relocation techniques for multiple-station shared use vehicle systems. Presented at 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Boyacı B, Geroliminis N, Zografos K (2013) An optimization framework for the development of efficient one way car-sharing systems. Presented at 13th Swiss Transport Research Conference, STRC

car2go UK Ltd (2014) Withdrawal from UK market. car2go UK Ltd. https://www.car2go.com/en/london/.

car2go N.A. LLC (2018) Financial year 2017: car2go grows significantly and strengthens its market leadership. https://www.car2go.com/media/data/na/press/releases/financial-year.pdf

Cepolina EM, Farina A (2012) A new shared vehicle system for urban areas. Transport Res C-Emer 21(1):230-243

Communauto (2013) Auto-mobile arrives in Rosemont and Côte-des-Neiges-Notre-Dame-de-Grâce. Communauto, Press Release. http://actualites.communauto.com/en/2013/10/17/auto-mobile-arrives-rosemont-cote-des-neiges-notre-dame-de-grace/. Accessed 7 August 2014

Correia GH d A, Antunes AP (2012) Optimization approach to depot location and trip selection in one-way carsharing systems. Transport Res E-Log 48(1):233-247

Di Febbraro A, Sacco N, Saeednia M (2012) One-Way Carsharing: Solving the Relocation Problem. Transport Res Rec: J Transp Res Board 2319:113-120

Fairley, P (2013) Car sharing could be the electric vehicle's killer app. IEEE Spectrum. http://spectrum.ieee.org/transportation/advanced-cars/car-sharing-could-be-the-electric-vehicles-killer-app.

Fan WD, Machemehl RB, Lownes NE (2008) Carsharing: Dynamic decision-making problem for vehicle allocation. Transport Res Rec: J Transp Res Board 2063:97-104

Fassi AE, Awasthi A, Viviani M (2012) Evaluation of carsharing network's growth strategies through discrete event simulation. Expert Syst Appl 39(8):6692-6705

Firnkorn J (2012) Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany. Transport Res A-Pol 46(10):1654-1672

Firnkorn J, Müller M (2012) Selling mobility instead of cars: new business strategies of automakers and the impact on private vehicle holding. Business Strategy and the Environment 21(4):264-280

Henley, J. (2014) Electric 'Boris cars' are coming to London – how do they work in Paris? *The Guardian*. https://www.theguardian.com/cities/2014/jul/09/electric-boris-car-source-london-how-work-paris-autolib

Jorge D, Correia G, Barnhart C (2012) Testing the validity of the MIP approach for locating carsharing stations in one-way systems. Presented at 15th edition of the Euro Working Group on Transportation. International Scientific Conference, EWGT, Paris

Jorge D, Correia G (2013) Carsharing systems demand estimation and defined operations: a literature review. European Journal of Transport and Infrastructure Research 13(3):201-220.

Kek A (2006) Decision support tools for carsharing systems with flexible return time and stations. Thesis, National University of Singapore

Le Vine S, Adamou S, Polak J (2014) Predicting new forms of activity/mobility patterns enabled by shared-mobility systems through a needs-based stated-response method: Case study of grocery shopping. Transport Pol 32:60-68.

Martin E, Shaheen S (2016) Impacts of car2go on vehicle ownership, modal shift, vehicle miles traveled, and greenhouse gas emission: An analysis of five North American Cities. Working Paper. Transportation Sustainability Research Center, UC Berkeley. July 2016.

Morgan, R. Hertz closes its door on 24/7 service *New York Post* http://nypost.com/2015/08/04/hertz-closes-its-door-on-247-service/

Nakayama S, Yamamoto T, Kitamura R (2002) Simulation analysis for the management of an electric vehicle-sharing system. Transport Res Rec: J Transp Res Board 1791:99-104

Papanikolaou D (2011) A New System Dynamics Framework for Modelling Behaviour of Vehicle Sharing Systems. SimAUD '11: Proceedings of the 2011 Symposium on Simulation for Architecture and Urban Design 126-133

Rogowsky M (2013) Kandi crush: an electric-car vending machine from China could upend the auto industry. Forbes. http://www.forbes.com/sites/markrogowsky/2013/12/28/kandi-crush-an-electric-car-vending-machine-from-china-could-upend-the-auto-industry/.

Shahhen SA, Cohen AP (2007) Growth in Worldwide Carsharing: An International Comparison. Transport Res Rec: J Transp Res Board 1992:81-89

Shaheen SA, Cohen AP (2012) Carsharing and personal vehicle services: Worldwide market developments and emerging trends. Int J Sustain Transp 7:5-34

Shaheen, Susan, Nelson Chan, and Helen Micheaux (2015). "One-Way Carsharing's Evolution and Operator Perspectives from the Americas," *Transportation* 42: 519-536. DOI: 10.1007/s11116-015-9607-0

Swiatek, J (2014) Indy start BlueIndy, all electric 'car-share' program. IndyStar. http://www.indystar.com/story/news/politics/2014/05/19/indy-starting-electric-car-share-program/9275179/.

Trepanier M, Robert B, Viviani M (2013) Electric one-way shared vehicles in Montreal. Presented at 2013 Carsharing Association Conference, Toronto. http://www.slideshare.net/AlanWoodland/trepanier-and-viviani-oneway-carsharing-inmontral.

Weikl S, Bogenberger K (2012) Relocation strategies and algorithms for free-floating car sharing systems. 15th International IEEE Conference on Intelligent Transportation Systems Anchorage, Alaska, USA.

Yoon B, Lee S (2013) An Operation Model of Carsharing Service: Application of Simulation Method, JTLE 1(1):15-19