STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV 10/98)

ADA Notice

For individuals with sensory disabilities, this document is available in alternate formats. For alternate format information, contact the Forms Management Unit at (916) 445-1233, TTY 711, or write to Records and Forms Management, 1120 N Street, MS-89, Sacramento, CA 95814.

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA17-2651		

4. TITLE AND SUBTITLE

The Impact of the Sharing Economy on Latent Individual Modal Preference

5. REPORT DATE

01/04/2017

6. PERFORMING ORGANIZATION CODE

7. AUTHOR

Maitagorri Helene Schade; Elizabeth Deakin; Robert Cervero; Joan Walker

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

University of California, Berkeley
Department of City and Regional Planning
230 WURSTER HALL #1820
BERKELEY, CA 94720–1820

10. WORK UNIT NUMBER

11. CONTRACT OR GRANT NUMBER

65A0528 TO 006, A01

12. SPONSORING AGENCY AND ADDRESS

State of California Department of Transportaion,
Division of Research, Innovation, and System Information
PO Box 942873, MS-83
Sacramento, CA 94273-0001

13. TYPE OF REPORT AND PERIOD COVERED

Final, 2013-2016

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Mobility patterns in our cities are changing with the onset of shared mobility services. However, publicly available information on the use of shared mobility services is lagging behind. This study set out to fill this data gap by gathering web-based travel diary survey from carsharing and Transportation Network Company (TNC) users in the San Francisco Bay Area. Respondents were screened to be regular users of shared mobility services. The shared use reported in our sample was primarily car sharing and TNC, with bike sharing not being reported enough to be studied here. Our analysis drew on a convenience sample of 821 individuals, and all results are specific to our sample. Our objective was to use the data to provide insights on the shared mobility user base, environmental sustainability implications, and equity issues. Compared to the general population, the shared mobility users in our sample were more male, substantially younger, more middle income, and owned fewer cars. Regarding travel behavior, carsharing vehicles and TNCs were used for very different types of trips, with carsharing used mostly for longer-distance leisure trips, while TNCs were most often used for short work trips. Moreover, TNC trips were significantly more likely to start away from home whereas carshare trips are the most likely to end at home. On the subject of sustainability, daily VMT per capita in the sample was less than the average among demographically similar urban CHTS respondents, though not significantly so. A higher share of vehicle miles compared to the Bay Area CHTS were shared between more than one passenger, supporting the notion of relatively sustainable travel behavior for TNC/carshare users. The data indicate that time savings benefits were realized for many carless users. Finally, regarding equity, correlations with income suggest fewer potential benefits for lower-income populations.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
shared mobility, travel diary, travel behavior, equity, sustainability, car share, carsharing,	No restrictions.

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Open	103	

DISCLAIMER STATEMENT

This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification or regulation. This report does not constitute an endorsement by the Department of any product described herein.

For individuals with sensory disabilities, this document is available in alternate formats. For information, call (916) 654-8899, TTY 711, or write to California Department of Transportation, Division of Research, Innovation and System Information, MS-83, P.O. Box 942873, Sacramento, CA 94273-0001.

Sharing Has Impacts on Transportation: Assessing the Effects of the "Sharing Economy" on Travel Patterns in the SF Bay Area

by

Maitagorri Helene Schade

A professional report submitted in partial satisfaction of the

requirements for the degree of

Master of City Planning

in the

Department of City and Regional Planning

of the

University of California, Berkeley

Committee in charge:

Professor Emerita Elizabeth Deakin, Chair
Professor Emeritus Robert Cervero
Professor Joan Walker

Fall 2016

Abstract

Sharing Has Impacts on Transportation: Assessing the Effects of the "Sharing Economy" on Travel Patterns in the SF Bay Area

by

Maitagorri Helene Schade

Master of City Planning

University of California, Berkeley

Professor Emerita Elizabeth Deakin, Chair

Motivation. Mobility patterns in our cities are changing with the digital age, with the introduction of the web-based carshare service Zipcar in 2000, the advent of smartphone-enabled Uber rideshare services in 2009, and the subsequent introduction of similar competitors. However, publicly available information on the use of carsharing services (e.g. Zipcar, City CarShare) and transportation network companies [TNCs] (e.g. Uber, Lyft) is lagging behind. For example, the most recent California Household Travel Survey [CHTS], conducted in 2012, did not collect data on whether a trip was taken using either of the above mentioned modes. This study set out to fill this data gap by gathering diary-based survey data on carsharing and TNC use in the San Francisco Bay Area, and to use the data to address questions about its user base, its environmental sustainability, and its equity.

Research questions. This report addresses the following questions pertaining to carsharing and TNC use:

Characteristics of private transit users Are users of carsharing different from those of TNCs, and are users of both of these modes different from other Bay Area residents in terms of their socioeconomic traits?

Environmental sustainability Do users of carsharing or TNCs exhibit either car ownership patterns indicating less cars produced and sold and less vehicles in need of parking, or travel behavior generating lower VMT indicating lower fuel consumption and transportation emissions per person?

Equity Do less privileged residents of the Bay Area access these new modes, and do they gain improved accessibility from them?

Methodology. In the fall of 2015, a team of undergraduate students handed out postcards for recruitment in locations in Emeryville, Oakland and San Francisco, and advertisements were posted on the online small ad platform Craigslist. From this effort a convenience sample of 1017 complete surveys was collected. Given the recruitment methods, the resulting sample was not representative of the general Bay Area population. In the spring a second round of surveys was distributed using the panel service offered by Qualtrics, from which an additional 238 surveys were completed. In this iteration initial panel members, prior to screening out non-users, were representative of the Bay Area according to the panel provider.

The survey was comprised of two components, an initial screening and socio-demographic background survey and a travel diary intended for one individual respondent. After excluding those responses with unreasonable reported travel dates, geocoding trip origins and destinations and attaching Bay Area traffic analysis zones to them, 821 individual records remained. Of these records, in the initial background survey, 397 reported TNC use only, 82 reported carshare use only, and 342 reported both. I conducted statistical analysis of these responses and the associated trips to detect differences between carshare and TNC users. In addition I prepared suitable comparison samples from the Bay Area CHTS as well as the most urban areas within the 9 counties, weighting for income, age and gender, and compared these datasets to the survey data. Comparison to the Bay Area CHTS was used for an assessment of demographic characteristics of my sample, while comparison with the weighted samples served as an indication of car ownership as well as travel behavioral differences between users of either of the services of interest and the general public.

Results/Conclusion. I found that respondents to my survey were predominantly male (70% percent versus 48% in the Bay Area CHTS subset) and substantially younger than the general population (only 1% older than 54, as compared to 49% in the Bay Area CHTS), and with a more narrowly focussed income distribution (only 10% living in households with an annual income below $50,000 and the same number with annual household income above $150,000, as opposed to 18% and 23% respectively in the Bay Area CHTS). The differences were most convincingly explained by a high percentage of young professionals among their number. The only subgroup that was different were exclusive users of carsharing, who were less predominantly male than the rest of my sample (at 52%), and lived in lower income households than the Bay Area CHTS respondents as a whole or in urban areas alone (with 28% below $50,000). Respondents owned fewer cars than the average for similar demographics, at a mean household car ownership of 0.7 as opposed to 2.2 in the Bay Area CHTS (or to 1.5 in dense urban centers), consistent with the car shedding observed in previous studies of car sharing, and true of TNC users as well as carsharing users. Regarding travel behavior, carsharing vehicles and TNCs were used for very different types of trips, with carsharing used mostly for longer-distance leisure trips, while TNCs were most often used for short work trips. Moreover, TNC trips were significantly more likely (in 51% of cases as opposed to 33%) to start away from homewhereas carshare trips are the most likely to end at home. Regarding trip purposes, both of these modes were different in their use cases from all other modes observed, including taxi.

On the subject of sustainability, I found that daily VMT per capita in my sample was less than the average among demographically similar urban CHTS respondents, though not significantly so, and a high share of vehicle miles compared to the Bay Area CHTS were shared between more than one passenger, supporting the notion of relatively sustainable travel behavior for TNC/carshare users. Of the 82% of carshare/TNC trips made by carless respondents that could have alternatively been completed on public transit, only 20% would have been faster on transit. While both of those numbers were significantly higher than the respective numbers for driving alone, an indicator that these modes were used as substitutes for public transit as opposed to supplementing, they also indicate that time savings benefits were realized for many carless users.

Finally, regarding equity, I found that within my sample, carshare and TNC trips were the only two modes whose use showed a positive correlation with income, indicating fewer potential benefits for lower-income populations. I was unable to find convincing evidence of previously transit captive users, but the use of these modes by carless respondents may be an indicator. The small subsample of those using only carsharing appeared to be from a lower-income and more diverse population than either the sample overall or the comparable Bay Area population, suggesting further investigation into the use of carsharing by low-income or minority members.

Contents

Chapter 1

Introduction

For some time, information and communications technology [ICT] has enabled novel modes of shared consumption. As a result, the so-called Sharing Economy ("the peer-to-peer-based activity of obtaining, giving, or sharing the access to goods and services, coordinated through community-based online services" [15]) has received increasing popular attention. While many industries are affected by this shift in transaction and consumption habits, transportation is arguably among the foremost: 4 out of 14 so-called "pioneers of the share economy" named by Forbes magazine were transportation-related.[2], ICT-enabled mobility has been on the rise, and mentions of "car sharing" in published books more than septupled between 1990 and 2008 according to Google's Ngram viewer.[23]

In the United States, carsharing was first popularized by Zipcar starting in 1999, and many new ventures been founded since then. Although the mode share of all of these services is still small (currently around 2.5% in San Francisco [12]), given their newness and rising popularity, transportation researchers and city planners have been wondering and speculating what the effects will be for society and the environment.

Proponents of carshare companies such as Zipcar or City CarShare and carhailing services such as Uber or Lyft – first and foremost these companies themselves – claim great benefits for drivers, users and the environment: However, while one could certainly argue that such forms of automobility mark a trend away from the one-car-per-citizen mentality of the second half of the 20th century, their ramifications are still all but certain. The possible effects for society and for the planet are hotly contested. Are users across the board benefiting from an increase in mobility choices, or are only the privileged profiting? Are vehicle miles traveled [VMT] actually decreasing when people join carsharing, or could the overall VMT of a region increase with rising and simplified access to automobility? At the same time, the body of empirical research is still limited [32] [19], and relies predominantly on aggregate post-ex reported behavior (the most prominent exception being a large-scale study of City CarShare from 2002 to 2005 by Cervero et al., which included travel diaries [8].

The current conjecture is that the new sharing modes can effect lifestyle changes, and hopefully lead to more sustainable cities. However, household travel surveys to date provide very limited information on Uber, Zipcar and similar services – more data on the modes in question

is necessary. With this study, I add to the growing body of research by contributing a type of data so far missing from the literature – day-long trip-level travel diaries of more than 800 users of carsharing or TNCs – and analyzing their demographics and travel patterns within my sample, as well as in comparison to the 2012 California Household Travel Survey [CHTS].[18]

Chapter 2

Background

2.1 Motivation and definitions

Motivation

As ICT-enabled transportation that does not involve ownership of the mode of transportation has grown, policy-makers have asked what impact these new modes have on VMT, transit use, and conventional ridesharing services such as taxis. However, there has been limited data available to provide rigorous answers.[36] Researchers and transit professionals are curious, e.g. APTA commissioned a report on shared modes and ridesourcing, which highlights the growth of what they call "shared-use mobility" as well as the need for more data, and for data sharing between transportation providers.[22]

Researchers too have become more and more interested in the impacts of travel patterns corresponding to these forms of use. Consequently, within the last 10 years the volume of studies and academic articles on this topic has grown, raising questions regarding the characteristics of users, as well as potential implications for en- vironmental sustainability – viewed as largely positive – as well as equity – a more controversial topic.

Modes of interest to this study

While some types of carsharing have been around for a long time (e.g. Trenam mentions post-war carsharing in 1942 [34]), the internet and especially ubiquitous access to it via mobile phones has changed the landscape drastically over the past twenty years: Where early carsharing organizations required telephone booking ahead of time [30], reservation on the current carsharing services can be either via a smartphone or a home computer, and TNCs are accessed natively via a smartphone, with the option for access via a computer's browser in many places.

TNC or car/ride hailing here refers to services initially often referred to as "ride sharing", in which a car not licensed as a taxi, driven by someone not employed by the TNC, is summoned through an online platform via a smartphone. This class includes for-pay services such as those mediated by the platforms Uber and Lyft, in which the driver receives payment for driving, as

well as other services which are based on cost-sharing between driver and passenger, may be donation-based or impose caps on driver earnings.[3] The other key class of transportation considered here is "car sharing". This encompasses services that provide infrastructure for users to book a short-term rental of a car through an online platform. This class is again subdivided into those providers, that own a fleet of cars and supply them either at fixed locations or distributed throughout a service area, such as ZipCar, City CarShare or Car2Go (business-to-consumer or B2C), and those that serve as arbiters between users to rent each others' cars, such as Getaround (peer-to-peer or P2P).[5] [1]

ICTEM in detail

As defined above, this study focusses on ICT-enabled modes [ICTEM], i.e. modes of transportation that rely on information- and communications technology to match riders with services. The use cases for such modes are similar but slightly different from taxis or rental cars, and while there certainly are big differences between TNCs and carsharing, they do share certain aspects that distinguish them from other modes. These delineations are laid out in more detail in the following paragraphs.

Common traits

The unifying aspects of ICTEM as they may affect travel behavior fall into two categories: the user experience and the economic factors involved.

User experience At the core of the services considered here is the use of a standard automobile to transport passengers whose household(s) do no own the car. This implies many of the advantages of automobile use to the user – including point-to-point connectivity even off of public transit networks, independence from public transit schedules, and physically not demanding mobility with long reach compared to the active modes of transportation walking or cycling – without the potential drawbacks – purchase, maintenance and storage – of automobile ownership. At the same time, due to the shared nature of the resource (cars in the carshare case, drivers with cars in the TNC case) users may experience limited availability in time (i.e. all cars are booked) and space (all services only operate in certain coverage areas, and may not be feasible in the US outside denser metropolitan regions).[5] This also touches upon the limitation of both types of services to dense areas that offer sufficient demand for a critical number of either carsharing vehicles or TNC drivers to reach a dense enough network for a high-quality level of service: only urban areas will generally be able to meet this criterion.

[1] One could argue that certain other sharing services, in particular bike sharing, fall into the same category, especially where they provide an app to interface with the system. Given that the overall bike commute share is still below 2% even in the Bay Area, the metropolitan region with the largest bike mode share in the US, with only a fraction of those cyclists using bike sharing, I am not concerned with bike sharing here.[12]

Beyond the characteristics inherent in a non-owned automobile mode, certain traits stem from the ICT-based nature of the services described: cars or rides can be booked/requested using ICT on short notice, without requiring the visit of a branch of an organization or interaction with a representative (such as a traditional car rental). The same applies to the payment; it is generally conducted online, separated from the good sold (the ride or car rental). ICT may also contribute, beyond just simply reducing the transaction time (e.g. standing in line at a car rental branch), to shorter wait times and improved feedback (with consequently better service) in particular in the case of TNCs as compared to taxis [26]. In the case of carsharing the absence of agent involvement in the transaction may enable more different pickup locations and times outside normal business hours[2], and a more streamlined process without additional license checks or insurance contracts once one becomes a member. All of these factors add convenienc to the user experience. In addition, the existence of electronic records and, in the case of P2P platforms, systems for users to rate each other (in the case of TNC, the driver), facilitate trust between the strangers involved in the transaction.[27].

Economics All services considered here charge the user for trips taken, with no or low fixed membership charges. Consequently, the economic implications of ICTEM to the user are similar to those of any pay-per-use transaction: rather than investing a large sum up-front to purchase a car, or paying a fixed rate for a lease or long-term rental, only trips actually taken are billed – this cost however is considerably higher than that of driving an own car, and can be higher than that of a car rental or a taxi depending on the use case.[3] For both types of services, the cost of travel becomes (almost) entirely a variable cost, as opposed to the fixed or sunk cost of other automobile alternatives.

Differences

The key differences and distinguishing characteristics between the modes discussed here can be grouped in the same categories of user experience and economics.

User experience As already touched upon when discussing the similarities of ICTEMs, the location of origin of a trip is an important factor here: many carsharing schemes operate on a system of pods or parking points, where some number of cars are based and can be

[2]It should be noted that in some cases of car rental, the agency will bring the car to the customer, which of course is also not possible without agent involvement. In the case of peer-to-peer carsharing of course the pickup occurs wherever a car is offered, which may or may not be convenient for the renter.

[3]Uber in Berkeley: cheapest option UberX 1.5-1.9$/mile, but can rise to multiple times this price during high demand; taxi rates according to `www.taxifarefinder.com` around $3.8/mile – which becomes cheaper than an Uber once the dynamic pricing reaches a multiplier greater than 2. A ZipCar for one hour at $12.75 with insurance and fuel included does not have any direct competitors in the traditional car rental world (though of course some car rental agencies are now entering the carsharing market with functionally equivalent automated hourly rentals), but a ZipCar for an entire day starts at $79 depending on the day of the week, while a search for a rental car on `www.kayak.com` turns up car rentals for less than $40.

picked up by members after reservation. This may be an advantage if the location is convenient, but is also a limitation if no pickup location is nearby. TNCs on the other hand will respond to user requests, and drivers pick up passengers at their current location and drop them off at their immediate destination. Closely related to the topic of location is that of point-to-point travel: while TNC trips by default are generated from one point to another, without a return trip required, many carsharing schemes are designed as round trip systems where a car must be returned to the same terminal it was picked up from.[4] Finally, the most obvious difference in user experience between carsharing and TNCs is the driver: where a carsharing car always requires one of the passengers to also be the driver, TNCs provide one. Especially for those unable to drive themselves – for instance because of physical impairments especially in old age, or because of alcohol or other substance consumption – this is an important selling point.

Economics TNCs generally do not charge a membership fee, and only charge the user/customer for rides taken. B2C carsharing services charge the user a monthly or yearly membership fee which varies by provider, while P2P services do not.[5] At the same time, prices are assessed differently (based on distance for TNC, based on time rented for carshare) and are also considerable more expensive for TNCs compared to carshare: prices for Uber and Lyft start at around $1.5 per mile, whereas miles driven on B2C carsharing can be as cheap as about $0.28, P2P even less than that. [6]

All this makes TNCs more attractive for short, ad-hoc or one-way trips or trips where a driver is required, whereas in other cases from a utilitarian point of view the economic incentives are more favorable for carsharing.

2.2 Potential impacts

So far, the mode share of TNCs as well as car sharing in my study area is still almost negligible: both of these modes combined in 2015 made up less than 2.5% of all trips in the City of San Francisco, home to the headquarters of Uber and Lyft [12]. However, assuming broad adoption, non-private automobility could ultimately result in substantive changes to travel patterns, with potentially far-reaching implications. Based on the above description of user experience and

[4] Some carsharing providers such as Car2Go and most recently Zipcar are already experimenting on smaller scales with one-way systems that allow users to check out of their car at their destination, but these services are to date limited.

[5] In the Bay Area at the time of writing, membership fees vary by plan but start at $70 per year or $7 per month for ZipCar or $10 per month for City CarShare. P2P services Getaround and Turo do not charge renters any fixed fees.

[6] TNC prices are calculated for the cheapest non-pooling option (shared options were not available yet at the time of data collection), while ZipCar prices are calculated assuming a rental time of 4 hours and use of the full 180 miles included. Getaround and Turo have similar mile caps at prices that can be as low as 60% the ZipCar base rate.

economic incentives, it is possible to make some conjectures regarding the usage and their potential impacts on sustainability and transportation equity.

Use

From the user experience and incentives discussed above follow some likely use cases and behavioral patterns of ICTEM users, as well as conjectures about those users' demographics.

Behavior

Carsharing Given the similarity of carsharing to driving a personally owned car[7] – with regards to the fact that a driver is needed and that for most carsharing schemes currently in place in the US the car must be returned to the point of origin – the use cases for carsharing should be similar to those for personal cars. However, since in all cases of two-way carsharing charges are based on time, i.e. accrue even when the car is parked, carsharing is not an advantageous mode trips that involve a long dwell time in the destination. Trips that last for more than about 5 hours and are planned ahead of time would in almost all cases be cheaper in traditional rental cars than using carsharing (see 2.1), and therefore make carsharing a disadvantageous option for trips that involve a considerable distance travelled as well.[8] For this reason, the most likely uses for carsharing are not regular daytrips such as a daily commute nor long weekend getaways, but instead short round trips that may not be home-based – e.g. grocery shopping or delivering items from a workplace – or occasional daytrips – e.g. spontaneous hiking excursions. Especially in regions where most trips require driving, incentives will rarely align for carsharing; it is therefore unlikely that users outside dense metropolises would choose to join a carsharing scheme at any point (regarding this last point, see also [5]).

