
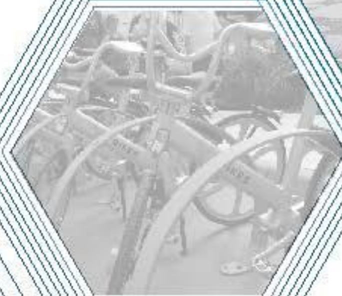


Assessing The Viability of Car-sharing for Low-Income Communities

Kate Hyun, Ph.D.

Courtney Cronley, Ph.D.



FINAL REPORT

Center for Transportation Equity, Decisions & Dollars

ASSESSING THE VIABILITY OF CAR-SHARING FOR LOW-INCOME COMMUNITIES

FINAL PROJECT REPORT

by

Principal Investigator: Dr. Kate Hyun
Co-Principal Investigator: Dr. Courtney Cronley
Graduate Researchers: Farah Naz, Sarah Robinson, and Joseph Harwerth

University of Texas at Arlington

Sponsorship
Center for Transportation, Equity, Decisions and Dollars **(CTEDD)**

for
Center for Transportation, Equity, Decisions and Dollars **(CTEDD)**
USDOT University Transportation Center
The University of Texas at Arlington
601 W. Nedderman Dr. Suite 103
Arlington TX 76019-0108 United States
Phone: 817-272-5138 | Email: C-Tedd@uta.edu

In cooperation with US Department of Transportation-Research and Innovative Technology Administration (RITA)

Acknowledgment

This work was supported by a grant from the Center for Transportation Equity, Decisions and Dollars (CTEDD) funded by U.S. Department of Transportation Research and Innovative Technology Administration (OST-R) and housed at The University of Texas at Arlington.

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The Center for Transportation, Equity, Decisions and Dollars (CTEDD), the U.S. Government and matching sponsor assume no liability for the contents or use thereof

Technical Report Documentation Page

1. Report No. CTEDD 018-04 SG	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle ASSESSING VIABILITY OF CARSHARING FOR LOW-INCOME COMMUNITIES		**5. Report Date** Jan 31, 2019 **6. Performing Organization Code**
7. Author(s) : Kate Hyun, Courtney Cronley, Farah Naz, Sarah Robinson, Joseph Harweth		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Center for Transportation, Equity, Decisions and Dollars (CTEDD) USDOT University Transportation Center The University of Texas at Arlington 601 W. Nedderman Dr. Suite 103 Arlington TX 76019-0108 United States		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.**
12. Sponsoring Organization Name and Address United States of America Department of Transportation Research and Innovative Technology Administration		**13. Type of Report and Period Covered** Feb 1, 2018 – Jan 31, 2019 **14. Sponsoring Agency Code**

15. Supplementary Notes

Report uploaded at www.ctedd.uta.edu

16. Abstract

Over the past 20 years, car-sharing technology has become an important transportation option in population-dense, car-centric cities in the U.S. as it provides mobility and promotes public transit ridership without vehicle ownership. For successful implementation, pro-car-sharing policies and incentives have also actively supported the car-sharing programs. Members of low-income communities may benefit especially from the technology due to lower rates of vehicle ownership and high dependency on public transit. To maximize the benefit, it is important to understand the extent of car-sharing services within transportation Environmental Justice (EJ) population and travel behavior of individuals using car-sharing services. In this study, social workers and transportation engineers collaborate to understand the needs, accessibility, affordability, and willingness to use car-sharing. A mixed methodology was used including spatial analysis, mathematical modeling and qualitative focus group. For quantitate analysis, the 2017 National Household Travel Survey (NHTS) data was used to investigate the effects individuals' socio-economic characteristics, travel behavior and technology access on car-sharing usage. Zero inflated binomial regression method was used to investigate the relationships between sociodemographic, travel behavior and financial related variables and car-sharing usages. The results indicate that individuals experience financial burden tend to use car sharing service as their mobility option along with rideshare service. Focus group was conducted with service providers providing assistance in low-income communities to assess their awareness of and sense of clients' willingness to use car-sharing. The results showed that the participants were relatively unfamiliar with car-share programs than its shared-mobility counterpart, ride-sharing. The participants also identified that affordability and technological barrier besides a lack of familiarity and consequence misconception as the potential causes of the lack of awareness or willingness to use car-sharing service.