TNC Given the relatively high price per mile compared to other automobile options, TNC travel will be most desirable when its special characteristics – comes to users location, ad-hoc hailing, driven by a driver – outweigh the cost. Unlike for carsharing, this will mostly be the case for shorter one-way trips or trips with longer dwell time at the destination. Especially for car owners, it will also be the case if the user will be or has been drinking, and for non-home based trips. This last conjecture is supported by the findings of Rayle et al. and the APTA report, who found that users report being particularly prone to take TNC trips on social night-time outings when they have been drinking, i.e. when there are factors that make TNCs by far the most desirable option.[9] [26],[22]

[7] This is certainly how they are advertising themselves; Zipcar employs the slogan "Wheels when you want them" and advocates the substitution of a Zipcar membership for a personally owned car

[8] Of course once a user becomes accustomed to using carsharing they may find it easier than carsharing even in the cases where it would be more expensive; it is difficult to predict when this scenario would occur.

[9] The question of whether TNCs are merely another form of taxi service has been raised by various authours, especially since apps such as Flywheel have entered the realm of phone-based hailing and arguably could fulfill the same function as ride hailing apps such as Uber.[3] Some argue that due to regulations and monopolistic behavior,

Demographics

Two characteristics that all users must have in common are a) access to at least the internet (in the case of B2C carsharing), and in many cases a smartphone (for P2P carsharing and TNC car hailing) and b) ownership of a credit card for payment. Together with the not insignificant price of using these services (compared to walking or public transit), those characteristics mean that the user base does not include extremely low income users. One might also conjecture that senior citizens, often more reluctant to adopt new technologies according to a recent Pew center study, might be less likely to use ICTEM.[24] Within the user base, given the high variable-cost nature of these services, use is likely to be more frequent with higher income and correlated factors.

Yet there are also likely marked differences between the user bases of carsharing and TNCs. Given the similarity of carsharing to car ownership, one would expect users to be either carless or have fewer cars than needed to always satisfy their needs. For the users that are carless, they could be deliberately carless (and even have become carless as a result of their carshare membership, a popular scenario for carsharing advocates[21]), or because of financial or other constraints. In both cases, to become users of carsharing, one would assume that the decision to use car sharing was a result of deciding that the utility gained by carsharing was greater than that of owning a car – because of infrequent use, parking or other barriers, or the initial upfront investment in a personal car. Those carsharing users might therefore be infrequent drivers, live in dense neighborhoods and/or have comparatively low household income. Those users who own a car but still choose to use carsharing at least occasionally might live in larger households where most of the time, the number of cars owned suffices to satisfy household members' automobility needs, but occasionally an additional car is needed.

Given the characteristics of TNC service – one-way, no advance reservation, not location-bound – usership likely is less correlated with car ownership. Given the higher price and not self-driving nature, users will likely choose TNC as a matter of convenience and consequently have larger disposable income than those of carsharing. Alternatively, they might also live or work in locations where carsharing is not an option and therefore resort to TNCs. Household size on the other hand might discourage TNC usership, since a larger number of household members entails a higher likelihood that another member of the household could be able to serve as the driver.

Impacts

Potential impacts following from the use cases of shared modes/ICTEM can be divided into environmental sustainability effects, and transportation equity effects.

taxi companies have not been able to provide the same services as reliably. [26, 7] Moreover, possibly because of flying under the radar of current regulatory frameworks, possibly because of the absence of market failures riddling the traditional taxi industry [14], TNCs are able to offer prices that are often cheaper than taxis, with one source citing an average price advantage of 20%. [35]

Environmental sustainability

Most arguments around the sustainability of new transportation modes focus on the reduction of fuel use and emissions through a variety of mechanisms.[32][13][4] On the other hand, easier access to car travel may encourage motorized travel by the carless population and increase VMT. [25, 16]

New modes could affect the amount of transportation emissions through two general mechanisms: the overall number of VMT could change, or the same miles could be traveled with cleaner cars. Several authors have made the argument that vehicles in use for carsharing and TNCs are more fuel-efficient and less polluting than the average car driven in the US.[10] [37, 21, 3] However, given that the focus of this paper is on behavior, the other mechanism – a change in number of VMT – is more relevant.

To analyze these effects, I adopt a framework used by Anderson to distinguish between VMT-additive and VMT-subtractive behavior in the context of TNC use and adapt it for carsharing.[3]

Subtractive behavior is ICTEM-induced or enabled behavior that reduces the overall number of VMT per person, primarily through a shift away from single-person car trips to other modes. There are two pathways for such behavior change to occur: firstly, in all cases, multi-modal trips become easier through facilitated access to transit and more convenient with the option of car trips that are one-way or not home-based [29, 11]. This may lead to a change in mode split from car travel in favor of public transit and/or active transportation. Secondly, especially in the case of users that choose to reduce or eliminate the vehicles they own, the shift from fixed to variable cost of driving could create a more salient economic incentive for sharing some rides – e.g. in carpools – or choosing alternate non-motorized modes [30, 3]. In this vein, Shaheen et al. argue that by making car ownership superfluous, car sharing is contributing to more sustainable mobility choices in the US [28].

Additive behavior is ICTEM-induced behavior that increases the overall number of VMT per person. This could on the one hand occur because previously carless individuals or households add occasional car trips to their modal portfolio.[3] For all participants, the added convenience of car-hailing and carsharing, combined with slight cost savings under certain circumstances compared to the closely related alternatives taxi and car rental, may lead users to shift miles traveled away from public transit and active transportation towards TNC or carshare and thereby add to the VMT per capita.[32] (Note that increased VMT could also be the result of TNC drivers taking empty return trips to likely pickup locations; that potential effect however is not within the scope of this research and would need to be investigated to draw definitive conclusions regarding the extent of VMT-additive behavior.)

[10] On the other hand, they may not be newer or more efficient than the taxi fleet, the mode they are most likely to substitute for based on use cases.

Transportation equity

Our current transportation system suffers from the shortcoming that certain disadvantaged groups are "disproportionately impacted by burdens of the transportation system but do not receive an equal share of the benefits".[33] Given the average costs associated with leasing a car, one would have to do upwards of 60 hours of carsharing per month for car ownership to be economically preferable.[11] – this means that at least theoretically, many who might be deterred from car ownership by its price, for instance because of low income, might be able to now use carsharing to simplify necessary errands such as grocery shopping. Consequently, there is hope that wider availability of carsharing may improve access to amenities – i.e. shorter travel times and a larger radius of activities – in particular for lower-income households. [22]

This potential is not as pronounced for TNCs given the relatively much higher price; after only about 400 miles of TNC travel the price supersedes that of leasing a new car.[12] Especially for frequent travel that cumulatively exceeds this limit, such as commuting to work, TNCs are more likely to be chosen as a matter of convenience and therefore less likely to benefit disadvantaged communities.

2.3 Existing research

A body of research regarding shared and ICT-enabled modes and the behavior of their users provides evidence regarding some of the hypothesized behaviors.

Carsharing

Early studies focus on non-ICT-enabled carsharing organizations in Europe where they first gained traction. Steininger, Vogl and Zettl in 1994 conducted a study of 198 car-owning and carless households joining an Austrian carsharing program, and found that while trip mode share did not change significantly overall, car trips became shorter and therefore overall VMT decreased. While the authors do not offer an explanation about the mechanism of this effect, this finding supports the notion of shared cars promoting more sustainable behavior, as well as the need to collect diary-based data for detailed visibility of behavior change. [30]

An early study of US carsharing, albeit still phone-, not app-operated, was conducted in 2000 by Katzev et al. in Portland, where the researchers followed 120 members of CarSharing Portland with a survey as well as an optional one-week travel diary pre-membership and after one year of membership and tracking of each trip taken in a carshare vehicle. The study found a mild increase in VMT, suggesting that easier access to car travel may have a VMT-increasing

[11] Rough estimate based on AAA numbers at `http://exchange.aaa.com/automobiles-travel/automobiles/driving-costs/#.WDYTWLWp_Qo`, using ZipCar rates and assuming an average speed of 20mi/hour including time stopped at the destination.

[12] Using a similar logic as above, but comparing an average $0.10 for fuel cost as opposed to upwards of $1.50 for Uber or Lyft

effect. At the same time, alternative modes were also increased, 26% of households sold personal vehicles as a result of membership, and 53% of households avoided purchase of a new vehicle.[16]

The two largest empirical studies on the impacts of carsharing in the US since the beginning of ICT-enabled carsharing were conducted by Cervero et al. in the Bay Area over the course of several years [8], and Martin and Shaheen across North America in 2008 [20].

Cervero et al. began their long-term study encompassing hundreds of City CarShare members with the start of the program – a not-for-profit carsharing organization in the San Francisco Bay Area – in 2001. Over the course of 4 years, five iterations of surveys were conducted using a matched-pair methodology with members as well as a control group of individuals that signed up, but did not fully enroll in the program (new respondents were recruited each time). Their base of responses grew from 147 total responses in 2001, with non-members in the majority, to 527 members and 45 non-members in 2006. Each installment of the survey consisted of a background questionnaire as well as a travel diary of two consecutive days, and was supplemented with member questionnaires disseminated inside the cars and recording member information as well as carshare trip information.[10, 6][9]. This study examined trip characteristics, including mode, length and purpose, as well as respondents' demographics. Key findings include a "win-win proposition" for members, where VMT decreases while at the same time car share members' accessibility improves. These effects go hand in hand with significantly reduced vehicle holdings and increased transit use, supporting all conjectures for possible positive impacts laid out above.

Martin and Shaheen employed a different methodology, using self-reported behavior pre- and post joining a carsharing program. Their sample encompassed responses of 6281 members of 11 different carsharing organizations across North America, collected in 2008 through an online survey. Their analysis focuses chiefly on vehicle holdings and shedding, and finds that while 60% of members were already carless when joining the program, a majority of the membership still exhibited a reduction of household vehicle ownership. This, together with respondent-estimated VMT, is used to determine an overall reduction in greenhouse gas emissions.[20]

Investigating specifically the relationship between transit and carsharing, Stillwater, Mokhtarian and Shaheen investigate 2006-2007 GIS data from a US carsharing operator; however, using this method they are not able to establish a clear relationship between transit availability and carsharing demand. They argue that private transit could act as a complementary good to local transit only, manifesting itself in highest demand for car sharing where vehicle ownership and non-car accessibility are at a medium level.[31]

The only research I am aware of that focuses specifically on the equity implications of carsharing was conducted by Shellooe in 20013 with a spatial analysis of carsharing locations in relation to equity indicators in New York City. Her findings indicate that higher education is strongly correlated with ZipCar car locations, and that low-income segments of the population are geographically excluded from accessing this potentially equalizing mode. [29]

TNC

TNCs, being a newer development , have attracted a lot of attention in the press, but the body of empirical research regarding their impacts is still developing.

Most studies so far have focused on the comparison of TNC operations to taxis, the most similar mode on many of the parameters discussed above.

Anderson in 2014 conducted a survey of drivers for three "for-profit ridesharing" companies, and analyzes their strategies with respect to the environmental impacts of these platforms. He identifies both additive and subtractive effects of the service, and finds that the impact of TNCs is largely dependent on how drivers choose to offer their services.[3]

The largest demand-side survey so far is an exploratory study conducted by Rayle et al. in 2014. They collected background information as well as information on the last TNC trip taken by 380 respondents to an intercept survey in San Francisco. These data were matched to a previous similar taxi trip survey. Key findings include distinct demographics (TNC users are younger than taxi riders and use less cars), and TNC users reporting significantly faster and more consistent hail times compared to taxi. The fact that most ridesharing trips would have taken more than twice as long on transit as calculated by the author for this sample indicates that VMT-additive behavior from transit cannibalization is rare. [26] This last finding however may be in part due to evening- and late-evening surveys, when transit schedules become less dense.

2.4 Open questions

Several authors have engaged with the questions raised above, and there is significant evidence for car shedding related to carsharing, as well as several studies that find evidence for VMT reductions. However, to date there is not a significant body of diary-based survey data (including complete trip details for a comprehensive sample of respondents) for more than one carsharing organization at a time. The phenomenon of TNCs as a whole, being much younger still than carsharing, has not received as much attention so far, and I am not aware of any studyto date producing diary-based trip data specifically of users of TNCs.

Travel surveys of the entire population, given the so far low mode share of ICTEMs, still yield too low sample sizes to make substantive statements about ICTEM users' behavior in comparison to the population at large, and even Cervero's San Francisco study compares carsharing members to those that considered becoming members but didn't.[9] For this reason, I set out to produce an exploratory dataset similar to that collected by Rayle et al. that would allow for a comparison between users of carsharing and of TNCs, and shed light on how their effects compare to each other.

Conjectures for investigation

Based on the above framework and literature review, a framework emerges for the analysis of TNC/carshare travel survey data.

Characteristics of ICTEM users and use

Who chooses to use carsharing, who TNCs? What trips are they used for?

The differences between carsharing and TNCs suggest that their user bases should be somewhat different on the following socioeconomic indicators:

Income One would expect to find more lower-income users in carsharing, which is a cost-efficient and convenient option for low numbers of short necessary two-way trips (e.g. grocery shopping. This is true less so for TNCs, which I suspect to stand in for needs of convenience most of the time (in line with [26]).

Age Given the use of technology to secure rides with TNCs, we would expect somewhat fewer seniors to make use of this mode than their younger counterparts. Likewise, carsharing would not be an option for seniors who are no longer able to drive themselves. (However, since I excluded everyone below the age of 18 from participation, and the very old may have been underrepresented in our survey because much of our recruitment happened among pedestrians and because of its web-based nature, findings about respondent age are unlikely to be conclusive.)

Household size Given the expected use cases, carsharing should be comparatively more likely in larger households, for two reasons: first, in households without a car, household outings with multiple participants are more attractive to take in a carshare car, given that the per-capita cost goes down as the number of passengers rises. Secondly, households that already own one or more cars likely own less than one car per household member, and may substitute occasional additional home-based car needs with carsharing instead of purchasing more cars (an argument already raised by Stillwater & Shaheen [31]). If TNC use, as expected, is more like taxi use – one-way, potentially ad-hoc trips that are not based at home – it should depend more on the individual, less so on household size.

Employment If TNC in line with my framework is a high-end mode correlated with higher income, one should find fewer unemployed individuals using TNCs than in carshare, which – with sparing use – may help lower-income users. However, there probably is a contingent of lower-income, special-needs (for example mobility-impaired) users of TNCs as well, who otherwise would have taken taxis but now take advantage of improved wait times and better user experience – at least the handout portion of my recruitment might not detect those users if they are unable or unwilling to walk.

Student status Given the student lifestyle with occasional short trips across town, relatively low car ownership for all income groups, and facile adoption of new technologies, I expect lots of students using TNCs. Within the carshare sample, there may be some students, but as typical short out-and-back trips such as grocery shopping or other errands are often accomplished without a car by students (who do not shop for a family and are able to accomplish most of their errands within the vicinity of

their universities) there may be a lower number of students among carshare- than among TNC users.

Although the sample analyzed here is non-random, some directional insights can be gained from comparing characteristics of my sample to the Bay Area CHTS data. (Only effects *opposit* to what one would expect based on the likely biases of my sampling method discussed in 3.5 can be meaningfully supported by this study).

Income If overall ICTEMs have transportation equity enhancing effects in the sense that they benefit lower-income or otherwise disadvantaged populations, one would expect to find a lower-than-average income in a random sample of ICTEM users.

Age Based on the studies referenced above, both carsharing and TNC users are on average younger than the average, and one would expect to find a younger demographic within any sample of ICTEM users.

Household size Since car ownership becomes more economically advantageous as more individuals use one car, fewer households of large size should be completely reliant on carsharing or TNCs – but on the other hand, larger households are more likely to have occasional additional car needs. It is unclear which one of these effects will dominate, and whether on average households in my sample should be smaller or larger than the average. There is likely to be a spike for families, which may have multiple cars for the adults in the household, but may be sharing these and therefore occasionally resort to carsharing.[31]

Employment If, in line with the income considerations, low-income segments of the population benefit considerably from ICTEMs, unemployment might be higher in this group than the average population. This could be offset by the fact that unemployed individuals likely have a lower value of time and could preferentially choose cheaper but slower modes of travel. Sampling methods of course may further obfuscate any effect on employment.

Student status Given the channels of recruitment, I expect to find more students than in the general population.

Homeownership Based on the characteristics of the modes of interest considered above, there is no reason to suspect different homeownership among carshare and TNC usership, except as an artifact of other socioeconomic factors such as age or income.

Trip characteristics Some of the inherent characteristics of carsharing and TNCs lead to conjectures regarding the trips they are used for, which should become apparent in travel diaries of their users.

Trip purpose Based on the discussion of the economic incentives, carsharing is unlikely to be used for travel to and from work, given the disavantages of parking a carshare car for long periods of time; the primary trip purpose likely are personal errands or shopping trips. TNCs on the other hand are likely similar in their use to taxis,

and trip purposes might include quicker, spontaneous one-way trips which require a driver. This could include work travel, especially in affluent areas like San Francisco, but also health or evening socializing.

Time of day and O-D If TNCs are used for work trips, this could result in a preponderance of morning trips. Socializing trips, which Rayle et al. observed predominantly due to their sampling strategy, would lead to more evening trips. All TNC are more likely than trips in other modes to originate at a location other than home, since TNC cars can be hailed from anywhere. Carshare travel on the other hand is more likely to occur during times when members are not working, i.e. evenings or weekends. Carsharing members probably have a familiar station near their home location (otherwise membership would not seem very attractive), and thus carsharing trips might be expected to originate and end at or near home more frequently than TNC ones (though probably less often than trips in household-owned cars).

Sustainability

Do users of private transit exhibit either more sustainable car ownership choices, or more sustainable travel patterns indicative of reduced VMT? The latter could be manifested in less/shorter vehicular trips, an increase in active transit or, in the negative case, a marked substitution of private for public transit trips.

Car ownership If the claim of car shedding and foregone purchases made by Shaheen et al. holds true, and if the easy availability of automobility without owning a car enables less car-centric lifestyles, this should manifest itself in the car ownership patterns of either one or both user groups. (In a one-time observation, the causation could go either way – certain choices about car ownership could be conditioned on ICTEM availability, or ICTEM use on car ownership. Nevertheless, certain correlations can be used as indicators for future study.)

Average car ownership in my sample compared to a socioeconomically similar CHTS set from comparable locations within the Bay Area is likely lower than the CHTS average, given the significant car shedding found across the literature, and especially so if households previously without access to any car are adopting ICTEMs. Note that such lower average car ownership could be emblematic of both VMT-subtractive (shifting incentives against vehicle trips) and VMT-additive (giving access to motorized travel to previously carless households) behavior.

Correlations between car ownership and ICTEM use on the survey date could further illuminate the uses of both carsharing and TNCs. Overall I expect to find a negative correlation, since a household with many cars should be less likely to resort to external cars for transportation. This negative correlation should be stronger for carsharing than for TNC use, since the overlap in use cases between carshare and driving

an own car is larger, i.e. one would expect stronger substitution effects. As a second-order effect, a peak in use of carsharing for a low number of cars owned would support Stillwater's hypothesis of supplementary carshare use in car-dependent households.[31]

Trip length in relation to both the general public and among different types of ICTEM could be an indicator of VMT-subtractive or -additive behavior.

Overall trip length/time compared to the corresponding CHTS subset: if usership of either carshare or TNC encourages a shift to in travel behavior, trip distances should on average be shorter than the CHTS Bay Area average for similar demographics in comparable locations. Travel times might be proportionally longer if there is a correlation between use of these modes and active transportation, which one might consider the most environmentally sustainable form of travel.

Trip length/time compared between modes should be different. Based on expected use cases carshare trips ought to be most like private car trips, whereas TNC trips should be most similar to taxi trips. Correlations of trip mode and trip length/duration within trip database reveal which modes are used for what type of trip (long- or short distance).

Transit cannibalization Comparing travel times between origin and destination, Rayle et al. [26] found that within their sample the public transit alternative in most cases would have taken substantially more time, or have been altogether impossible, such that users would have otherwise taken a taxi (not transit). For both TNC and carshare trips, if do not cannibalize from transit, trips taken on these modes should in their majority be impossible or considerably more cumbersome on transit (i.e. an unlikely choice even prior to carsharing). On the other hand, if these modes are used as substitutes for transit, there might be a substantial number of trips that would have been possible and not disproportionately longer on transit.

More trips and/or VMT in alternative modes could be another indicator of (comparatively) VMT-subtractive behavior.

Mode shares compared to the Bay Area CHTS , if the effect of ICTEM availability is environmentally beneficial, ought to show less car travel and more public transit as well as active transportation compared to geo- and demographically similar members of the general population.

Mode shares compared between ICTEM user groups can reveal differences between the impact of TNC use and carsharing: when comparing the modeshare of active transportation, transit and car travel between users of carshare and TNC, I expect to find a higher use of alternative modes for carshare users .

Equity

Effects of new modes on transportation equity are difficult to detect using a one-time observation of demographics and travel behavior, but one can expect to glean some indicators.

Income discrepancy , i.e. are users of ICTEMs generally more wealthy than the average, or those of TNCS wealthier than of carsharing?

Income comparison with CHTS if indeed alternative forms of automobility help lower-income groups gain access, the income of a sample of users of such modes ought to be lower than the average. On the other hand, if so far mostly groups with a significant amount of privilege are served as described by Shellooe [29], there should be no difference, or the income in such a sample might even be higher than the average.

Income comparison between user groups Given the different use cases for and economics of carsharing and TNC, carsharing appears as the more economical option for necessary trips for users unable or unwilling to afford an owned car. Meanwhile TNCs economically fall into a similar category as taxis, and are unlikely to provide much additional benefit for lower-income users. Thus one might expect to find a higher average income among TNC-users than among carshare users, which would support (albeit by no means prove) the notion that carsharing adds to transportation equity.

Transit captive users Do car ownership numbers or trip patterns suggest improved accessibility?

Car ownership overall Migration of involuntarily carless passengers to TNCs and carsharing should lead to higher numbers of carless users among the usership, and lower average car counts compared to a socioeconomically similar population (for either one or both user groups). Given the many other factors at play, low car ownership alone cannot be interpreted as a clear indicator for improved transportation equity.

Time savings by carless population If a subset of my sample is constituted by formerly transit captive individuals, there should be a high number of trips taken a) on carshare/TNC b) by car-less respondents that c) would have been impossible or taken longer on public transit. In the counterpositive, if most trips taken by carless passengers appear to be substitutes for equally convenient transit trips, I can confirm that not many users experience ICTEMs as a travel time improvement.

In the following, I analyze the results of 821 travel diaries collected from users of novel transportation modes in the fall of 2015 and spring of 2016, and attempt to assess their travel behavior as well as socioeconomic composition, with the 2012 California Household Travel Survey [CHTS] as a point of reference.

Chapter 3

Survey methods and limitations

3.1 Research Approach

In order to better understand users of ICT-enabled modes (ICTEMs) and their travel patterns, specifically how they differ a) between TNC- and carshare users and b) between a sample of such users and the general population traveling in the Bay Area, the focus of this study was a set of travel diaries from car sharing/TNC members designed to supplementrecent household travel surveys and generate a meaningful trip database for this demographic in the Bay Area. After collecting these diaries, this report analyzes the demographics and travel behavior of the respondents, and draws conclusions about who was using these modes, what notable features their travel behavior exhibited, and whether such behavior was likely more economically and environmentally sustainable than average Bay Area travel patterns. In the following sections, I first outline the entire process and then describe in detail the design of the survey instrument, the cleaning of the data and the limitations of this approach.

Steps involved

1. At the core of my approach was a web-based survey instrument, easily disseminated to respondents with internet access, which selected only respondents who were active users of ICTEMs and collected basic socio-economic background data as well as self-reported trips for one day.
2. The first wave of recruitment for data collection was based on handing out flyers in central locations in San Francisco and Alameda County and posting ads in the San Francisco and East Bay sections of the classified ads website Craigslist to obtain a convenience sample. A second batch of respondents was recruited through online panels offered by Qualtrics, the platform hosting the survey.
3. Survey responses required processing and cleaning to filter out incomplete or clearly erroneous responses. Responses were then geocoded and those with trips outside the Bay Area discarded.

4. The set of intra-Bay Area responses was analyzed using statistical methods to yield insights about its composition and about travel patterns of interest.

3.2 Survey instruments

The core piece of this research consisted of an online survey carried out during the fall of 2015 and spring of 2016 using the Qualtrics platform. Overall, this survey was designed to be a pared-down version of the CHTS, collecting a set of as-comprehensive-as-possible data about respondents and their households given my time and research limitations, as well as a day's worth of trips. Given the goal of being comprehensive, it included also questions that were not directly relevant to the analysis conducted here, but may be of use to transportation researchers for future study.

The survey was comprised of two components, an initial screening and demographic background survey, and a travel diary. In 2015, the background part of the survey – the gateway into my study, performing respondent intake and collecting basic demographic information – was distributed as a separate online survey, which was later followed by an invitation into the second – travel diary – survey on a date determined by myself. In 2016, due to complications within the Qualtrics panel framework, I combined both surveys into one, leading to slight modifications throughout. Another key difference is that in the 2015 survey, answers to most questions were voluntary as a way to reinforce the statement that participation in the study was voluntary, which led to numerous responses being of limited use because of missing vital information. In the 2016 survey most questions were therefore mandatory, i.e. the survey could not be completed without answering each question. Both versions of the survey instrument are described in more detail below, and can be found in their entirety in appendix B.

Background survey

This background survey (see appendix section B.2) was open for general access via a link during the months of September and October 2015. Only responses prior to the 28th of October were included in the following stages. A modified version (see appendix section B.4) was opened only to Qualtrics panel respondents in March 2016.

Informed consent

In keeping with requirements imposed by the Committee on the Protection of Human Subjects (CPHS), the survey included an informed consent document at the beginning. In order to participate, respondents had to accept the terms outlined here. This document introduced the research team (myself) and the purpose of this study, and highlighted to the reader the actions required for participation, i.e. filling in both parts of the survey from a web-enabled device. It also alerted prospective participants to potential sources of discomfort or inconvenience associated with participation, chiefly consisting of potentially triggering recall of past travels and of

the possibility of breach of confidentiality should the dataset be leaked. Finally, the document provided contact infomation for both the researcher and a contact person at CPHS. A complete version of my informed consent document is attached in appendix section B.1.

Screening

The informed consent was followed by a number of screening questions, ensuring that only those who were a) of legal age of consent and b) able to provide a response useful for my research were able to participate. The latter part is broken up into two parts:

Travelers in the SF Bay Area For practical reasons, I set out to collect responses that would be on the one hand originate from Bay Area residents and therefore be comparable to household travel surveys collected here, and on the other hand analyzable using traffic analysis zones [TAZs] defined by the Metropolitan Transportation Commission [MTC] such that travel times and distances could be obtained from skims of the MTC's regional travel model. Therefore, this section included the question "Do you live in the SF Bay Area for most of the year?" The 2016 survey, which enquired about travel the day prior to taking the survey, also asked whether respondents had been in the Bay Area the day before. Negative responses to either of these questions were screened out.

Active users of ICTEMs Given the low overall modeshare of the modes of interest, this section also included the question whether the prospective respondent had used some form of car- or ride sharing during the previous month ("cab hailing apps like Uber, Lyft or Sidecar", "carsharing services like City CarShare or Zipcar", or "other forms of car sharing"). In order to avoid priming effects, this question also asked about a number of different transportation options such as "own car" or "public transportation," and let only the relevant ones continue on.

Demographics

The remainder of the background survey asked for a range of demographic variables and relevant household transportation information. In designing the survey, I arranged questions such that those asking for more private information, i.e. with higher potential to make the respondent uncomfortable and less likely to answer accurately, were positioned towards the end of the survey, at a stage when participants might have become more comfortable with the process overall.

Personal demographics Here I asked for personal information which has been identified as having significance for individuals' travel behavior . This included respondents' marital status, their parent status (only if children in the household are reported), student status (the 2015 survey included options for full/part time, in 2016 this distinction was removed to simplify the questionnaire), possession of a drivers' license, gender identification, age, racial/ethnic background (the options given here were non-Hispanic white, non-hispanic

black, hispanic, Asian and mixed), as well as their disability status (specifically for a "disability or condition that has lasted 6 or more months and which makes it difficult to go outside the home alone").

Household demographics This section similarly asked for household characteristics linked to transportation choices, specifically the household size, number of children in the household, whether the residence was classified as single-family, home ownership, residential tenure, the number of workers in the household and the combined household income (by category, in steps of $5000 up to $50k, then progressively larger steps until $150k & above, based on the assumption that smaller differences in income have higher relevance for lower-income households).

Transportation variables Lastly, in order to determine possible mode choices and the cost of trips, this section requested information on the number of motor vehicles and number of bicycles owned by the household, the number of licensed drivers and the individuals' transit pass ownership & type.

Contact information

Finally, the 2015 background survey recorded respondents' email addresses to later contact them with the scheduled date for their travel diary, and with possible questions regarding their response. This question was moved to the end of the diary for the 2016 version.

Travel diary

The travel diary survey was designed to capture an individual's travel patterns by recording their trips, with approximate time of day, origin, destination and mode. It was broken up into two stages, one capturing constants and the next repeating in a loop for every trip taken. The original diary questionnaire can be found in appendix section B.3, the slightly modified 2016 version in appendix section B.4.

Constants

First, in order to have an explicit record of the day participants are reporting on, the diary asked them to choose the "day for which you are reporting your travels" from a drop-down menu. In order to facilitate entry of pre-recorded locations later, it requested information for the potentially frequently visited locations of home, work and school. These locations were requested in the form of

- street address OR street/cross street
- city, state and ZIP code.

Given all of these pieces of information a location could later be geocoded and associated with a TAZ.

Before launching the trip collection loop, the questionnaire asked for the location of the respondent at 3am on the date of the travel diary. This again involved the abovementioned address fields, or, if they had already completed a home, work or school location, they could choose to use that location. (Due to technical difficulties with the Qualtrics platform, many respondents to the 2015 travel diary did not see this 3am question, and I had to reconstruct their first location, introducing an additional source of error. See 3.4 for more detail.)

Trips

Upon completing the constants described above, participants were prompted to enter their next location, again choosing either a frequent location entered in the constant section, or a new location with address or street/cross street, city and ZIP code. For each stop, the survey also asked for the time of day of arrival (morning, afternoon or evening/night), mode of transportation (a choice of 9 distinct options), for car trips the number of people in the car, and the main activity at the destination (a choice of 8 options). After each stop, respondents could select whether this was their last stop of the day, which terminated the diary. Given that during the beta phase, many participants did not report their home destination as the final destination, this diary survey also contained an added prompt after the first stop reminding participants to record every single stop during the day, as well as a conditional confirmation page for participants who did not finish their day in their home location.

3.3 Recruitment

All recruitment involved disseminating information and a link to the study questionnaire, with an incentive promised upon successful completion. A beta version of the study was distributed to about 200 individuals over the summer of 2015, which resulted in 6 final travel diaries collected and some corrections to the survey instrument. The bulk of data collection occurred in the fall of 2015, with participants recruited through handouts and Craigslist ads, and the spring of 2016, with participants recruited through a commercial panel. The recruitment for this study changed over time, adjusting for both response rates and technical constraints. The following sections describe in detail all methods employed.

Key limitations included a selection bias for individuals who either walked through certain areas (for those recruited by flyer), or who frequented Craigslist or one of Qualtrics' recruitment channels (for all others), as well as a nonresponse bias for people with easy internet access and with sufficient perceived free time to respond to a detailed travel diary survey. Survey validity is discussed in more detail in section 3.5.

2015

Flyers

2000 postcards were printed with an announcement regarding a transportation study at UC Berkeley, with a weblink to the survey as well as a QR tag for easier access via mobile phone. The postcard can be found in appendix A. 9 undergraduate UC Berkeley students were instructed to hand out those flyers over the course of September and October 2015 in 3 areas where I expected high pedestrian volumes and high incidence of users of private transit:

1. Downtown Oakland, in the vicinity of the 12th or 19th St. Bart stop
2. Emeryville, in the vicinity of the Baystreet Mall
3. Downtown San Francisco, in the vicinity of the Embarcadero Bart stop

The undergraduates were given autonomy in how far they went from the specified location. They were also instructed not to mention car sharing, although they reported at an intermediate stage recruiting participants by asking them if they used Uber or Zipcar, which may constitute a potential source of error. The survey team handed out about 400 flyers in Emeryville, about 400 in Oakland and the remaining 1000 in San Francisco. (While despite instructions to the contrary they did not record the numbers handed out in each location on each day, those were the numbers given out to team members assigned to each location.)

Response- and follow-through rates are listed in Table 3.2.

The chief incentive for participants were Amazon gift certificates adding up to a total amount of $20 per respondent upon completion of the final travel diary.

Craigslist

By October 16, 2015, having handed out most of the flyers and only obtained 57 finished diaries up to that point, I designed a small ad to be posted on the classified ads page Craigslist. These postings were made in the San Francisco and East Bay local pages, under the categories "gigs>computer gigs" and "gigs>domestic gigs", as well as "housing>real estate - by owner" and "housing>real estate wanted - by owner". The former categories were chosen based on the assumption that those browsing for small gigs might be most inclined to respond to my incentive, the latter to target individuals actually living in the Bay Area.

The ad contained the same information as the handout and directed the reader to the background survey. The incentive remained unchanged with Amazon gift certificates in the amount of $20.

Respondents to the first survey were grouped into three week-long waves of travel diaries, and randomly assigned a weekday during that week (Oct.10 - 16, Oct.19 - 23, Oct.28 - Nov.3 of 2015). They were sent an email assigning them a day at least 3 days beforehand, and sent a reminder email the day of. This email contained a link to the diary survey itself, which participants could choose to fill in either using their mobile phone as the day progressed, or in one go at the end of the day.

2016

In early 2016, preliminary analysis of the responses obtained through the two aforementioned channels showed a relatively low data quality, with many addresses located well outside the Bay Area (some as far away as China) and reported dates disagreeing with the date of the survey.

Qualtrics panel: Joint survey

This led to a third wave of recruitment using a Qualtrics panel during the last week of March 2016. Panels were, according to Qualtrics, representative samples of the population in a specified area, in my case the 9-county Bay Area, recruited through a variety of contracted providers. The incentive with Qualtrics varied depending on how the respondent was recruited by Qualtrics, and could take the form of monetary compensation, vouchers or other non-monetary forms. Using this method, Qualtrics was tasked with collecting 200 responses to the survey (with a questionnaire slightly modified for this purpose).

For this recruitment channel, the Qualtrics portal supplied detailed information on how many responses were rejected based on each screening question. This information is listed in table 3.1; for 238 complete responses, 797 (or about 77% of respondents that followed the survey to a determined end point) had been screened out through one of the screening questions.

Table 3.1: Numbers of respondents screened out by different qualifying questions from the Qualtrics panel.

Screen	number
Consent	1
>17 years old	18
Resident in Bay Area	74
Present yesterday	84
ICTEM user	620
Total	797

3.4 Data processing

Upon collection, data from all surveys were cleaned, repaired where necessary, and combined into one set of data. This section describes in detail the steps involved. After excluding those responses with unreasonable reported travel dates, 821 individual responses remained for analysis of household characteristics, of which at least 33 were recruited via handouts, 538 most likely through Craigslist ads, and 204 stemmed from the Qualtrics panel. Upon geocoding trip origins and destinations and attaching Bay Area TAZs to them, 668 individual records with all trips in the Bay Area remained. Of these, at least 30 stemmed from handouts, 461 most likely from Craigslist, and the 2015 data collection, and 177 from the 2016 Qualtrics panel; see alse table 3.2.

Cleaning

The basic cleaning and combining of the dataset was structured as follows:

1. From all responses in the Qualtrics database, only those fully completed by real respondents (i.e. not preview, from a real IP address) were selected and downloaded. This yielded a pool of 1553 complete backgrounds and 1359 complete diaries, as well as the 238 joint questionnaires collected by Qualtrics.

2. In the next step, variables were cleaned and unified across all batches of data collection. This involved renaming variables and changing certain variable types. Categories that were more detailed in the 2015 version were collapsed into joint categories (i.e. student and employment status were stripped of part-time information).

3. Diaries and background questionnaires from the 2015 data collection were joined based on email address, since the email address given in the background had been used to send out personal invitations to the diary questionnaire. I dropped all duplicate entries except for the last one, assuming that duplicate entries were a sign for mistaken/incomplete first attempts and therefore the last one should be kept. This left a total of 779 combined background-diary responses from 2015.

4. Responses from both years were combined into a joint dataset of 1017 responses, and a trip database was generated by breaking up each personal response's diary. The total number of trips collected was 2373.

In addition to these basic steps, I executed two further steps to arrive at a useful dataset: I first reduced the dataset to one that would be as reliable as possible by filtering out unreasonable diary dates. Then I further culled the trip database by joining on MTC TAZs to obtain one that could be used with skims from the MTC's travel model.

Date filtering

Multiple dates pertained to each response in my survey scheme: the date on which the questionnaire (or questionnaires, in the case of the 2015 survey) was recorded ("survey date"), and date selected by the respondent as the day of travel logging ("travel date"). Two types of responses cast doubts on the reliability of their travel log:

Diary for future date The travel date for the diary was in the future relative to the survey date, i.e. clearly not an accurate report of either the date or the entire travel log. (This accounts for 136 out of 1017 cases of diaries successfully matched up with backgrounds, or 13%.)

Diary > 1 week in past The reported travel date was more than 8 days in the past relative to the diary's survey date, raising suspicions regarding the accuracy of the individual's memories. (Another 60 responses, or 5.9%, fall in this category.)

Responses with questionable dates were discarded at this stage of cleaning (leaving 821).

Geographic filtering

Each trip in the diary was associated with a location. These locations were geocoded using the QGIS MMQGIS plugin, which is based on Googles Maps API. The majority of addresses/cross streets could be linked to a latitude-longitude pair in this way; for those left over (because of misspellings or non-existent addresses) I manually associated locations with the address. Where a clear location could not be assigned, I approximated by a location in the same municipality.

Once geocoding was complete, for the purposes of analysis in the MTC TAZ framework, TAZs were joined to each trip origin and destination. Those responses for which one or more locations lay outside the Bay Area were discarded, since travel time and cost could not be retrieved from MTC skims in those cases. (This process filtered out another 153 responses.)

Fixing

There were three technical problems with the Qualtrics questionnaire that were not discovered until after survey collection. I attempted to correct these problems as follows:

1. In the 2015 survey, respondents were only shown the question of where they were at 3am on the day of their diary if they provided *both* home *and* work addresses. As a result, most respondents were *not* shown this question. This affected 605 of 821 responses used for analysis, or 74%, and 479 of 668 final trip records, or 72%.

2. In the 2016 survey respondents were forced to give both a 3am *and* a first stop location, i.e. there was no way for a participant to indicate that they stayed at home all day. As a result, 10 respondents provided home as both their initial and final location, with a mode and other attributes for the "trip".

3. It appears that (in 17 cases overall), when after designating a trip as the last one, respondents indicated they were not actually ready to terminate their diary by selecting "Oops, enter another trip", they were not shown another possible destination.

To be able to still use the affected responses, I make the following assumptions:

1. To fill in the missing 3am destinations, I assumed that everyone who did not provide a 3am location started at home. This is definitely a source of uncertainty, but was supported by the fact that of all respondents that *did* give a 3am location, only 13.5% of respondents started somewhere not at home. More specifically, I assume that

    - respondents without 3am location whose first reported location was *not* home had *missed* their home location; I therefore filled their missing 3am location with "home".
    - respondents without 3am location with a first reported location of "home" had shifted their entire diary over by one stop; I therefore shifted all variables back to identify Stop 1 as the starting location, Stop 2 as Stop 1, etc.

2. For diaries from 2016 with both their initial and final location at home, I assumed that respondents had meant to indicate remaining at home for the duration of the diary; I therefore deleted the first stop with all its attributes to reflect a respondent staying at home.

3. To compensate for lost trips in cases where respondents were unable to enter further locations even though they wanted to, I added a final stop at home in cases where this had occurred.

The resulting corrected dataset consisted of 821 observations, with at least 33 from handouts, 538 from Craigslist responses, and 204 from Qualtrics panel responses.

CHTS subset

The CHTS data used here is stored at the National Renewable Energy Laboratory's [NREL] data store, and can be retrieved after registering for an account with NREL.[1]

In order to compare my sample to the general population, I selected two subsets from the CHTS dataset. First, I extracted only those responses whose trips are entirely within the Bay Area (corresponding to the processing of my own sample, in order to be able to process trips using MTC skims) for demographic analysis of my sample. Secondly, in order to perform rudimentary comparisons between the general population and my sample, I weighted the Bay Area CHTS subset by categories to obtain similar distributions to those in my sample. In this process, I categorized respondents by age (0-20, 20-30, 30-40, 40-50, 50-60, and 60-100), by gender (male or female) and by household income (0-10,000, 10,000-25,000, 25,000-35,000, 35,000-50,000, 50,000-75,000, 75,000-100,000, 100,000-150,000 and >150,000) and calculated weights associated with each category; those categories that did not exist in my sample were removed from the comparison set. Weights obtained in this way were used in the following analysis to scale the CHTS data for comparative analysis of trip patterns.