17. Key Words Car-sharing, Environmental Justice, Equity, ZipCar		**18. Distribution Statement** No restrictions.	
19. Security Classification (of this report) Unclassified.	**20. Security Classification (of this page)** Unclassified.	**21. No. of Pages** 44	**22. Price** NA

TABLE OF CONTENTS

1. INTRODUCTION 9
2. RESEARCH FRAMEWORK AND EXPECTED RESULTS 11
3. BACKGROUND ON CARSHARING OPERATION 13
   An overview of Car-sharing operation 13
   Car-sharing Business Model 13
   Zipcar 14
Environmental Justice Population AND Transportation Disadvantage 16
4. METHODOLOGY 18
   4.1. QUANTATITIVE MODELING APPROACH 18
   4.2. COMMUNITY ENGAGEMENT WITH QUALITATIVE APPROACH 22
5. FINDINGS 24
   5.1. QUANTITATIVE ANALSIS 24
   Spatial analysis of car-sharing location 24
   Zero Inflated Negative Binomial Regression Model 27
   5.2. QUALITATIVE ANALYSIS 32
   (Lack of) Familiarity 32
   Affordability 33
   Perceived (In)Convenience Due to Misconceptions 34
   Accessibility 34
   Technological Barriers 35
6. CONCLUSION 36
7. REFERENCES 39

LIST OF TABLES

Table 1: Top 10 states and cities with highest number of Zipcar locations.................................. 18
Table 2: Description of variables.. 19
Table 3: Zipcar by Race/Ethnicity (2016 5-year ACS, Zipcar API)... 24
Table 4: Zipcar by Income (2016 5-year ACS, Zipcar API) 25
Table 5: Summary descriptive statistics for modeling variables 27
Table 6. Carsharing Usage.. 28
Table 7: Estimation Results for the (a) Count and (b) Zero-inflation Models.............................. 29

LIST OF FIGURES

Figure 1: Zipcar Access with income distribution map 26

1. INTRODUCTION

The share culture has become increasingly popular in recent years with the invention of new technologies which allow individuals to share homes, cars, and rides with ease (McLaren, 2015). The basic idea of car-sharing involves the shared use of a vehicle by community members for a by trip basis (Ferrero, 2018). Car-sharing provides individual with an opportunity to avoid a large capital cost of owning a car and additional maintenance costs for registration, insurance, parking, and basic operation cost. In a qualitative studying which interviewed individuals who use car sharing as their primary means of transportation, Dowling, Maalsen, and Kent (2018) found incorporating car-sharing required individuals to shift from a viewpoint that a car is an object that is independently owned to a view that a car is a resource for a community to share. Transportation and environmental studies have found several positive aspects of car-sharing, such as reductions in vehicle ownership which results in less VMT and emissions, reductions in parking challenges in urban areas, and increases in the use of public transit ((Kim, 2015); (Martin, 2016)). Shaheen et al., (2010) specified that car-sharing services could reduce between 90,000 and 130,000 vehicles off the road.

Little research, however, has explored who is adopting car-sharing technologies and how broadly the services are being used, even though in the US alone, more than 40 car-sharing operators operate over 20,000 fleets with one million members (Martin, 2016). With the increasing benefits of car-share programs, it is important to understand how individuals characterize each service as well as their familiarity with the availability of programs in their locations. This information could be used to target services more effectively to those who already adopted this shared form of mobility and those who are expected to benefit, e.g., individuals who lack economic resources to own their own cars, but who need on-demand, door-to-door transportation, e.g., lower-income individuals working evening and overnight shifts in distant locations, lower-income, homebound, older adults, lower-income single parents living in food deserts or not proximal to social services.

Historically, there has been many evidences that show spatial disconnections between residence and work particularly for the groups with limited mobility. Glaeser et al., (2001) showed that 70 percent of the jobs are located more than 3 miles away from the central business district (Glaeser E. L., 2001). However, there has been very little effort made to break the loop and decentralize the transportation disadvantaged population since businesses grow towards the center of the town and low-income people tend to live in the center of the city because they prioritize access to basic needs such as food, entertainment, medical over employment opportunity due to unavailability of personal vehicle. (Glaeser E. L., 2008). If these population hold the jobs during the off-peak hours (weekends and nights), their mobility are particularly limited because of their heavy dependence on public transit for job access (Kodransky, 2014). Another study (Tomer A., 2011) evidently showed spatial segregations between the low-income neighborhoods and their job locations where low income population can only access 22% of the job within 90 minutes of commute. As a result, low income people face longer commute times and higher transportation costs compared to their middle- and higher-income counterparts (Kneebone, 2015).