Given the disproportionately high fraction of residents of highly urban regions (specifically, the Oakland/Berkeley/Emeryville area and the city of San Francisco), this process was repeated with only residents of the corresponding MTC superdistricts to create an additional densely urban point of reference.

Response rates

Given that handouts and Craigslist ads pointed to the same survey, certain distinction between the resulting dataset is impossible. However, given the temporal separation and spike in responses after posting of the Craigslist, I assumed that the vast majority of responses after posting of the ad were indeed recruited through the Craigslist ad. The response rate for my postcard flyering was about 8.9%, with a questionnaire completion rate of 36% for those that entered the questionnaire. For respondents recruited through online channels, the number of persons that saw the recruitment is unknown, but completion rates for those that entered the survey was 82% and 16%, for Craigslist ads and Qualtrics panel respectively. This attrition includes both

screening out not qualifying respondents and dropping out of respondents on their own. Survival rates of responses through data cleaning into the final dataset were 58%, 41% and 86% for handouts, Craigslist and Qualtrics respectively, and of those 91%, 86% and 87% met the all-Bay Area-trips criterion for inclusion in the trip analysis. Counts are listed in table 3.2.

Table 3.2: Number of responses obtained, respondents finishing survey and responses surviving in final dataset by recruitment channel.

	responded	complete diaries	fraction completing diary	remainder post-cleaning	fraction diaries in final sample
flyers	≥ 160	≥ 57	0.36	33	0.58
Craigslist	≤1589	≤ 1302	0.82	538	0.41
Qualtrics	1492	238	0.16	204	0.86

3.5 Survey validity/success

There were a number of concerns regarding the validity and success of my experimental design, organized here by the four categories of survey errors in order of relevance to this research.

Coverage

The probably largest source of uncertainty was the lack of access to a representative sample, which in turn required close attention when drawing conclusions from the analysis conducted within this study. My survey was not designed to achieve representativeness of the Bay Area or even a subset thereof. Due to my convenience-based methods of recruitment – handing out flyers and posting online ads – my sample contained a mix of those who frequented downtown Oakland, Emeryville and San Francisco (excluding non-pedestrians and those from outside central areas), those who read the respective Craigslist sections on 'Gigs' and 'Odd jobs' (excluding those who do not spend time reading such small ads), and those who participated in Qualtrics' recruitment channels (excluding those who did not – due to Qualtrics' outsourcing much of their panel recruitment it is unclear exactly what this entails, but judging by respondents' answers to the question of recruitment channel it certainly included a number of online survey portals and possibly handouts in Bay Area cities, leading to similar exclusions as my other sources of respondents). Of course a web-based survey generally excluded anyone without internet access as well.

Considering this coverage and given recent internet permeation rates for different groups of Americans, based on the web based nature of the survey and some recruitment channels alone one would have expected more younger respondents than senior ones, as well as a relative preponderance of representatives of higher educational status and income.[24] The reliance of my 2015 recruitment on pedestrians on one hand and 'Gig'/'Odd jobs' ads further discriminated against older people, who are more likely to have impaired mobility, and probably less likely to be looking at this type of advertisement. If the recruitment methods in this study favored

younger individuals, or those with higher educational and income status (and likely better correlated employment statistics), no conclusive statements about the age income of ICTEM users versus the general public can be made. However, finding higher than average unemployment or an income distribution skewing lower-than-average could be considered support for impacts beneficial to disadvantaged populations, and similarly finding higher-than-average mean age would have been a surprising and noteworthy result.

As the intent of this study was not to create a rigorous comparison, representativeness of the sample was not a major concern. However, for a directional comparison I weighted the CHTS responses to achieve demographic similarity.

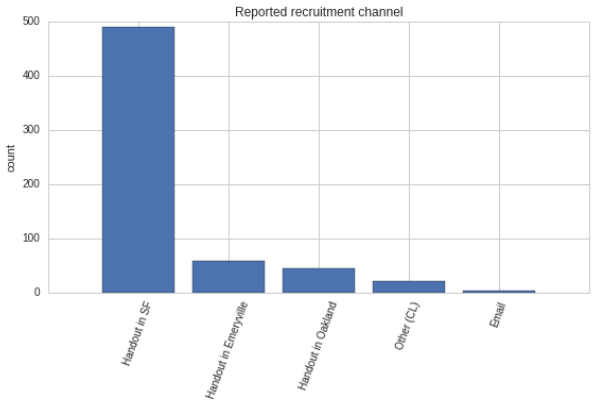
Measurement

There were three main issues calling into question the validity of responses to my survey instrument.

Survey instrument As described in section 3.4, there were technical problems with my survey instrument that were corrected ex post, but introducing uncertainty regarding initial locations.

Recruitment channel The recruitment channels reported in the introductory section of my survey did not appear to match actual recruitment channels. Of 1714 initial respondents to the flyer/Craigslist effort 1337 reported recruitment through a flyer in San Francisco, 173 through flyers in Emeryville and Oakland, and only 61 through a different channel, i.e. Craigslist. Despite efforts to keep a record of flyer dissemination, the survey team did not keep track of all flyers they handed out; but of those recorded, 521 were handed out in San Francisco, and 382 in Emeryville and Berkeley combined. Additionally, responses increased drastically after posting of the Craigslist ad. (Even Qualtrics-recruited respondents in many cases reported recruitment by handout, which to my knowledge was not a method employed by Qualtrics, though there was some opacity within Qualtrics regarding their recruitment channels). This suggests that disproportionately many respondents selected the first answer option for recruitment channel, and may not have paid attention or answered truthfully to other questions, either. (Recruitment channels for the 821 responses remaining after data cleaning are charted in fig.3.1).

Date In 132 out of 1017 cases where diaries were successfully matched up with backgrounds, or 13%, the date reported for the diary was in the future at the time the diary was filled in. These responses were filtered out, but suggest that respondents were knowingly giving faulty responses, possibly suggesting that they were not paying attention.



(a) Recruitment channels reported in Fall 2015 (flyers/Craigslist).

(b) Recruitment channels reported in Spring 2016 (Qualtrics panel).

Figure 3.1: Recruitment channels as reported by respondents remaining after data cleaning. Certain channels were overrepresented, others (such as 'Email', or handouts for the 2016 survey) were not intentionally utilized as methods of recruitment).

Non-response

Given the recruitment channels it was difficult to assess the non-response error in my sample. I have to suspect that many potential participants did in fact not respond to the recruitment described above; future efforts to generate representative samples of ICTEM users may want to employ different methods to better control for such errors.

One specific hypothesis regarding non-response error is that the recruitment by undergraduates may have deterred older demographics. Indeed respondents recruited by handout had the lowest mean age at 26.9±1.1 years, those recruited most likely via Craigslist ad had an average age of 30.4±0.5, and Qualtrics panel respondents 31.7±0.8. The age distributions as illustrated in fig. 3.2 did not appear drastically different between recruitment batches.

Sampling

In order to achieve reasonable certainty despite possible sampling error, I collected a sample of 821 responses. However, some subgroups of my sample are still small enough to result in non-negligible margins of sampling error, such as the group of carshare-only users with only 82 members. Sampling error estimates based on variance and/or number of responses are provided wherever relevant.

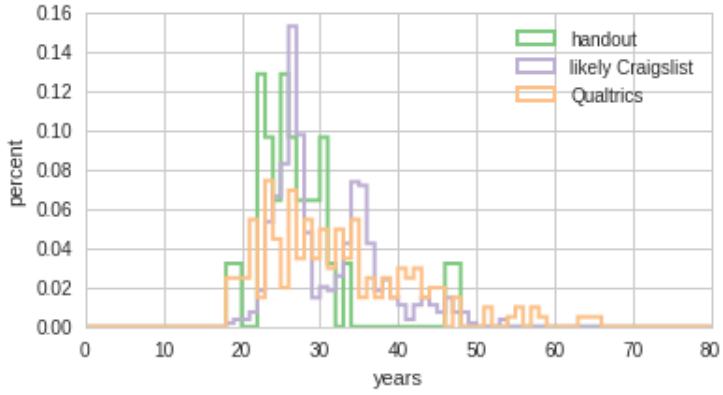


Figure 3.2: Age distribution by recruitment channel (percent of batch in each age category).

Chapter 4

Analysis methods and findings

This chapter contains a description of my analysis structure and methods, as well as the results thereof.

4.1 Analysis methods

I performed the following analyses the survey results in order to test (some of) the hypotheses laid out in 2.4.

Characteristics of carshare and TNC users

In order to understand the specific characteristics of users of ICTEMs, I divided my sample into three general groups based on their reported use of carsharing and TNCs preceding the survey: those that reported using only TNCs, those that reported using only carsharing, and those that reported using both. I conducted basic exploratory analysis with further distinction between residents of very densely populated zones like San Francisco (where a carless lifestyle is easy), suburban or less densely urban areas such as South San Francisco (where a carless life is still possible but cumbersome), and areas far removed from dense urban centers in the North and South Bay (where living without a car becomes very difficult); zones are displayed in fig. 4.1. I also distinguished between the different batches of data collection.

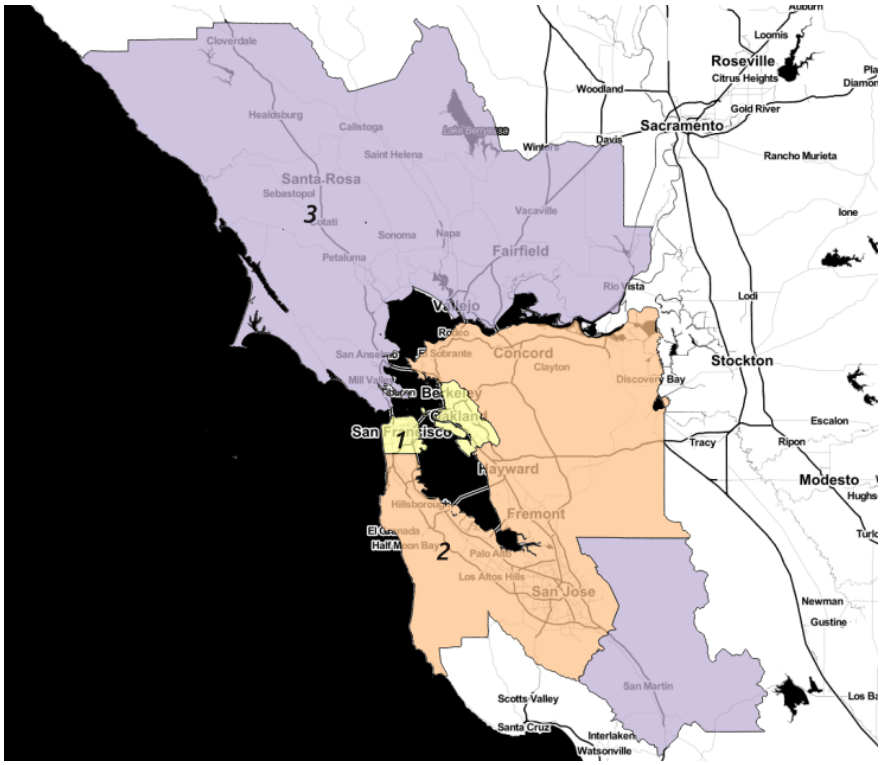


Figure 4.1: Zones used for categorization of my analysis. 1 includes dense urban areas in San Francisco and the East Bay, 2 are dense suburbs or less dense cities, and 3 are the least dense areas and those furthest removed from the urban centers.

Many variables of interest are generally differ greatly between urban and less urban areas. I compared to a subset of CHTS responses with trips within the Bay Area weighted to have the same income, age and gender distributions as my sample for a low-density bound (given that the majority of my sample came from zone 1), and to a similarly weighted subset with residences only in zone 1 for a highly urban bound on the variables of interest.

The first variables of interest here were general demographics – age, income, household size, employment and student status, as well as home ownership status. The objective was to find out whether these variables correlated with membership in the different usership groups. I also determined whether there was a significant difference between my entire sample and the Bay Area CHTS population (for those variable involved in weighting this comparison occurred with an unweighted sample of geographically matched CHTS respondents) – note however that given my methodology there is a possibility that such differences were due to sampling as opposed to actual differences between ICTEM users and non-users.

For ordinal variables (age, income, household size) I calculated margins of error for the group averages based on variance and sample size and determined the significance of the difference between groups using a χ^2 statistic. For categorical variables (home-ownership, employment and student status) the χ^2 was calculated from the crosstabulation of group membership

versus status.

In addition, I examined trip profiles for the different modes used in my survey to assess which types of trips different modes are typically used for. This involved cross tabulations of different activities and times of day versus the trip mode across all trips observed. In doing this, I also investigated whether those living in urban centers (those that gave a residential address in San Francisco, Berkeley or Oakland) exhibited different behavior from those outside of larger cities.

Sustainability

As laid out in the previous chapter, more sustainable behavior – either in my sample compared to the population at large, or between the different subgroups of my sample – should manifest itself in significant differences of the variables of interest between the groups of interest.

First, I examined trip lengths for the different modes (time and distance based on TAZ skims). I then tested whether the average distance traveled by mode differs significantly for each user group, or between my sample and the weighted Bay Area CHTS (and its zone 1 subset). In the mode share comparison, I focused on motorized, shared motorized (>1 traveler, not counting driver), public transit, or active (bike, walk or wheelchair) miles traveled.

In order to assess how these modes may affect transit ridership, I also determined (using the TAZ's skims) what percentage of the trips taken either on a TNC or using carsharing could have been completed using transit instead,and on average how much longer the transit trip would have taken. Margins of error were calculated using the variance of my sample.

In view of the car shedding hypothesis, I then calculated the correlation between car ownership and use of ICTEM on the actual survey date; to assess the significance of the correlation a Kruskal-Wallis test was employed. In addition, I visually examined the actual distribution of car ownership and the usage of modes in question to find potential aberrations from a simple linear correlation. I also compared the average car ownership in my sample to the weighted Bay Area CHTS subsets.

Equity

The first question here was whether my sample's income distribution differed significantly from that of the Bay Area's population prior to weighting. This test was easily performed using a χ^2 test, however results again were not definitive since much of the difference might be due to my sampling method. Furthermore, I tested whether income is different between the subgroups in the ICTEM sample, using the same method, to probe whether one of the two modes might be more beneficial to the lower-income population. In a similar vein, I calculated the correlation between use of different modes on the diary date and the respondent's household income across all responses, to assess the access of the low-income population to all modes observed.

Finally, I attempted to detect instances of benefit to transit captive users, i.e. use of an ICTEM by a carless respondent to reach destinations that would have been either a) inacces-

sible using public transit or b) taken much longer on public transit. (Transit access and travel time were determined using MTC skims.)

4.2 Findings

Characteristics of carshare and TNC users

User groups

Counts of respondents by residential location zone, recruitment batch and use category (prior to survey reported use of carsharing, TNC or both) are listed in table 4.1. It is noteworthy that 60% of this sample came from the most urban zone 1, including San Francisco, Berkeley and Oakland. This was a large fraction compared to a mere 28% of the Bay Area CHTS respondents, indicating a more urban population within the sample considered here.

Respondents were categorized by their reported use of TNC or carsharing in the month leading up to the survey. By that categorization, the largest group were TNC-only users, making up over 48% of the sample, closely followed by users of both modes with almost 42%. Carshare-only users were in the clear minority at 10% of the total sample.

While the line between handout and Craigslist respondent could not be drawn clearly as the accessed the same survey link, it appears clear by temporal separation that Craigslist respondents were in the majority at 71% of the sample, with handout respondents at only 4% making up a small fraction (even if some more came from late responses during the Craigslist phase). Qualtrics respondents, probably the group most representative of the Bay Area as a whole with only 28% living in the most urban zone 1, made up 25% of the sample.

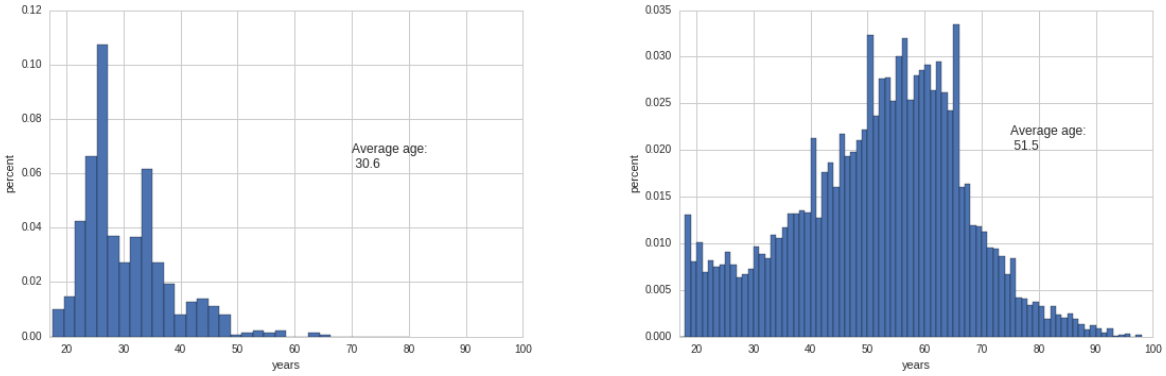
Table 4.1: Cross tabulation of residential zone (see fig. 4.1), recruitment batch and use category within sample.

Recruitment channel	Qualtrics			handout			likely Craigslist			Total
Use category	TNC	both	carshare	TNC	both	carshare	TNC	both	carshare	
Residential zone										
1	31.0	21.0	6.0	20.0	7.0	3.0	150.0	228.0	23.0	489.0
2	84.0	21.0	18.0	2.0	0.0	0.0	66.0	25.0	21.0	237.0
3	9.0	4.0	4.0	1.0	0.0	0.0	5.0	3.0	0.0	26.0
elsewhere	2.0	3.0	1.0	0.0	0.0	0.0	27.0	30.0	6.0	69.0
Total	126.0	49.0	29.0	23.0	7.0	3.0	248.0	286.0	50.0	821.0

Demographics

Age Respondents on the whole were, as expected, significantly younger than those of the CHTS with an average age of 30.6 years, as opposed to 51.5 years in the CHTS for the Bay Area (excluding respondents below the age of 18 to account for our screening) – the standard deviation is only 0.3 years on this difference of over 20 years. To further support this fact,

the CHTS had 46% older than 54, whereas just about 1% of my sample falls into that category; see fig. 4.2a). For the urban CHTS subsample, the average age was only marginally younger at 51.2, and similarly 46% were below the age of 54.



(a) Age distribution of survey sample.

(b) Age distribution of CHTS sample.

Figure 4.2: Age distribution in this sample and the Bay Area CHTS.

Those that used only carsharing preceding the survey were significantly older than those that used TNCs only or both modes, at an average of 33.4±1.0 years compared to 30.8±0.6 for users of carsharing and TNCs and 29.8±0.7 for TNC only. This was also reflected by the age distributions for each use category, with TNC users' ages peaking earliest and sole users of carsharing exhibiting a comparatively fatter tail for higher ages, as seen in fig.4.3.

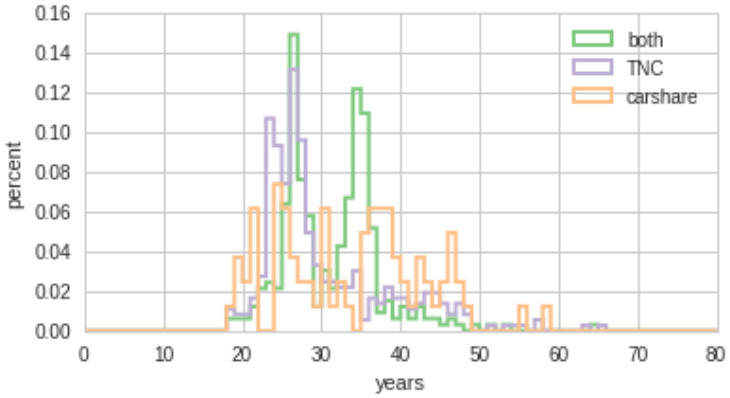
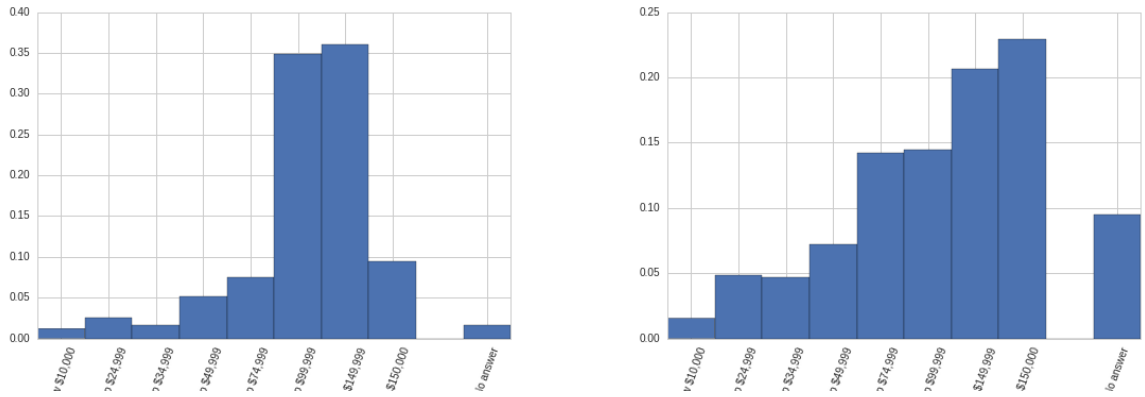


Figure 4.3: Percentage of respondents in each age group for each of the three use categories.

Gender While of the Bay Area CHTS respondents, males were in the minority at 48.4% ±0.9%, (0.49±0.01 for the urban regions only), individuals in my sample were predominantly male (69.5% ±3.8%). Here, there was a marked difference between those in the carsharing

group (only 52.4±5.5% male, indistinguishable from the population average) and those in TNC only and both modes groups (66.8±2.4% and 76.9±2.3% male, respectively). [1]

Income At the same time, these ICTEM users had more narrowly focused income distributions than the Bay Area average: Only 10.5% ± 1.2% of my respondents declared a household income below $50,000, whereas 18.3% of those in the Bay Area CHTS (and 20.0% in the highly urban subset) did. At the same time, only 9.5±1.0% of respondents declared an income *above* $150,000, a small fraction compared to 23.0% in the Bay Area CHTS (and 22.7% among the highly urban subset). This focused distribution can be observed in fig. 4.4, which shows income distributions for both this sample and the Bay Area CHTS.



(a) Respondent incomes (percentage).

(b) Bay Area CHTS incomes.

Figure 4.4: Percentage in each income category for this sample and the Bay Area CHTS.

Notably, the carshare-only group was again a (low-income) outlier, with 28±5% below the $50,000 line and only 7±3% above $150,000. The TNC-only group was quite balanced and narrowly focused with only 11±2% outside each of these limits, while the group of users of both modes had the narrowest peak with the lowest number of low-income respondents at 5±1% below $50,000 and 9±2% above $150,000; see fig. 4.5. It appears that users of both ICTEMs were more affluent than other groups in the population.

Household size The average household size in this sample was 3.1, with little variation among the use categories: carsharing users reported an average household size of 3.1±0.4, TNC users 2.9±0.2, and reported users of both ICTEMs 3.3±0.2. For comparison, weighted Bay Area CHTS respondents lived in households averaging 3.3 members, while those living in the most urban zone 1 on average lived in smaller households with a mean size of 2.9.

[1] One could speculate that women, more frequently exposed to discrimination and assault, are less comfortable getting into a car with a stranger, and therefore do not use TNCs, while in carsharing this deterrent effect does not exist. However, since previous studies of carsharing also found males to be predominant among carsharing early adopters, this may be a peculiarity of my sample only, see [17].

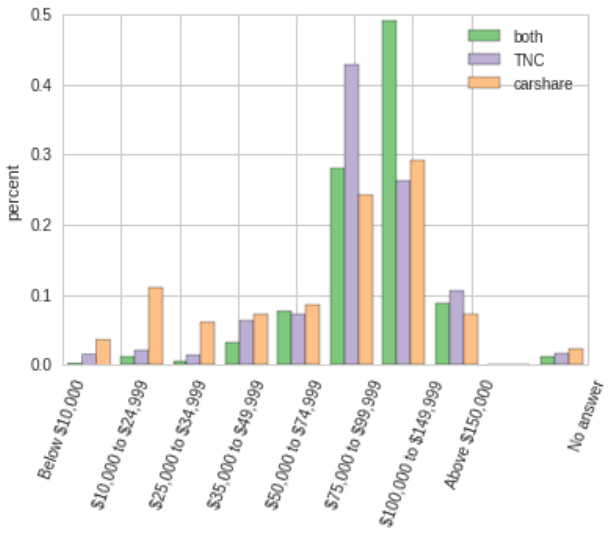


Figure 4.5: Percent of respondents in each use category falling in each income group.

It appears that neither of the use categories differed significantly from the population average given the slightly urban skew of respondents' residential locations.

Home ownership About 79.7%±1.4% own their homes as opposed to 72.2% in the weighted Bay Area CHTS sample and only 58.4% in the highly urban subsample – a significant difference at a high level of confidence. This is true especially of members of the both-modes use group with a home ownership rate of 87.7±1.8%; for carsharing-only users at 78.0±4.6% the difference was less significant and TNC-only users at 73.0±2.2% were very similar to at least the Bay Area as a whole. This reinforces the notion that users of both modes may be comparatively more privileged.

A high percentage of 87.0±1.2% lived in single-family homes as opposed to 78.7% in the Bay Area CHTS (and only 62.2 of those in the highly urban subsample). This significant difference, given large differences between the individual recruitment channels (with Qualtrics respondents, the probably most reliable sample, coming in at 73.5±3.1% even below the regional average) may have been an artifact. Carsharing-only users here emerged as the most space-consuming at 91.5±3.1% of single-family homes, with users in the group reporting use of both modes a close second with 89.2±1.7% and users of both modes last with 84.1±1.8% of single family homes.

Race White/Caucasian was the most chosen race identification at 81.5%±4.3%, higher than the white majority in the Bay Area CHTS weighted for comparison (70.1%, or 71.8% in the urban subset). While whites were in the majority in all groups, the one use group where this majority was significantly more pronounced was that of reported users of both modes with a fraction of 89.5±1.7% Caucasians. For those in either one of the other use categories, the predominance of white respondents is less stark at 75.1±2.2% for TNC only

and 76.8±4.7% for carsharing only. (It should be noted that 95% of Craigslist respondents identified themselves as white, whereas the percentages among both other recruitment channels were below 60%.)

Employment and student status 94.4±0.8% of the sample respondents reported working for pay, as opposed to 72.0% of the weighted Bay Area CHTS respondents above the age of 17 (and only 58.7% of those in highly urban areas), a clear difference. Those reporting use of TNCs or of TNCs and carsharing had much higher employment rates at 95.3±1.1% and 95.2±1.1%, respectively. Unsurprisingly given the household income findings, the carshare-only respondents to my survey had a notably lower employment rate at 86.6±3.8% – though still significantly above the weighted population average.

Overall, 10.6±1.1% were students (either full- or part-time), as opposed to 8.2% in the weighted Bay Area CHTS sample (and 5.1% in highly urban zones), a higher percentage but not by much compared to the Bay Area as a whole. There was an even higher student population within the carshare-only group at 17.1±4.2%, compared to 10.1±1.5% for TNC-only users and 9.6±1.6% for users of both services. Of my few unemployed respondents, 52.4±7.7% are students, whereas of the unemployed CHTS respondents, only 10.2±0.6% are students.

This, together with income and homeownership status, indicates a generally higher socioeconomic status in this sample compared to the general population observed in the CHTS. Respondents were younger, wealthier, more male and more white than the average Bay Area resident even in urban areas. This was especially true of those identifying as users of both TNCs and carsharing. A further indication of such privilege is the fact that most of the unemployed respondents were students, i.e. likely not actively seeking employment but rather preparing for future employment.

It is interesting to note that while the subset of respondents that used only carsharing, but not TNCs, was relatively small (82 respondents), their average socioeconomic status (considering indicators such as income, homeownership and employment) was significantly lower than of those who (also) use TNCs.

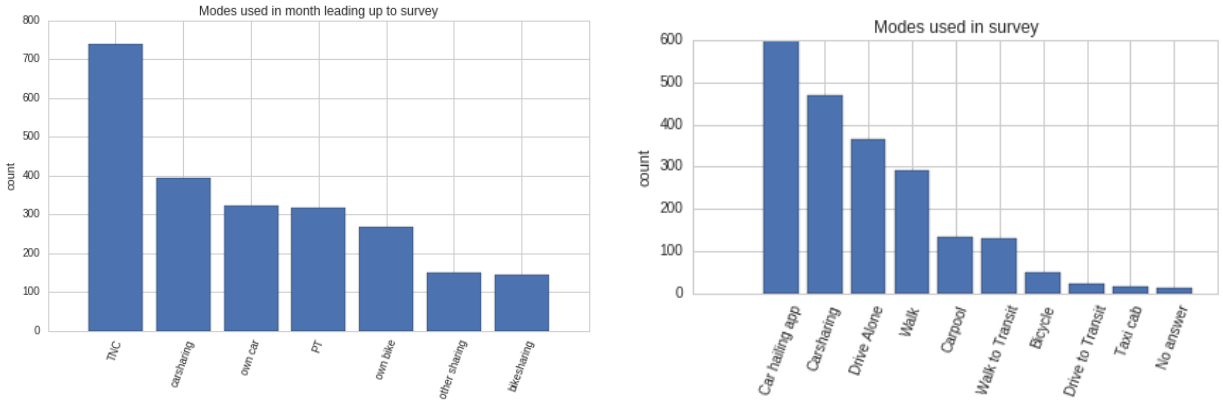
Car ownership The sample as a whole had a quite low car ownership, with the average number of cars owned per household at 0.8±0.1 and 45.7±1.7% of respondents living in households owning one or more cars – this, not surprisingly, was particularly low among highly urban households in zone 1 at an average of 0.5 cars and only 38% living in car-owning households, whereas those in zone 3 had 1.4 cars on average in their households and 77% living with at least one car. For comparison, in the weighted Bay Area CHTS, respondents had an average number of 2.2 cars in their households, and about 94.3% of them lived in households owning a car. For zone 1 respondents, these numbers were lower at an average number of cars of 1.5, and 83.0% of households with at least one car – still significantly higher than the numbers observed in this study.

The average number of cars in respondent households was higher for respondents reporting use of both ICTEMs prior to the survey (though still lower than CHTS respondents), at an average of 1.0 car, and accordingly 56.3±2.7% lived in car-owning households. Those reporting use of either mode alone had consistently lower car ownership at an average of 0.7±0.1 cars in respondent households, and 38.5±2.4% and 35.4±5.3% of TNC-only and carshare-only respondents respectively living in car-owning households.

Car ownership is further discussed with respect to its sustainability implications in section 4.2.

Mode distribution

The initial screening question enquired about modes used in the month leading up to the survey (as this question was intended for screening, only the modes of interest as well as some decoy modes to avoid priming were enquired). The distribution of responses is illustrated in fig. 4.6a. As expected given that the sample was conditioned on use of ICTEMs, those modes were most commonly reported, with the vast majority (739 respondents) using TNCs and nearly half (394 respondents) using carsharing. Of 821 respondents, 324 or 39% reported using their own car, consistent with a slightly higher car ownership of about 46% and closely followed by public transit usership of 316 respondents or 38%. Substantial fractions of the sample also reported bicycling, with 274 or 33% stating use of their own and/or a bikeshare bike, and of those 137 using both an owned bike and bikesharing. (For comparison, in the weighted Bay Area CHTS, 34% of respondents reported one or more bike trips in the week leading up to the survey, a similar number.)



(a) Count of responses reporting use in month leading up to survey for each mode.

(b) Number of trips in each mode on travel diary date.

Figure 4.6: Mode distribution prior to and during survey date.

During the travel survey, the mode share reflected the modes reported leading up to the survey, with TNCs the most commonly used mode and carsharing a close second, making up

28 and 22% of trips respectively. Personal cars were the third most common mode used at 17% of trips followed by walking at 14%, with other no other mode used for more than 10% of trips. Fig.4.6b illustrates the mode distribution of all 2114 trips. Most respondents used just one mode on the survey date; of those using more than one mode the most common combination was carsharing and TNC, reported by 180 respondents or 22% of my sample (no other combination accounted for more than 3% of the sample).

A high percentage of those participating in carsharing also used TNCs/carhailing apps, and TNC trips were generally much more common than carsharing trips. (Interestingly, a higher percentage used carsharing on the survey date than reported using carsharing before, suggesting that a number of respondents used carsharing for the first time in over a month during the travel diary. It is unclear what this means, and may indicate an error in reporting.) Consequently, the use categories interest to this study amounted to the following numbers and fractions in the overall sample:

Table 4.2: Membership in use categories prior to survey, and use of modes on the diary day.

	used TNC only	used carshare only	used both
month prior to survey	397 (48%)	82 (10%)	342 (42%)
on survey date	177 (21%)	109 (13)%	193 (24)%

(Note that these numbers are rather high, and may suggest that something about the protocol – e.g. priming through team handing out flyers – encouraged respondents to use TNCs or carsharing more than they might otherwise on the survey date, or report specifically for a day when they used the modes in question. Another hypothesis is that recruitment of an unusually young sample may have skewed these results; refer to fig. 3.2 for more detail.)

Use of ICTEM

Trip purposes There was a clear distinction between the activities that carshare and TNCs were used for. Comparing respondents that gave an address within urban centers in zone 1 (about 60% of the sample) to those in less urban areas their activity patterns were not obviously different, although TNC trip purposes clearly differed from carsharing. Most TNC use occurred for work purposes, whereas a typical carshare trip served personal purposes as expected from theoretical considerations, see fig. 4.7.[2]

[2]These were the only trip purposes given as options in the survey.

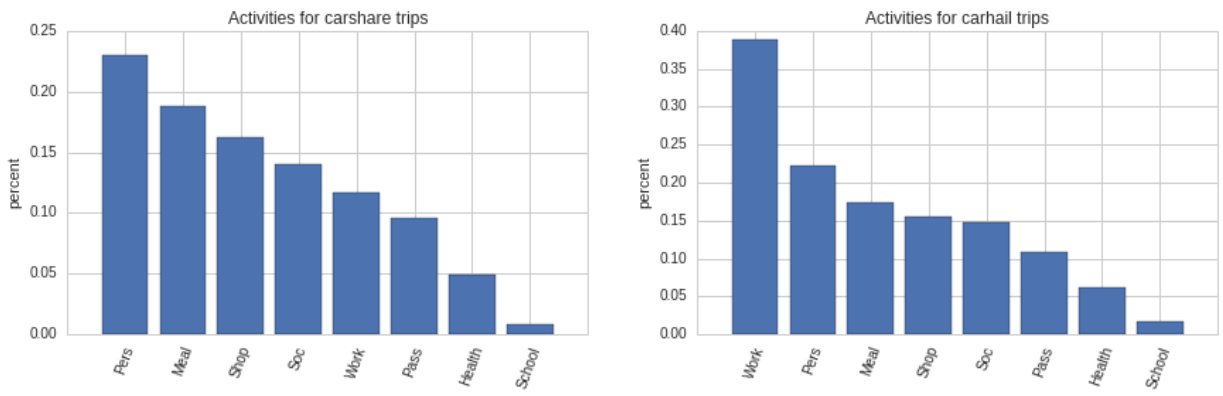


Figure 4.7: Activity shares for different modes (carshare & TNC).

To round out the activity comparison, I calculated correlations for all modes with all different activity types recorded in my survey, seen in fig. 4.8. Judging from these correlations, the applications of both carhailing and carsharing were quite different from other modes. Two comparisons are particularly interesting: that between TNC and taxi, and that between carshare and private car.

Directionally, taxi and TNC (labeled 'car hailing' in the graph) appeared to exhibit similar relationships to most activities. Distinctive features compared to all other modes were use for health care trips, which makes sense given the need for a driver when transporting a sick passenger, and for social activities, the same trip type already observed by Rayle et al.[26] Both modes were alse comparatively rarely used for travel to meals. TNCs however were preferred strongly for work trips, whereas taxi travel did not have the same correlation with work travel, for which it was not preferred more strongly than other modes.

Comparing driving alone with carsharing, their use seemed to differ notably. Driving alone was a preferred mode only for work travel, a trip purpose for which carsharing was rarely used. Carsharing was a preferred mode for many trip types, except for work and school. This supports the idea that carsharing should rarely be used for commute trips based on economic considerations.

Overall in this sample, carhailing was preferred for work trips and anti-correlated with travel for meals, and carsharing was least preferred for commute trips to work or school, and most for social activities.

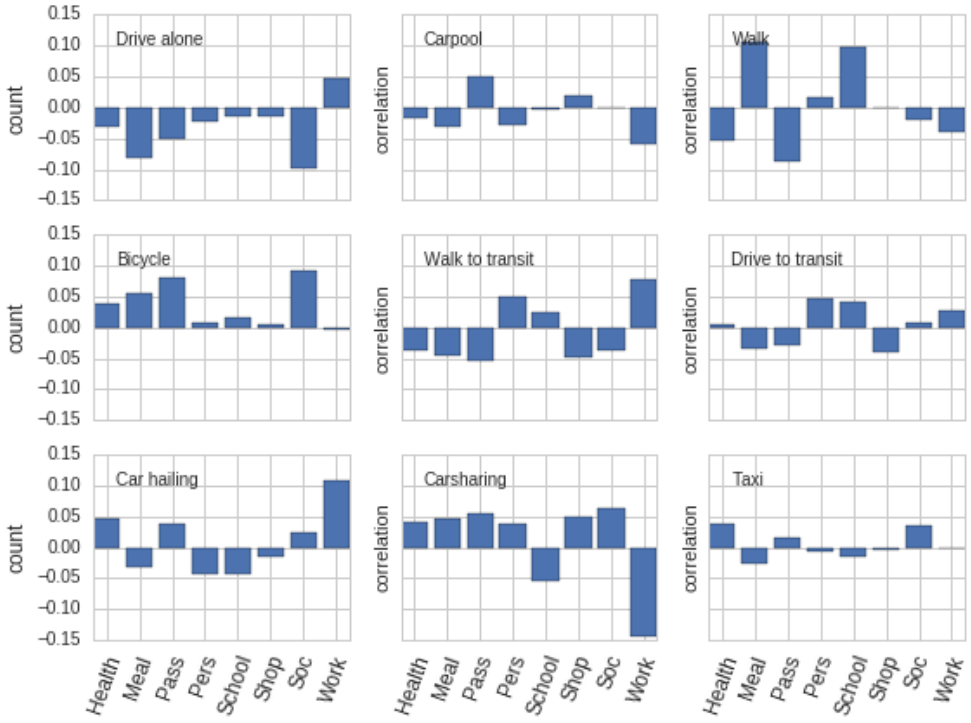


Figure 4.8: Correlations between activity type and mode choice, for all modes observed. Positive values mean a mode is used more often than the average mode for a given activity.

Origins and destinations Analyzing common origins and destinations, it became evident that carhailing trips were significantly more likely to start somewhere not at home, compared to all other modes. Whereas about 67% of all other trips originated at home, only 49% of carhailing trips did, a difference significant at above a 99% confidence level. Carhail trips were also significantly less likely to finish at home than other trips, with only 28% of carhail trips going home as opposed to 33% for all other modes, significant at 95% level of confidence. In comparison, carsharing was similar to all other modes in starting at home most often. Considering the distribution of destinations, however, carshare trips had home as their destination more often than other modes, at 38% versus 30% of trips significant at the 95% level.[3]

In summary, TNCs were used for trips that either start or finish at a place other than home, whereas carsharing could be characterized as a more home-based mode, compared to other modes used in this study (which had a low fraction of trips taken in respondent-owned cars).

Time of day Lastly, the time of day during which trips take place most often appeared to differ significantly for the modes of interest, as seen in fig.4.9.

[3]These are probably trips to the respondents' habitual home-base carsharing station. The overall number of carshare trips *to* and *from* home is almost equal, not suggesting that there are many carshare trips that were not round trips.