Therefore, members of low-income communities may benefit especially from the car-sharing technology due to their lower rates of vehicle ownership and high dependency on public transit. However, scant research has been conducted exploring these individuals' knowledge of, willingness to use, and actual utilization of car-sharing programs. This study aims to identify the viability of car-sharing in transportation low income communities by assessing current implementations of car-sharing and accessibility to car-sharing technology.

2. RESEARCH FRAMEWORK AND EXPECTED RESULTS

Research Outline

This study aims to two major questions throughout the study.

- Who are the users of current car-sharing operation and what are their driving factors to utilize carsharing?
- Is carsharing a viable option for low income population? Do they have any perceptional or any other barriers to car sharing?

The study uses mixed methods including a quantitative mathematical modeling and a qualitative focus group to understand whether car-sharing meets the mobility demands of low-income users. As a part of quantitate modeling, spatial analysis was conducted to examine current car-sharing locations in five major metropolitan areas in the U.S. Although various car-sharing services have been successfully implemented in the most car-centric cities, their locations tend to be determined by evaluating economic feasibility or available parking spaces. The analysis therefore seeks to understand whether the current car-sharing locations offer easy and fair access to low-income communities or provide disproportionate access to higher income groups. To understand the influential factors to carsharing, this study analyzed the 2017 National Household Travel Survey (NHTS) to investigate the impacts of individuals' socio-economic characteristics, travel behavior and land use on the carsharing usages. Since we observed excessive zero counts in carsharing usages in the survey data, this study chose zero inflated negative binomial (ZINB) regression modelling to understand what precludes people to access to carsharing (zero-inflation model in ZINB) and drives them to use more carsharing than the others (count model in ZINB).

The second phase focuses on perceptions of awareness of and willingness to use car-sharing among residents of low-income communities through qualitative analysis. We expand our target population to Environmental Justice (EJ) population to include not only low-income individuals but minority-race individuals, persons with disabilities, and older adults in communities. In order to register and use carsharing service, knowledge and access to technology (e.g., Smart phone and App) is required. Therefore, this study assumes the possible factors that constrain these communities from using car-sharing would be lower accessibility and a lack of knowledge of the technology, types of trip needs, unique safety considerations, and higher costs. The study conducts focus groups among social services providers in the Dallas-Fort Worth metropolitan area in order to assess their knowledge of the technology, previous car-sharing experiences if any, and potential travel behavior changes through car-sharing for low-income populations. Understanding these reasons may enable policy makers and car-sharing programs to implement more active policies, which enable residents of transit-dependent, lower-income communities to utilize car-sharing services more readily and equitably compared to individuals living in more advantaged communities.

Expected Outcomes

The study anticipates the following outcomes from the study.

- Identification of the current implementation patterns of carsharing in the five major US cities where carsharing is actively provided with more than 10 parking locations. Carsharing parking locations and income level of the neighborhoods are identified to assess accessibility of carsharing for low-income communities
- Statistical associations between carsharing usages and socio-economic characteristics in the US
- Assessment of services providers' perceptions of feasibility, accessibility, and affordability on the carsharing technology among low-income communities
- Policy implementation strategies to encourage carsharing for low-income transit dependent communities

3. BACKGROUND ON CARSHARING OPERATION

Owning is no longer the absolute desire for consumers (Chen, 2008). Rather, a proliferation of consumption models for sharing services has been redefined through technology and peer communities (Bardhi & Eckhardt, 2012). With this evolving paradigm of ownership, the concepts of vehicle ownership or mobility has been changing as well. The acceptance of sharing economy enables individuals to manage lifestyle beyond personal realm, which in results in improved societal welfare (Belk, 2007; Fraiberger & Sundararajan, 2015; Paundra, Rook, van Dalen, & Ketter, 2017).

As car-sharing offers mobility without vehicle ownership, it has been shown to complement or supplement the current public transit ridership. Positive aspects of car-sharing have been reported through transportation and environmental studies: (i) vehicle ownership has been reduced, which results in less VMT and emissions, (ii) parking problems, especially in urban areas, were mitigated, and (iii) public transit and active transportation were more encouraged through car-sharing ((Kim, 2015); (Martin, 2016)). To respond to this very positive feedback, governments have implemented pro-carsharing policies including allocating more parking zones in cities for car-sharing operators, giving start-up funds to establish programs, and allowing DOT to use car-sharing for work activities ((SFMTA, 2013); (Minneapolis, 2016); (Kim, 2015)).