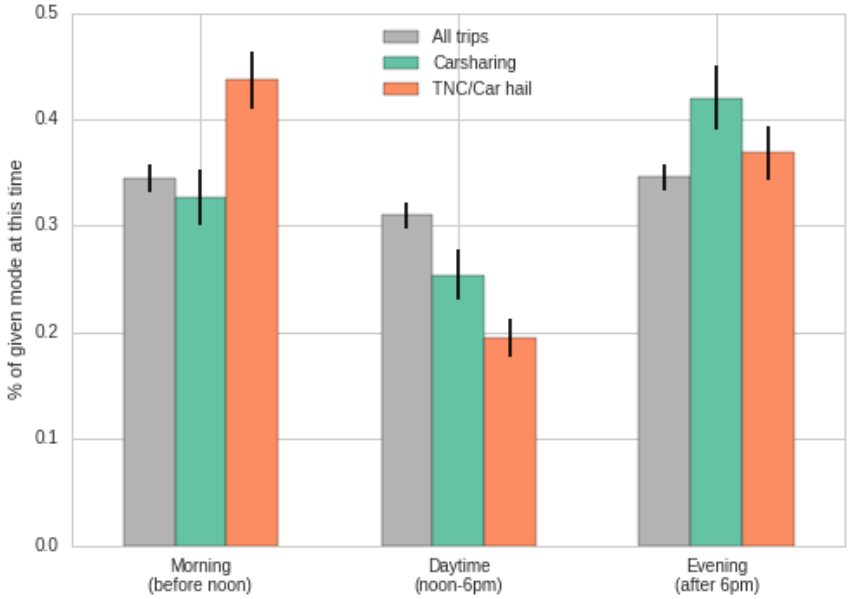


Figure 4.9: Percentage of trips for each mode taking place during the respective time of day. Margins of error based on counting errors.

While trips overall were fairly evenly distributed between morning, daytime and evening, the percentage of carhail trips taken in the morning was much higher than the other modes at 44% (compared to 34% for all modes combined). Car sharing on the other hand was predominantly used after 6pm, with 42% of carsharing trips taken during this time of day (compared to 35% overall). Both modes were significantly less likely to be used during the daytime (noon to 6pm) compared to the average of all modes. This finding of course goes hand in hand with the activity distributions noted above, characterizing carsharing as a leisure/personal trip mode, and TNCs as a mode used predominantly for mandatory/work trips.

Sustainability

Although only one aspect of the environmental sustainability of transportation modes, I focused here on the transportation emissions generated, using as indicators the VMT traveled by users and the number of cars owned (employed by Martin et al. as a proxy for greenhouse gas emissions [20]). As mentioned before, some aspects of the sustainability of ICTEMs, such as backhauling and empty trips of TNC cars, cannot be captured by passengers' travel diaries and are therefore not considered in this study at this time.

Trip length & VMT

The basis for the analysis presented here were travel times and distances extracted from skims of the MTC's travel model.

Mode comparison Investigating the correlation between mode and trip length/trip time, I calculated the correlation coefficients graphically represented in fig. 4.10. Judging from these results, it would appear that respondents used carsharing for similar distances at similar speeds as driving, whereas TNC trips were typically very short both in time and distance.

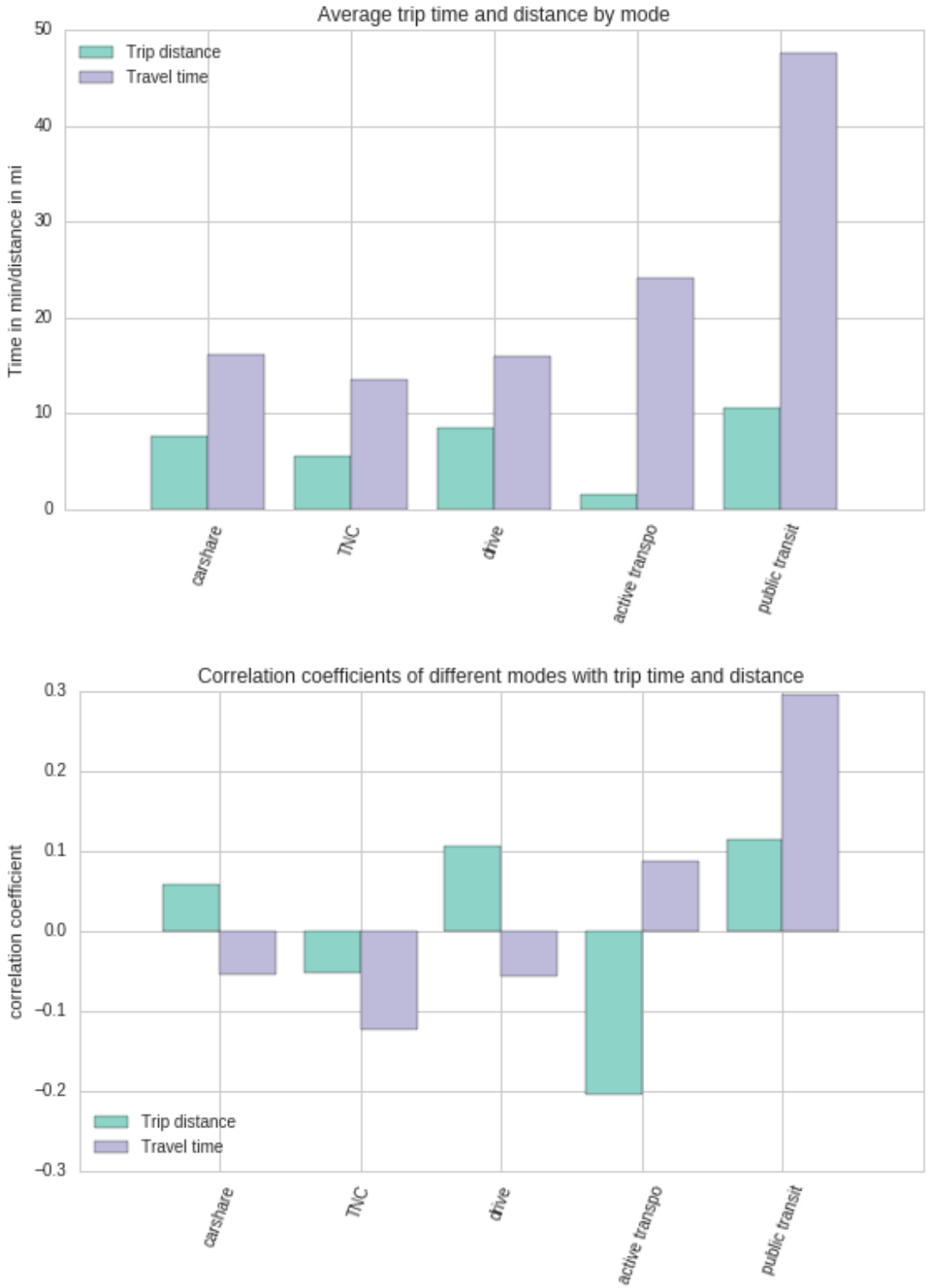
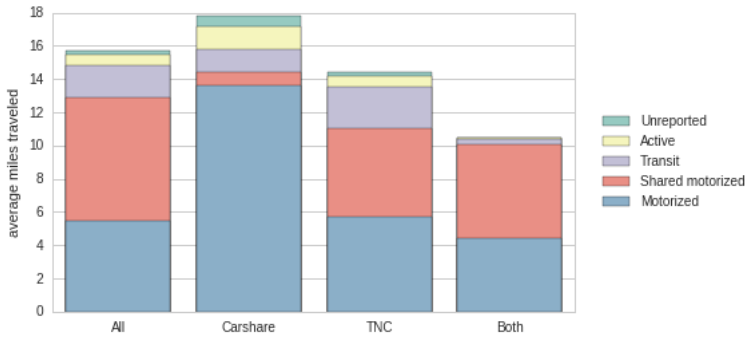


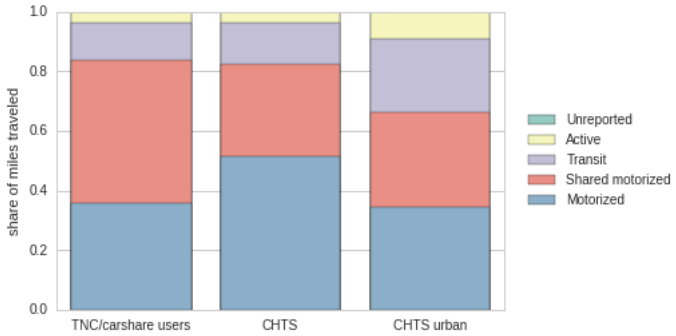
Figure 4.10: Average trip times and distances for different modes, and correlations between mode choice and trip time and distance.

While public transit trips on average had long distances and even longer travel times, active transportation naturally took long times for comparatively short distances. Clearly carshare trips had a very similar trip profile to private driving regarding typical time and distance (although times on average are slightly shorter, likely predicated on the per hour rates paid for carsharing). Even though trip purposes for owned- and shared-car trips were differently distributed, the distances and speeds were similar: longer distances and quicker speeds compared to trips on other modes. TNC trips on the other hand had the shortest travel distances and times on average, suggesting that this mode was used for short trips (again this makes sense based on the relatively expensive fee structure). This also suggests that some percentage of these TNC trips might otherwise have been accomplished on a non-auto mode.

Comparative mode share The three different user groups displayed quite different patterns in this respect as well. As displayed in figure 4.11a, the average number of miles traveled varied considerably between those that report using carsharing, those that reported using TNC, and those that reported using both. Respondents in the "carshare" group traveled furthest in this study, and also have the highest distance traveled alone on a motorized mode. Their most used mode (by miles traveled) was drive alone; in addition they displayed the largest numbers of active transportation miles (bicycle or walking) as well as distance traveled without reported mode. TNC-only users had the highest share of transit miles, whereas those utilizing both TNC and carsharing appeared to travel the least in terms of absolute distance.



(a) Miles traveled in each mode for different use categories. ("Shared motorized" indicates trips with more than one passenger in one car.)



(b) Mode share of miles traveled; comparison of survey respondents with weighted Bay Area and zone 1 (highly urban) CHTS. ("Shared motorized" indicates trips with more than one passenger in one car.)

Figure 4.11

Comparing to the weighted Bay Area CHTS sample, the share of active transport miles as well as public transit was nearly identical, contradicting the hypothesis that use of shared modes makes users more likely to engage in multimodal travel. The overall motorized modeshare was notably higher in this study than among the most urban CHTS respondents, mostly at the expense of public transit. This might be due to the fact that participation was conditioned on the use of motorized modes (the ICTEMs considered here), but may also be an indicator of transit cannibalization.

The percentage of shared travel was notably higher in this sample than in the weighted Bay Area CHTS, accounting for more than half of the motorized mode share, but accounted for a lower percentage of motorized miles than the urban comparison sample. A high share of sharing might indicate that users of ICTEMs could be more likely to share their rides, thereby again reducing overall VMT, but a for a more certain statement a more robust comparison is needed.

Given that my respondents traveled only 15.7 $\pm$ 0.03 miles on average, less than the 27.4 of weighted Bay Area CHTS respondents, and also less than the 21.5 average miles trav-

eled in the most urban subset, this may support the conjecture that users of alternative motorized modes could reduce their travel as a result of more awareness of its impacts and costs, similar to Steininger et al.'s findings.[30]

Transit relationship

Besides miles traveled and mode share, another crucial determinant of whether ICTEMs could be more sustainable than private cars is whether they help enable multimodal travel, or whether they instead replace trips otherwise traveled on more sustainable modes. To this effect, the percentage of trips taken on carshare or TNC that would have been possible on transit is about 82% (with no notable difference between the two ICTEMs), and of those trips that were possible on transit, almost 20% of ICTEM trips would have been *shorter* on public transit (again with no difference between TNC and carshare). Comparing these numbers to those for traditional drive trips yields surprising results: only 25% of the 259 drive trips reported in my survey would have been possible on transit, and none of them would have been shorter to complete on transit. Considering the average time savings on these motorized trips compared with the transit alternative, TNC and carshare trips would have taken 2.9 ± 1.2 and 3.0 ± 1.1 times as long on average, whereas the average non-ICT drive trip would have taken 4.3 ± 2.1 times as long.

While this difference was not significant, it appears that in while in general all motorized modes were used as clear time-savers over transit, in many cases the ICTEMs were used as a replacement for transit even when no clear time savings were involved. This indicates indiscriminate use of ICTEM to substitute for transit, with potential negative implications for transit ridership and the environment[4]. (This suspicion of transit cannibalization is also supported by the previous section's finding of low transit modeshares.)

Where the environmental impacts of indiscriminately replacing transit- with ICTEM-trips may not be positive, this finding does however suggest substantial added benefit for their users, in time and convenience.

Car ownership and use of ICTEMs

Car ownership in this sample in general is already discussed in section 4.2, finding lower-than-average car ownership in all use categories of this study, even when comparing only to urban CHTS respondents.

During the travel diary date, there was also a clear negative correlation with the number of cars owned by the household, with respondents without vehicles the most likely to take a trip using either of these modes, as illustrated in fig. 4.12. A Kruskal-Wallis test for correlation between use of an ICTEM and number of cars in the respondent's household confirmed that this correlation was significant at the 99% level of confidence.

Considering all findings regarding car ownership, they would be consistent with a theory of car shedding, enabling individuals to fulfill their mobility needs without owning a car, especially

[4]If many of these trips are used to substitute for transit trips in San Francisco and the East Bay during peak periods this may actually be a positive effect, but more detailed analysis is needed to support that hypothesis

given that the overall private car mode share for respondents to my survey was lower than the population average. The relation found here also supports Stillwater's hypothesis regarding increased usage of carsharing for family households with 2+ cars, which might generally have sufficient cars to cover their needs but may occasionally supplement using carsharing [31] – judging from fig. 4.12, this effect could be even more pronounced with TNCs.

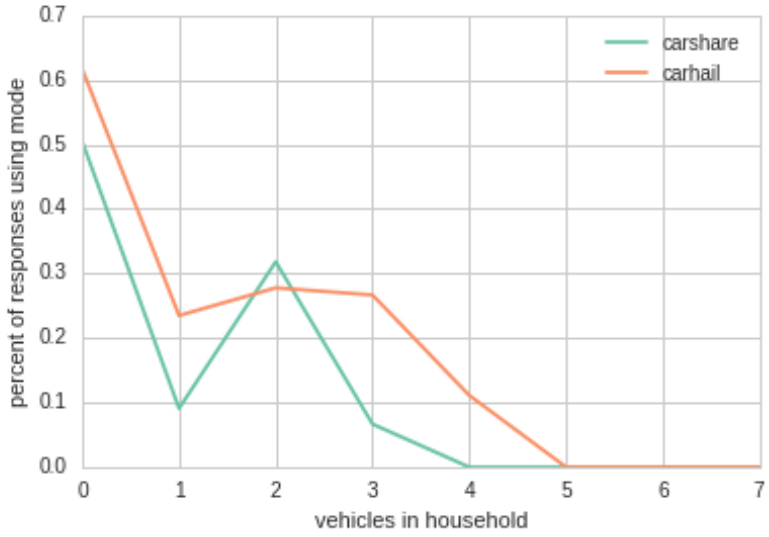


Figure 4.12: Percentage of survey respondents in each car ownership category that used a given mode.

Equity

Who takes what mode

As already discussed in section 4.2, the sample analyzed here was wealthier and generally of higher socioeconomic status than the average Bay Area resident – while it is possible that my sampling methods selected a more privileged group, there was not evidence to suggest that low-income groups particularly benefited from ICTEMs. It did however appear that those using only carsharing, not TNCs, leading up to the survey were of lower income not only than the other two usage groups, but also than the CHTS by a significant margin (52±19% with household income below $50,000 compared to 20.1% ±0.5% of those in the CHTS). Similar trends were true of racial identification and gender, where carsharing had a higher share of the less privileged subgroups (non-white and female) compared to other user groups and to the general public. This suggests that while TNCs may be a mode used as a convenient addition to modal portfolios by those already able to access modes they need, carsharing could indeed help lower-income groups expand their access.

The correlation between income and different modes used on the diary date is also of interest for the equity question. The only two modes whose use on the survey date positively correlated with higher income were carsharing and TNC, with correlation coefficients of 0.17 for both, at a p-value less than 10^{-10} – a weak correlation, but statistically significant. Given that no other modes showed a positive correlation with income, this correlation is also meaningful to the extent that wealthier respondents were more likely to actually use ICTEMs on any given day. This would appear to contradict the hypothesis that these novel modes particularly help lower-income residents, but might also be an artifact of high rates of ICTEM use in my sample (59% using either carshare or TNC on diary date) and the fact that lower-income Bay Area residents generally travel less. I view this correlation as evidence that due to the variable costs of ICTEM use, they were used sparingly by lower-income residents, as opposed to other modes with lower variable cost .

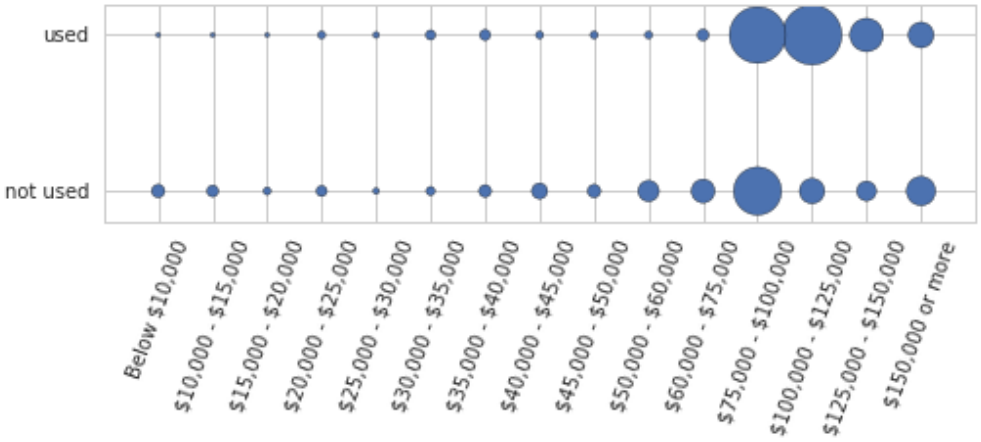


Figure 4.13: Respondents use of either carshare or TNC on the diary date (size of circle is proportional to number of users).

On the whole, investigating income across user groups and in comparison to the CHTS, I found no indication that TNCs are of particular benefit to disadvantaged households. Carsharing may be useful to lower-income households, although more investigation is needed.

Transit-captive users

Following the hypothesis that users foregoing the purchase of a car because of income considerations may be able to use ICTEMs for more efficient travel, I attempted to detect hypothesized previously transit-captive private transit users in my sample by looking for trips that were taken by carless users and significantly faster than the transit alternative. Comparing to the average in my sample, it appears that benefits of using ICTEMs as opposed to transit were *lower* for carless users than for the sample as a whole, or perhaps that they more gratuitously used ICTEMs over transit: I found that only 15% (17%/14% respectively) of all carshare/TNC trips taken by carless users could not have been completed on transit as compared to 18% in my entire sample

population; only 65% of carless users' carshare/TNC trips were faster than using public transit compared to 82% for the sample as a whole. There was not an overwhelming number of trips taken by carless users that would have been much longer or impossible on transit, as one might have expected if benefits to transit-captive users were large.

On the other hand, the average relative time savings with ICTEMs were considerable: respondents' ICTEM trips, for TNCs and carsharing alike, would on average have taken 3 times as long as the transit alternative, where one was possible. (This was still lower than the same number for private car trips, which would have taken on average 4.3 times as long – possibly due to the fact that those traveling long distances frequently are more likely to own a car.) The average time saved over a trinsit trip was 22 minutes for TNC trips and 27 minutes for carshare trips.

While there appeared to be a fair amount of ICTEM use where transit would have been a feasible option, 15% of ICTEM trips occurred in the absence of a transit alternative, and on average time was saved over transit, indicating that transit-captive users could indeed benefit.

Chapter 5

Conclusion

5.1 Summary of findings

By convenience sampling, I obtained a sample of 821 Bay Area residents that use either carsharing or TNCs. Dividing this group based on reporting prior to the trip diary into those that only used TNCs, those that only used carsharing, and those that used both, I arrived at 3 comparison groups.

Demographics I found that respondents to the survey, compared to comparable Bay Area CHTS (even those in only urban regions) respondents, are predominantly male and white, substantially younger (only 1% older than 54), and wealthier, most convincingly explained by a high percentage of young professionals among their number. While it remains unclear whether this difference stems from survey error or an actual difference in user demographics, I found that on several metrics of socioeconomic status, carshare-only users in my sample were less privileged: they demonstrated a gender and racial minority ratio comparable to the general population, and were less wealthy than that population. This is an indication that carsharing may be more likely to further transportation equity than TNCs.

Car ownership Respondents to my survey had fewer cars, at an average of 0.7, as opposed to 1.5 in a CHTS subset drawn from purely urban zones in the Bay Area and weighted for demographic similarity. The number of ICTEM trips was anticorrelated with the number of cars owned in the respondent's household. Both of these findings support the notion that carsharing and TNCs facilitate less car-reliant lifestyles, consistent with the finding of car shedding observed in previous studies of carsharing. TNC users reported car ownership rates comparable to those of carshare users in this study, which of course does not establish a causal relationship but raises the question of whether car shedding might also occur among TNC users. I also observed a spike in ICTEM use for households owning a low nonzero number of cars, supporting a conjecture by Stillwater et al. regarding families supplementing their own vehicle holdings with carsharing.

The low car ownership rates found here also suggest benefits that cities may reap from smaller numbers of cars taking up space for parking, if these modes reach broader adoption.

Travel patterns & sustainability Regarding travel behavior, I found that TNC trips on average had the shortest travel times and distances of all motorized modes, and – unlike one might have suspected following Rayle et al.'s study different from taxi travel – unlike taxis were often used for work trips, in particular in the morning (before noon).[1] Carsharing on the other hand was rarely used for work or school and more often for leisure trips in the evening, especially ones that were comparatively longer in time and distance. While TNC trips were much more likely to start away from home than other modes (51% of trips, as opposed to 33% for all other modes), carshare trips were more likely to finish at home (38% as opposed to 31% for trips on all other modes). The two products served very different purposes, in line with their different pricing schemes and user experiences.

Considering the question of sustainability, respondents to this survey reported lower VMT per capita than the weighted Bay Area CHTS comparison sample both in general and in the most urban zones, although this difference was not significant. The motorized modeshare was also similar to the general population (and larger than that of the urban population), but I observed more sharing of rides, especially among TNC-only users.

On the subject of transit cannibalization, it appears that only 18% of ICTEM trips could not have been completed on public transit. Of the 82% that would have been possible on transit however, only 20% would have been faster on transit.[2] In addition, the average ICTEM trip in my survey would have taken about three times as long on transit.[3] This suggests that in some cases, these modes are delivering greater benefits than transit in the form of time savings, in other cases in the form of convenience.

Equity Finally, regarding equity, I could not find clear evidence of formerly transit-captive (i.e. unable to afford a car) passengers among my respondents based on trip patterns. ICTEM trips however saved their passengers on average 60% of travel time compared to transit, and 15% of trips taken by carless respondents would not have been possible on transit, suggesting that otherwise transit-captive travelers could be benefiting. I also found that within my sample, carshare and TNC trips were the only two modes whose use showed a positive correlation with income, indicating that lower income populations were using these modes less than others. The only finding that might support an improvement to transportation equity is the fact that those using carsharing only had lower average income than the Bay Area CHTS average, which may merit further investigation.

[1] It is possible that Bay Area residents have begun adopting this mode as an alternative commute mode, similar to how residents of New York City have used taxis for a long time.

[2] Of the drive alone trips, in my survey none would have been faster on transit.

[3] While the average car trip would have taken more than 4 times as long if taken on transit.

Synopsis Overall, many observations already made about carsharing were confirmed. Although motorized travel remains similar, a tendentially lower distance traveled per day and higher propensity for sharing vehicle trips supports hopes for improved sustainability through ICTEM use. Evidence specifically regarding equity could not be observed.

5.2 Subjects for further investigation

Low-income users Future research should follow some of the points of investigation begun here in more detail. One of the main shortcomings of this study was a lack of low-income participants and older participants; follow-up studies ought to investigate the use of new technology-enabled modes by these often marginalized groups in more detail. Such investigation ought to seek firstly to uncover whether these groups are underrepresented within the TNC and/or carshare user base at large or only within my sample, and secondly to better understand their usage in the context of transportation equity. In particular the apparent predominance of such groups in the carshare-exclusive user group raises questions of how these two different products affect disadvantaged groups differently.

Car shedding and TNCs Given the low car ownership rates for exclusive users of TNCs (as compared even to a weighted CHTS subsample of the most urban parts of the Bay Area) also raises questions on how TNCs affect their users' behavior more long term. A study similar to the various studies conducted in the past regarding car shedding among carshare users would be called for to shed light on this question.

Demand models & representative data Finally, in order to more rigorously and in detail understand the effects of different factors on both usership and on mode choice, a representative sample collecting sufficient data both on users of ICTEM and of non-users is necessary. Given such a sample, more advanced methods of discrete choice modeling could be employed.[36] One would hope that by the time data collection for the next CHTS takes place penetration rates by that time will be high enough to give sufficient sample sizes, and/or that the CHTS's data collection methodology will address this concern and explicitly collect information on whether a trip was taken on a carshare or TNC vehicle.

Bibliography

[1] *2010–2012 California Household Travel Survey data (sorted by person)*. URL: https://www.nrel.gov/transportation/transportationdata/dataFiles.cfm (visited on 10/25/2016).

[2] *AirBnB, snapgoods, and 12 more pioneers of the Share Economy*. Forbes. 2016. URL: http://www.forbes.com/pictures/eeji45emgkh/airbnb-snapgoods-and-12-more-pioneers-of-the-share-economy/ (visited on 11/13/2016).

[3] Donald N. Anderson. ""Not just a taxi"? For-profit ridesharing, driver strategies, and VMT". In: *Transportation* 41.5 (2014), pp. 1099–1117. ISSN: 1572-9435. DOI: 10.1007/s11116-014-9531-8. URL: http://dx.doi.org/10.1007/s11116-014-9531-8.

[4] Patrícia Baptista, Sandra Melo, and Catarina Rolim. "Energy, Environmental and Mobility Impacts of Car-sharing Systems. Empirical Results from Lisbon, Portugal". In: *Procedia - Social and Behavioral Sciences* 111 (2014), pp. 28–37. ISSN: 18770428. DOI: 10.1016/j.sbspro.2014.01.035. URL: http://linkinghub.elsevier.com/retrieve/pii/S1877042814000366.

[5] Julien Bert et al. *What's Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales*. Tech. rep. The Boston Consulting Group, Feb. 2016. URL: http://www.bcg.de/documents/file206078.pdf.

[6] Robert Cervero. "City CarShare: First-year travel demand impacts". In: *Transportation Research Record: Journal of the Transportation Research Board* 1839 (2003), pp. 159–166.

[7] Robert Cervero. *Paratransit in America: Redefining mass transportation*. Greenwood Publishing Group, 1997.

[8] Robert Cervero. "San Francisco City CarShare : Longer-Term Travel-Demand and Car Ownership Impacts". In: May (2006).

[9] Robert Cervero and Yuhsin Tsai. "City CarShare in San Francisco, California: second-year travel demand and car ownership impacts". In: *Transportation Research Record: Journal of the Transportation Research Board* 1887 (2004), pp. 117–127.

[10] Robert Cervero et al. "City carshare: Assessment of short-term travel-behavior impacts". In: *Institute of Urban & Regional Development* (2002).

[11] Gigi Cooper, Deborah A Howe, and Peter Mye. "The Missing Link: An Evaluation of Car-Sharing Portland Inc. Portland, Oregon". In: (2000).

[12] Canapary & Galanis Research Corey. *San Francisco Municipal Transportation Agency (SFMTA) Travel Decisions Survey 2015 Summary Report*. Tech. rep. San Francisco Municipal Transportation Agency, 2015.

[13] Dimitrios Efthymiou. "Modeling the Propensity To Join Carsharing Using Hybrid Choice and Latent Variable Models and Mixed Internet / Paper Survey Data Modeling the Propensity To Join Carsharing Using Hybrid Choice and Latent Variable Models and Mixed Internet / Paper Survey Da". In: JANUARY 2014 (2014).

[14] Gorman Gilbert and Robert E Samuels. *THE TAXICAB–AN URBAN TRANSPORTATION SURVIVOR*. Tech. rep. 1982.

[15] Juho Hamari, Mimmi Sjöklint, and Antti Ukkonen. "The sharing economy: Why people participate in collaborative consumption". In: *Journal of the Association for Information Science and Technology* (2015).

[16] Richard Katzev. "CarSharing Portland: An Analysis of Its First Year". In: *Public Policy Research, Presented at TRB, National Research Council* (2001). URL: /media/maita/9E2E5A952E5A66751/Users/mschade/Documents/Classes/MCP_MS/Thesis/bibliography/CarSharing_Portland_Review_and_Analysis.pdf.

[17] Ines Kawgan-Kagan. "Early adopters of carsharing with and without BEVs with respect to gender preferences". In: *European Transport Research Review* 7.4 (2015), p. 33. ISSN: 1866-8887. DOI: 10.1007/s12544-015-0183-3. URL: http://dx.doi.org/10.1007/s12544-015-0183-3.

[18] Martin Kunzmann and Vivian Daigler. *2010-2012 California Household Travel Survey Final Report*. Tech. rep. California Department of Transportation, June 2013. URL: http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/Files/CHTS_Final_Report_June_2013.pdf.

[19] Kristin Lovejoy, Susan Handy, and Marlon G Boarnet. "Technical Background Document on Impacts of Carsharing Based on a Review of the Empirical Literature". In: (2013). URL: https://www.arb.ca.gov/cc/sb375/policies/carsharing/carsharing_bkgd.pdf.

[20] Elliot W Martin and Susan A Shaheen. "Greenhouse gas emission impacts of carsharing in North America". In: *IEEE Transactions on Intelligent Transportation Systems* 12.4 (2011), pp. 1074–1086.

[21] Elliot Martin, Susan Shaheen, and Jeffrey Lidicker. "Impact of carsharing on household vehicle holdings: Results from North American shared-use vehicle survey". In: *Transportation Research Record: Journal of the Transportation Research Board* 2143 (2010), pp. 150–158.

[22] Colin Murphy, Sharon Feigon, and Tim Frisbie. *Shared Mobility and the Transformation of Public Transit*. Tech. rep. American Public Transportation Association Darnell, Mar. 2016. URL: https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf.

[23] *Ngram Viewer*. Google. 2016. URL: https://books.google.com/ngrams/graph?content=car+sharing%2Cride+sharing%2C+sharing+economy&year_start=1970&year_end=2016&corpus=15&smoothing=3&share=&direct_url=t1%3B%2Ccar%20sharing%3B%2Cc0%3B.t1%3B%2Cride%20sharing%3B%2Cc0%3B.t1%3B%2Csharing%20economy%3B%2Cc0 (visited on 11/13/2016).

[24] Andrew Perrin and Maeve Duggan. "Americans' internet access: 2000–2015". In: *Pew Research Center* 26 (2015).

[25] Franz E. Prettenthaler and Karl W. Steininger. "From ownership to service use lifestyle: the potential of car sharing". In: *Ecological Economics* 28.3 (1999), pp. 443–453. ISSN: 09218009. DOI: 10.1016/S0921-8009(98)00109-8. URL: http://www.sciencedirect.com/science/article/pii/S0921800998001098.

[26] Lisa Rayle et al. *App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco University of California Transportation Center (UCTC)*. Tech. rep. UCTC-FR-2014-08, 2014. URL: http://www.uctc.net/research/papers/UCTC-FR-2014-08.pdf.

[27] Juliet B Schor and Connor J Fitzmaurice. "26. Collaborating and connecting: the emergence of the sharing economy". In: *Handbook of research on sustainable consumption* (2015), p. 410.

[28] Susan Shaheen, Adam Cohen, and Melissa Chung. "North American Carsharing". In: *Transportation Research Record: Journal of the Transportation Research Board* 2110 (2009), pp. 35–44. ISSN: 0361-1981. DOI: 10.3141/2110-05. URL: http://trrjournalonline.trb.org/doi/10.3141/2110-05.

[29] Stephanie D Shellooe. "Wheels When Who Wants Them: Assessing Social Equity and Access Implications of Carsharing in NYC". In: (2013).

[30] Karl Steininger, Caroline Vogl, and Ralph Zettl. "Car-sharing organizations: The size of the market segment and revealed change in mobility behavior". In: *Transport Policy* 3.4 (1996), pp. 177–185.

[31] Tai Stillwater, Patricia Mokhtarian, and Susan Shaheen. "Carsharing and the built environment: Geographic information system-based study of one US operator". In: *Transportation Research Record: Journal of the Transportation Research Board* 2110 (2009), pp. 27–34.

[32] Gil Tal. "Evaluating the Effect of Car-Sharing: Exploring the Gap Between What We Know vs. What We Need to know and Its Effect on Optimism Bias". In: *Estados Unidos* (2009). URL: http://s3.amazonaws.com/academia.edu.documents/44000624/Evaluating_the_Effect_of_Car-Sharing_Exp20160322-31114-uazthp.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1479156656&Signature=N0VGFH30QWr9alpFMgsdtGEsSko%3D&response-content-disposition=inline%3B%20filename%3DEvaluating_the_Effect_of_Car-Sharing_Exp.pdf.

[33] *Transportation Health Equity Principles*.

[34] John J Trenam. “Commerce Power Since the Schechter Case”. In: *Geo. LJ* 31 (1942), p. 201.

[35] *Uber vs Lyft: Comparing the Rideshare titans*. rideshareapps.com. 2016. URL: http://rideshareapps.com/uber-vs-lyft-comparison/#Uber_vs_Lyft_Prices_and_Cost (visited on 10/29/2016).

[36] Akshay Vij, Sreeta Gorripaty, and Joan L Walker. “From trend spotting to trendsplaining: Understanding modal preference shifts in the San Francisco Bay Area”. In: (2015).

[37] Stephen M Zoepf and David R Keith. “User Decision-Making and Technology Choices in the US Carsharing Market”. In: *Transportation Policy* (Under rev (2014).

Appendix A

Recruitment material

A.1 Postcard of for flyer handouts

Appendix B

Survey material

B.1 Informed consent document

CONSENT TO PARTICIPATE IN RESEARCH

The Effect of Car Sharing on Travel Behavior

Introduction

My name is Maitagorri Schade, and I am a graduate student at the University of California, Berkeley, working with my faculty advisor, Professor Joan Walker, in the Department of Civil Engineering. I am planning to conduct a research study, which I invite you to take part in.

You are being invited to participate in this study because you are a user of (one or more) carsharing services. Participants must be at least 18 years old, be a member of one or more carsharing services and reside in the SF Bay Area.

Purpose

The purpose of this research study is to collect data on the travel behavior of individuals using car sharing services such as Zipcar/City CarShare or Uber/Lyft/Sidecar, in order to supplement previously obtained travel behavior data on conventional modes. The goal is to build a model of travel choice behavior and better understand the effect of shared modes on such behavior.

Procedures

If you agree to be in this study, before you begin the main part of the study, you will be asked to respond to a 3 item questionnaire to determine your eligibility for participation in the study. During the main part of the study, you will be asked to complete a short questionnaire about your household's socioeconomic and demographic characteristics and complete a survey about all the trips you take in a given 24 hour period. For this, you will have to keep track of your travel behavior for a day, and fill in an online questionnaire. This should take about 20 minutes.

Study time: Participation in this study will involve a total of less than one half hour of your time.

Study location: All study procedures will take place at your home PC or, if you choose to fill in the questionnaire on the go, your smartphone.

Benefits

There is no direct benefit to you anticipated from participating in this study. However, it is hoped that the information gained from the study will help us learn how to promote sustainable transportation in the Bay Area and beyond, which we will communicate through our findings.

Risks/Discomforts

- Some of the research questions may make you uncomfortable or upset. For sensitive questions, "Prefer not to answer" is given as an option; you are also free to skip any questions you don't wish to answer.
- You may feel discomfort about disclosing trip or location information to the study team.
- There is the possibility that you might not want to review your experiences; recalling trips may cause some level of suffering or unhappiness to you, for instance in the case of trips where people got injured (physically or mentally, e.g. being involved or witnessing a traffic accident).
- In spite of our precautions, data confidentiality and privacy may be breached. The main scenario for this to happen would be the (accidental) release of the exported trip database. In this case, data about user trips would be exposed. However, this data would not be linked to any user. So it would be possible to determine, for example, that user "3a307244-ecf1-3e6e-a9a7-3aaf101b40fa" took a "train" trip from Downtown Berkeley BART to Millbrae and then from Millbrae to Mountain View at 7:24pm on Tuesday, 13th May, but we don't know who this user is.

Confidentiality

Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used.

The data will be collected together with an email address to enable us to compensate you with a $20 Amazon certificate. The data will be de-identified upon download from the Qualtrics Survey Software, and a unique user ID will be assigned to each record in the trip data. Researchers will maintain a table that links home, work and email addresses with UUID for up to 5 years for research purposes.

To minimize the risks to confidentiality, we will follow best practices in securing the data and the servers. We will keep the data in encrypted, password protected electronic files with limited access. Only my faculty advisor and I will have access to your study records.

Retaining research records: After IP addresses have been removed; the remaining data set (including survey responses) will be retained for future research projects and education by myself and collaborators at UC Berkeley.

Your home and work addresses that are identifiable in nature will be separated from the remaining data collected from surveys and stored in encrypted hard drives with access only to the researchers of the study, for helping us in improving our trip identification algorithms. Your home and work addresses will be deleted at the end of 5 years.
Your travel data and your non-identifiable survey responses will never be discarded and will be retained for future study purposes and research activities"

Compensation

You will receive $20 in Amazon gift certificates for your participation in this study.

Treatment and compensation for injury

It is important that you promptly tell the researcher, Maitagorri Schade, if you believe that you have been injured because of taking part in this study.

If you are injured as a result of taking part in this study, University of California will provide necessary medical treatment. The costs of the treatment may be billed to your insurer just like other medical costs, or covered by the University of California, depending upon a number of factors. The University and the study sponsor do not normally provide any other form of compensation for injury. For more information in this regard, call OPHS at (510) 642-7461.

Rights

Participation in research is completely voluntary. You have the right to decline to participate or to withdraw at any point in this study without penalty or loss of benefits to which you are otherwise entitled.

Questions

If you have any questions or concerns about this study, you may contact Maitagorri Schade at carsharetravelstudy@berkeley.edu, or supervising PI Prof. Joan Walker at joanwalker@berkeley.edu.
If you have any questions or concerns about your rights and treatment as a research subject, you may contact the office of UC Berkeley's Committee for the Protection of Human Subjects, at 510-642-7461 or subjects@berkeley.edu.

****

CONSENT

Please print a copy of this consent form for you to keep.

If you wish to participate in this study, please click on "I have read the consent form and agree to participate in this study" below!

B.2 2015 survey – Background

Default Question Block

Thanks for agreeing to be part of our study on shared travel! Below we will ask you some questions about yourself and your household, including your access to different types of travel modes and some demographic and socioeconomic information.

We will then collect addresses of your primary locations (home and work/school) and finally ask you to keep a detailed record on your travel behavior for one given 24-hour period. This can be done from a computer or your smartphone, whichever you prefer.

Let's go!

What is your marital status?

- ○ Single
- ○ Married/domestic partnership
- ○ Widowed
- ○ Divorced
- ○ Prefer not to answer

How many people live in your household?

Do you have children living with you at this point?

- ○ Yes
- ○ No

Are you living in a single-family home?

- ○ Yes
- ○ No

Do you own or rent your home?

- ○ Own / Paying off mortgage
- ○ Rent
- ○ I do not know

Do you attend school (full-time or part-time)?

- Full-time
- Part-time
- Do not currently attend school
- Prefer not to answer

Do you currently work for pay (full-time, part-time or occasionally)?

- Full-time
- Part-time
- Occasionally
- Don't work for pay
- Prefer not to answer

How many members of your household currently engage in work for pay on a regular basis?

Please choose the category that best describes the total 2014 combined income for everyone living in you household:

How many motor vehicles are owned, leased, or available for regular use by the people who currently live in your household? Please be sure to include motorcycles, mopeds, and RVs.

And how many bicycles in working condition are available to people in your household?

Are you a licensed driver, or capable of driving a car?

- Yes
- No

How many members of your household are licensed drivers, or capable of driving a car?

Please choose your gender identification.

- Male
- Female
- Gender-queer/trans-gender
- Prefer not to answer

How old are you?

	0	10	20	30	40	50	59	69	79	89	99
Choose your age:											

What is your racial or ethnic background?

Do you have a disability or condition that has lasted 6 or more months and which makes it difficult to go outside the home alone, for example to shop or visit a doctor's office?

- Yes
- No
- Don't know
- Prefer not to answer

Block 2

Next, we need the addresses (or cross streets) of the locations you visit most, so you will not have to enter them over and over again in the travel diary. Please provide address information to the best of your knowledge!

What is your HOME address?

Street address OR street/cross street	
City	
Zip code	
State	

What is your WORK address?

Street address OR street/cross street

City

Zip code

State

What is your SCHOOL address?

Street address OR street/cross street

City

Zip code

State

Thanks a lot! Please move on to the next part of the survey on the date sent to you by email.

Block 1

We need you to keep track of all trips you take for the course of one 24 hour period. Please record each one of these trips in the form below!