An overview of Car-sharing operation

The very first car-sharing demonstration in United States was Mobility Enterprise operated from 1983 to 1986 in West Lafayette Indiana as a result of Perdue University research program (Doherty, 1987). In this experiment, each household rented small vehicles or shared vehicles such as large sedans, truck and recreational vehicles. The research showed that 75% of the households VMT miles were traveled with small vehicles while only 35% time of usage was operated by the larger special purpose vehicles (Shaheen S. A., 1999). The second major car-sharing project in US was deployed in December 1983 in San Francisco. The project called Short Term Auto Rental (STAR) operated as a private enterprise that provided a short term rental for the individuals living in an apartment complex (Shaheen S. A., 1999). In 1998, a car-sharing expert in Portland, Oregon launched the first official car sharing operation in the US, funded by Oregon Department of Environmental Quality and the US Department of Protection Agency. In 2000, the first hybrid car, Honda Insight, was added to the car-sharing fleet (Dave, 2018). One of the most representative early stage carsharing programs in San Francisco, City Carshare, started their operation in 2001 to rent a vehicle hourly basis for various types of vehicles including wheelchair accessible and electric vehicles ((NCMM), 2014).

Car-sharing Business Model

There are four main types of car-sharing business models such as business to consumer (B2C), business to business (B2B), peer to peer (P2P) and non-profit car-sharing (Movmi, 2018). The business to consumer (B2C) car-sharing is similar to a for-profit car-sharing business model which includes typical car rental companies that offer its members to rent a car hourly or daily basis with a rate plan and an annual fee. Members can reserve a vehicle through company website, third party website, and over the phone. The most commonly used round trip car-sharing operation requires customers to return a vehicle in the same spot where the vehicle has been picked up. On the other hand, one way or point-to-point car-sharing allows a customer to pick up and drop off the vehicle in two different places. The business to business (B2B) car-sharing model adheres to the cooperative car-sharing business model which includes members owning a car jointly rather than individually. In this type of car-sharing operation, members avoid large expenses of owning and maintaining a private car although they can use the vehicle whenever they needed it. Western European countries have been using the cooperative car-sharing for long time, and it has recently started to gain popularity in North America ((TUS), 2013). The peer to peer (P2P) car-sharing operation allows individuals to make their personal vehicle available for rent when they do not use their vehicles. Vehicle owners can list their vehicles in the specific P2P car-sharing network, and users communicate with the owners through P2P networks to reserve and pay for the car. Another type of for-profit peer to peer car-sharing operation called Niche car-sharing operation allows individuals to make their car available for rent while left at the airport parking lot (Parzen J., 2015). The nonprofit car-sharing operation focuses on equity and accessibility over making profit from the car-sharing business. Often, nonprofit car-sharing is operated by private companies; however public assistances such as monetary funds or free parking were given to the company to make the service to be a non-profitable. In this case, the service often offers free car-sharing membership and lower user rates (Bullen, 2016).

Zipcar

This study focused on Zipcar as it is the one of the largest car-sharing operators with B2C model in the US. The operation was founded in January 2000 in Cambridge, Massachusetts. In March 2013, Zipcar was purchased by Avis Budget group and started to run as their subsidiary. As of 2018, Zipcar has 317,100 members (household) and remains the largest car-sharing operator (Statista, 2018). As conventional round-trip-based car-sharing programs such as ZipCar gain popularity, new types of car-sharing programs such as one-way rental programs (fleet floating) and specialized vehicle rental programs such as scooters, electric vehicles, and utility vans have been recently introduced in the market (Lovejoy, 2013).

Zipcar users are typically categorized as professional, young, and urban (Bardhi & Eckhardt, 2012; Frei & Rodriguez-Farrar, 2005; Levine, 2009). Zhou (2012) conducted a study on the university employee at UCLA about Zipcar usage pattern. Results showed that the commuter benefits associated to the carsharing service influenced the carsharing participation in addition to frequency of usage, time and quantity of carsharing consumption. In addition, car-sharing option is most popular among bus commuters, university students and female employees. The median income of the of the alternative commute participants (ACP's) was $30,000-$40,000. (Zhou, 2012). Watson et al (2011) found that although Zipcar in Boston, is moderately accessible in 30 location, the nature of the same pickup and drop-off policy limited its ability to customize a trip in an urban settings (Watson et al., 2011). Socio demographic attributes also play important roles in adoption of carsharing services. Individual who lives in the city center are more likely to use carsharing (Burkhardt & Millard-Ball, 2006; Prieto, Baltas, & Stan, 2017). In a 2006 study on the socio demographic factors of carsharing user, 50% of the survey respondents had an income $60,000 or more and 13% of the respondents were earning $30,000 or less (Burkhardt & Millard-Ball, 2006). In addition, 72% of the respondents have zero car ownership. Lane (2005) found that the motivating factor for carsharing service was affordability.