(Note that you can either enter the trips one by one as you take them, or record them somewhere else and enter all of them into the survey at the end of the day.)

Where were you at 3am on the day of your travel tracking?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street

City

Do you know the zip code?

Block 3

Where did you go next?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ☐ Yes, enter another trip!

trip2

Where did you go next?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ☐ Yes, enter another trip!

trip3

Where did you go next?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ☐ Yes, enter another trip!

trip4

Where did you go next?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ☐ Yes, enter another trip!

trip5

Where did you go next?

- ○ Home
- ○ Work
- ○ School
- ○ Transit stop
- ○ Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ☐ Yes, enter another trip!

Finished?

Thanks so much for taking the time to tell us about your travel behavior today! Are you sure you're all done traveling? You can still go back and enter another trip, or click forward to finish up this survey.

Please provide us with your email address so we may email you your $20 Amazon gift certificate!

B.3 2015 survey – Diary

Habitual locations

It's time to complete your travel diary!
We need you to keep a detailed record of all trips you take for the course of one 24 hour period. This can be done from a computer or your smartphone, whichever you prefer.

You may either keep track of your trips elsewhere and fill in this survey after the day is over, or record them right here as you go about your day.

First, we will collect the addresses (or cross streets) of the locations you visit most, so you will not have to enter them over and over again in the travel diary. Please provide address information to the best of your knowledge!

What is your HOME address?

Street address OR street/cross street	
City	
Zip code	
State	

What is your WORK address?
(Feel free to ignore this question if you never **travel to a fixed WORK location.)**

Street address OR street/cross street	
City	
Zip code	
State	

What is your SCHOOL address?
(Feel free to ignore this question if you never **travel to a fixed SCHOOL location.)**

Street address OR street/cross street	
City	
Zip code	
State	

Thanks a lot! Please move on to the next part of the survey when it is convenient for you.

Travel diary

(Note that you can either enter the trips one by one as you take them, or record them somewhere else

and enter all of them into the survey at the end of the day.)

Where were you at 3am on the day of your travel tracking?

- Home
- Work
- School
- Transit stop
- Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

Travel diary continued

Where did you go next?

- Home
- Work
- School
- Transit stop
- Other place (please describe)

Please describe to the best of your knowledge the location of that place:

Street address OR street/cross street	
City	
Do you know the zip code?	

When did you get there?
(Please answer in military time, i.e. HH:MM)

How did you get there?

How many people were sharing the ride with you?

What was your main activity there? What other activities did you engage in (choose up to three)?

Personal activities (sleeping, personal care, leisure, chores)
Preparing meals/eating
Hosting visitors/entertaining guests
Exercise (with or without equipment)/playing sports
Study / schoolwork
Work for pay at home using telecommunications equipment
Using computer/telephone/cell or smart phone or other communications device for personal activities
All other activities at my home
Work/job duties
Training

Did you move on to any other places after this one?

- ○ Yes, enter another trip!
- ○ No, I'm done.

B.4 2016 survey – Background & Diary

Q99 AFTER READING THE CONSENT FORM, PLEASE SCROLL TO THE BOTTOM OF THE PAGE TO CONSENT TO PARTICIPATE IN THE STUDY.

Q100

UNIVERSITY OF CALIFORNIA AT BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO

SAN FRANCISCO • SANTA BARBARA • SANTA C

Q101 CONSENT TO PARTICIPATE IN RESEARCH The effect of carsharing use on the travel behavior Introduction My name is Maitagorri Schade, and I am a graduate student at the University of California, Berkeley, working with my faculty advisor, Professor Joan Walker, in the Department of Civil Engineering. I am planning to conduct a research study, which I invite you to take part in. You are being invited to participate in this study because you are a user of (one or more) carsharing services. Participants must be at least 18 years old, be a member of one or more carsharing services and reside in the SF Bay Area. Purpose The purpose of this research study is to collect data on the travel behavior of individuals using car sharing services such as Zipcar/City CarShare or Uber/Lyft/Sidecar, in order to supplement previously obtained travel behavior data on conventional modes. The goal is to build a model of travel choice behavior and better understand the effect of shared modes on such behavior. Procedures If you agree to be in this study, before you begin the main part of the study, you will be asked to respond to a 3 item questionnaire to determine your eligibility for participation in the study. During the main part of the study, you will be asked to complete a short questionnaire about your household's socioeconomic and demographic characteristics and complete a survey about all the trips you take in a given 24 hour period. For this, you will have to keep track of your travel behavior for a day, and fill in an online questionnaire. This should take about 20 minutes. Study time: Participation in this study will involve a total of less than one half hour of your time. Study location: All study procedures will take place at your home PC or, if you choose to fill in the questionnaire on the go, your smartphone. Benefits There is no direct benefit to you anticipated from participating in this study. However, it is hoped that the information gained from the study will help us learn how to promote sustainable transportation in the Bay Area and beyond, which we will communicate through our findings. Risks/Discomforts The following risks/discomforts could be associated with the study: Some of the research questions may make you uncomfortable or upset. For sensitive questions, "Prefer not to answer" is given as an option; you are also free to skip any questions you don't wish to answer. You may feel discomfort about disclosing trip or location information to the study team. There is the possibility that you might not want to review your experiences; recalling trips may cause some level of suffering or unhappiness to you, for instance in the case of trips where people got injured (physically

or mentally, e.g. being involved or witnessing a traffic accident). In spite of our precautions, data confidentiality and privacy may be breached. The main scenario for this to happen would be the (accidental) release of the exported trip database. In this case, data about user trips would be exposed. However, this data would not be linked to any user. So it would be possible to determine, for example, that user "3a307244-ecf1-3e6e-a9a7-3aaf101b40fa" took a "train" trip from Downtown Berkeley BART to Millbrae and then from Millbrae to Mountain View at 7:24pm on Tuesday, 13th May, but we don't know who this user is. Confidentiality Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used. The data will be collected together with an email address. The data will be de-identified upon download from the Qualtrics Survey Software, and a unique user ID will be assigned to each record in the trip data. Researchers will maintain a table that links home, work and email addresses with UUID for up to 5 years for research purposes. To minimize the risks to confidentiality, we will follow best practices in securing the data and the servers. We will keep the data in encrypted, password protected electronic files with limited access. Only my faculty advisor and I will have access to your study records. Retaining research records: After IP addresses have been removed; the remaining data set (including survey responses) will be retained for future research projects and education by myself and collaborators at UC Berkeley. Your home and work addresses that are identifiable in nature will be separated from the remaining data collected from surveys and stored in encrypted hard drives with access only to the researchers of the study, for helping us in improving our trip identification algorithms. Your home and work addresses will be deleted at the end of 5 years. Your travel data and your non-identifiable survey responses will never be discarded and will be retained for future study purposes and research activities. Compensation/Payment You will receive Qualtrics' general compensation for your participation in this study. Treatment and compensation for injury It is important that you promptly tell the researcher, Maitagorri Schade, if you believe that you have been injured because of taking part in this study. If you are injured as a result of taking part in this study, University of California will provide necessary medical treatment. The costs of the treatment may be billed to your insurer just like other medical costs, or covered by the University of California, depending upon a number of factors. The University and the study sponsor do not normally provide any other form of compensation for injury. For more information in this regard, call OPHS at (510) 642-7461. Rights Participation in research is completely voluntary. You have the right to decline to participate or to withdraw at any point in this study without penalty or loss of benefits to which you are otherwise entitled. Questions If you have any questions or concerns about this study, you may contact me, Maita Schade, at carsharetravelstudy@berkeley.edu, or supervising PI Prof. Joan Walker at joanwalker@berkeley.edu If you have any questions or concerns about your rights and treatment as a research subject, you may contact the office of UC Berkeley's Committee for the Protection of Human Subjects, at 510-642-7461 or subjects@berkeley.edu. Protocol number: CPHS# 2015-03-7261

Q106 Consent If you wish to participate in this study, please confirm “I have read the consent form and agree to participate in this study” below! Please print a copy of this page to keep for future reference.

I have read the consent form and agree to participate in the research. (Check the box to indicate your agreement with the terms and conditions.) (1)

Q39 Thanks for agreeing to be part of our study on shared travel! To enroll you in this study, we have to ensure that you are 18 years or older (for legal reasons), that you live in the Bay Area and were here yesterday, and that you have previously used the transportation services we are interested in.

Q39 Are you at least 18 years of age?

I am at least 18 years old. (1)

I am less than 18 years old. (2)

Q44 Do you live in the San Francisco Bay Area for most of the year? (This means anywhere in the Counties of Alameda, Santa Clara, Contra Costa, San Francisco, Solano, Marin, San Mateo and Sonoma.)

Yes, I am a Bay Area resident. (1)

No, I do not live in the SF Bay Area. (2)

Q64 Were you in the SF Bay Area yesterday?

Yes, I was in the Bay Area yesterday. (1)

No, I was away from the Bay Area yesterday. (2)

Q40 In the last month, have you used any of the following types of transportation? (Select all that apply.)

Own bicycle (5)

Bike sharing programs like Bay Area Bike Share (7)

Own car (12)

Cab hailing apps like Uber, Lyft or Sidecar (1)

Carsharing services like City CarShare or Zipcar (2)

Other forms of car sharing (3)

Public transportation (i.e. bus or rail) (6)

Q41 Where did you find out about this study?

Handout in Oakland (3)

Handout in SF (2)

Online panel (11)

Other: (10) _____

Answer If Are you at least 18 years of age? I am at least 18 years old. Is Not Selected

Q42 We're sorry, it looks like you're not eligible to participate!Thanks so much for your time and interest thus far. If you have any questions, you may contact us at carsharetravelstudy@berkeley.edu.

If We're sorry, it looks like ... Is Displayed, Then Skip To End of Block

Q26 Thanks for answering those first few questions - it looks like you are eligible to participate! This is the beginning of the survey itself, which should not take more than 15 minutes to complete.In this section, we ask you some questions about yourself and your household, including your access to different types of travel modes and some demographic and socioeconomic information. All information is completely confidential and will only be used for research purposes. Any information about you will be stored separate from any identifying information (such as your email address). Let's go!

Q24 What is your marital status?

- Single (1)
- Married/domestic partnership (2)
- Widowed (3)
- Divorced (4)
- Prefer not to answer (5)

Q6 How many people live in your household? (Count all people, including babies, who live and sleep in your house, apartment or mobile home most of the time.)

- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- 6 (6)
- 7 (7)
- 8 (8)
- 9 (9)
- 10 (10)
- 11 (11)
- >11 (12)

Q25 Are there any children (under the age of 18) living in your household?

- Yes (1)
- No (2)

Answer If Are there any school-aged children living in your household? Yes Is Selected

Q48 And are any of these your children?

- Yes (1)
- No (2)

Q3 Are you living in a single-family home?

- Yes (1)
- No (2)

Q4 Do you own or rent your home?

- Own / Paying off mortgage (1)
- Rent (2)
- I do not know (3)
- Prefer not to answer (4)

Q45 How long have you lived in your current home?

(Table Truncated to 63 Columns)

Q17 Do you attend school (full-time or part-time)?

- Yes, I attend school (1)
- Do not currently attend school (3)
- Prefer not to answer (4)

Q14 Do you currently work for pay (full-time, part-time or occasionally)?

- Yes, I work for pay (1)
- Don't work for pay (4)
- Prefer not to answer (5)

Q7 How many members of your household currently engage in work for pay on a regular basis?

- 0 (1)
- 1 (2)
- 2 (3)
- 3 (4)
- 4 (5)
- 5 (6)
- 6 (7)
- >6 (8)

Q5 Please choose the category that best describes the total 2014 combined income for everyone living in you household:

- Below $10,000 (1)
- $10,000 - $15,000 (2)
- $15,000 - $20,000 (3)
- $20,000 - $25,000 (4)
- $25,000 - $30,000 (5)
- $30,000 - $35,000 (6)
- $35,000 - $40,000 (7)

$40,000 - $45,000 (8)
$45,000 - $50,000 (9)
$50,000 - $60,000 (10)
$60,000 - $75,000 (11)
$75,000 - $100,000 (12)
$100,000 - $125,000 (13)
$125,000 - $150,000 (14)
$150,000 or more (15)
Don't Know (16)
Prefer not to answer (17)

Q1 How many motor vehicles are owned, leased, or available for regular use by the peoplewho currently live in your household? Please be sure to include motorcycles, mopeds,and RVs.

0 (1)
1 (2)
2 (3)
3 (4)
4 (5)
5 (6)
6 (7)
7 (8)
8 (9)
9 (10)
10 (11)
11 (12)
12 (13)
13 (14)
14 (15)
15 (16)
>15 (17)

Q2 And how many bicycles in working condition are available to people in your household?

0 (1)
1 (2)
2 (3)
3 (4)
4 (5)
5 (6)
6 (7)
7 (8)
8 (9)
9 (10)

10 (11)
11 (12)
12 (13)
13 (14)
14 (15)
15 (16)
>15 (17)

Q12 Are you a licensed driver, or capable of driving a car?
Yes (1)
No (2)

Q8 How many members of your household are licensed drivers, or capable of driving a car?
0 (1)
1 (2)
2 (3)
3 (4)
4 (5)
5 (6)
6 (7)
>6 (8)

Q46 Do you have a transit pass?
Yes (1)
No (2)
I don't know (3)

Answer If Do you have a transit pass? Yes Is Selected
Q47 What kind of pass is it?
Clipper card (1)
Other local bus pass (2)
Dial-a-ride/paratransit pass (3)
Other express/commuter bus pass (4)
Other Light Rail/Subway/Train/Streetcar pass (5)
Ferry/Boat pass (6)
Other (7)

Q9 Please choose your gender identification.
Male (1)
Female (2)
Gender-queer/trans-gender (3)
Prefer not to answer (4)

Q10 How old are you?

(Table Truncated to 63 Columns)

Q11 What is your racial or ethnic background?

- White/Caucasian (non-hispanic) (1)
- Black/African-American (non-hispanic) (2)
- Hispanic (3)
- Asian (7)
- Mixed-race (4)
- Other (8)
- Don't know (5)
- Prefer not to answer (6)

Q16 Do you have a disability or condition that has lasted 6 or more months and which makes it difficult to go outside the home alone, for example to shop or visit a doctor's office?

- Yes (1)
- No (2)
- Don't know (3)
- Prefer not to answer (4)

Q61 Thanks so much for filling in this background information! Next up is a travel diary, which asks you to recall your travel patterns yesterday.

Q50 To help us better understand travel behavior in the Bay Area, the next – and last – step is to report every trip you took yesterday. We ask you to take note of every trip in the 24 hours between 3am yesterday until 3am today, and fill in the travel diary on the following pages. A trip is any movement from one location to the next. It could be your commute to work, or your detour to the gas station on the way there, or a quick walk to the coffee shop around the corner. It is very important for our research that you recall every single trip you take. Before starting to fill out the travel diary, take a minute to reflect on all of your travel and activities from yesterday. It may be helpful to consult your calendar, if you keep one. Ready?

Answer If opp Is Empty

Q52 To make sure we are on the same page, please let us know the day for which you are reporting your travels:

(Table Truncated to 63 Columns)

Q141 To make sure we are on the same page, please let us know the day for which you are reporting your travels:

(Table Truncated to 63 Columns)

Q56 First, we will collect the addresses (or cross streets) of the locations you visit most, so you will not have to enter them over and over again in the travel diary. Please provide address information to the best of your knowledge!

Q58 What is your HOME address?

- Street address OR street & cross street (1)
- City (2)
- State (3)
- Zip code (4)

Q60 What is your usual WORK address? (Feel free to ignore this question if you never travel to a fixed WORK location.)

- Street address OR street & cross street (1)
- City (2)
- State (3)
- Zip code (4)

Q62 What is your usual SCHOOL address?(Feel free to ignore this question if you never travel to a fixed SCHOOL location.)

Street address OR street & cross street (1)

City (2)

State (3)

Zip code (4)

Q64 Thanks a lot! Please move on to the next part of the survey.It is really important for our research to have a complete record of all your trips, with approximate locations, so that we may use this data to model and understand travel behavior. Please tell us about any trip you took, however small - even if it's just to the gas station on the way to work, or a quick walk around the block to grab lunch!

Q68 Where were you at 3am on the day of your travel tracking?

Home (1)

If What is your WORK address? (Feel free to ignore this question if you never travel to a fixed WORK... Street address OR street & cross street Is Not Empty

Work (at the usual location) (2)

If What is your SCHOOL address? (Feel free to ignore this question if you never travel to a fixed SC... Street address OR street & cross street Is Not Empty

School (at the usual location) (3)

Other place (please describe, e.g. "CVS" or "Cafe Strada") (5)

_____

Answer If Where were you at 3am on the day of your travel tracking? Transit stop Is Selected Or Where were you at 3am on the day of your travel tracking? Other place (please describe, e.g. "grocery store" or "Cafe Strada") Is Selected

Q70 Please describe to the best of your knowledge the location of that place - please give us enough information to be able to locate this place on a map!

Street address OR street & cross street (1)

City (2)

If you know the ZIP code, please enter it here: (3)

Answer If Did you move on to any other places after this one? (All Loops) No, I'm done. Is Not Selected

Q72 Where did you go next? Any trip counts!

Home (1)

If What is your WORK address? (Feel free to ignore this question if you never travel to a fixed WORK... Street address OR street & cross street Is Not Empty

Work (at the usual location) (2)

If What is your SCHOOL address? (Feel free to ignore this question if you never travel to a fixed SC... Street address OR street & cross street Is Not Empty

School (at the usual location) (3)

Other place (please describe, e.g. "CVS" or "Cafe Strada") (5)

_____

Answer If Where did you go next? Any trip counts! Transit stop Is Selected Or Where did you go next? Any trip counts! Other place (please describe) Is Selected

Q74 Please describe to the best of your knowledge the location of that place - please give us enough information to be able to locate this on a map!

Street address OR street & cross street (1)

City (2)
Do you know the zip code? (3)

Answer If Did you move on to any other places after this one? (All Loops) No, I'm done. Is Not Selected

Q76 When did you get there?

- Morning (before noon) (1)
- Afternoon (between noon and 6pm) (2)
- Evening/night (after 6pm) (3)

Answer If Did you move on to any other places after this one? (All Loops) No, I'm done. Is Not Selected

Q78 How did you get there?

- Drive Alone (1)
- Carpool (2)
- Taxi cab (9)
- Car hailing app (Uber, Lyft or similar service) (7)
- Carsharing (Zipcar, City CarShare or similar service) (8)
- Walk (3)
- Bicycle (4)
- Walk to Transit (5)
- Drive to Transit (6)

Answer If How did you get there? Carpool Is Selected Or How did you get there? Car hailing app (Uber, Lyft or similar service) Is Selected Or How did you get there? Carsharing (Zipcar, City CarShare or similar service) Is Selected Or How did you get there? Taxi cab Is Selected

Q80 How many people were sharing the ride with you?(IF this was a paid service, DON'T count the driver here!)

- 0 (1)
- 1 (6)
- 2 (2)
- 3 (3)
- 4 (4)
- more than 4 (5)

Answer If Where did you go next? Any trip counts! Home Is Not Selected

Q82 What was your main activity there

- Work (1)
- School/Education (2)
- Meals (3)
- Social activities (4)
- Pickup/drop off passenger(s) (5)
- Shopping (6)

Health care (7)
Personal activities (8)

Answer If Loop 1: , Is Current Loop

Q84 This is just another friendly reminder that any travel, however small, is important for our study. Stopping for coffee, getting gas or sitting in the park all count as destinations/activities in transportation research. So please tell us the little details, even if they seem insignificant - it's all for science :)

Okay, got it! (1)

Answer If Did you move on to any other places after this one? (All Loops) No, I'm done. Is Not Selected Or We noticed that you didn't finish your day at home. Is that correct? If not, please select "oops,... Oops, I went elsewhere after this, let me go back and fix it! Is Selected

Q86 Did you move on to any other places after this one?

Yes, enter another trip! (1)
No, I'm done. (2)

Answer If Did you move on to any other places after this one? No, I'm done. Is Selected And Where did you go next? Any trip counts! Home Is Not Selected

Q88 We noticed that you didn't finish your day at home. Is that correct? If not, please select "oops, I went elsewhere...", click the back button and enter your final trip home into your travel diary.

Yes, this was my last trip and I did NOT finish this day at my HOME location. (1)
Oops, I went elsewhere after this, let me go back and fix it! (2)

Q36 Thanks a lot for helping us with your information!If you would be willing to help out in case we have questions about your responses, please provide us with your email address below so we can be in touch. (This is completely optional, and will never be used for anything other than following up on this survey.)

Q50 Now submit by clicking "Next" at the bottom, and keep traveling safely!