4. Environmental Justice Population and Transportation Disadvantage

This study aims to assess viability of carsharing for transportation disadvantaged population. Although we focused on low income population as the subject of this study, we broaden our population to Environmental Justice (EJ) in the qualitative analysis to obtain a wide variety of opinions around the carsharing from the groups with limited mobility and access.

Environmental Justice (EJ) populations refer to lower-income, minority-race individuals, persons with disabilities, older adults, individuals who speak a language other than English, and immigrant communities ((AMPO), 2011); (Silverman, 2012); ((USDOT)). The Environmental Justice issue was first started with individuals, especially people of color with the civil right movement in 1960 (EPA). The EJ concept includes the fair distribution of environmental cost and benefit in the paradigm of sustainable development to connect the scope of environmental protection and social justice. President Clinton, through executive order 12898, provided protection for minority populations and low-income populations as environmental justice (EJ) populations with the purpose of "focus[ing] federal attention on the environmental and human health effects of federal actions…with the goal of achieving environmental protection for all communities" (United States Environmental Protection Agency, 1994). According to the study conducted in 2016 ("Poverty USA," 2016) 40.6 million people lived in poverty in USA where more women (16.3%) were in poverty than men (13.8%) including 21.2% of children and 9.3% seniors in poverty. This population cannot be denied their right to achieve a better quality of life in social justice platform (Belk, 2007; Fraiberger & Sundararajan, 2015).

Transportation mobility is considered a critical domain for livable communities, providing access to social connectivity, health care, civic participation, employment, housing, and other services especially for EJ population (Coughlin, 2009; Gonyea & Hudson, 2015). Persons identified as EJ are at an increased risk for Transportation Disadvantage which is characterized by a lack of access to adequate transportation options (Currie, Stanley, & Stanley, 2007; Currie et al., 2009; Currie et al., 2010). Many researchers found that transportation disadvantage can have detrimental implications on life opportunities including health, societal, recreational, and job (Li, Raeside, Chen, & McQuaid, 2012; Lucas & Jones, 2012; Nostikasari, 2015; Turnbull, Muckle, & Masters, 2007).

To achieve mobility and access to opportunities and essential activities with minimum financial investment, carsharing can be a solution for EJ population. Carsharing service allows individual with an opportunity to access and use carsharing service without possessing a ownership (Martin, Shaheen, & Lidicker, 2010). For low income households, transportation is essential for employment; individuals who had no access to a reliable vehicle were less likely to be employed (GARASKY, FLETCHER, & JENSEN, 2006).

Traditionally low income individuals and minority groups are underserved by transportation and often find it difficult to participate in different transportation programs (*Environmental Justice and Transportation Planning*, 2003). This study understands the unique position of EJ population in carsharing adoptions and utilizations and evaluates if the current carsharing framework have been successfully adopted to the population.

5. METHODOLOGY

5.1. QUANTITATIVE MODELING APPROACH

The quantitative modeling consists of two analyses: (i) spatial analysis and (ii) statistical modeling.

Spatial Analysis

Spatial analysis compares the current car-sharing locations in five major cities in the US to identify the relationships between car-sharing accessibility and income level of communities. As carsharing locations deem to be determined by evaluating economic feasibility or available parking spaces, the spatial analysis seeks to understand whether the current car-sharing locations offer easy and fair access to low-income communities or provide disproportionate opportunities for higher income groups. This study identified five major cities in the US such as New York City or Los Angeles where Zipcar has actively implemented. The identified car-sharing operating locations are matched with the income level of associated communities (Census Tract) extracted from the American Community Survey (ACS) using ArcGIS programming.

This study utilizes the following data sets for the spatial analysis:

- ZipCar location from ZipCar API
- Census Tract Level race/ethnicity and income data from the 2016 American Community Survey (ACS): 5-Year Data (2012 – 2016).

A snapshot of Zipcar location data was taken on June 18th, 2018 using the Zipcar API. This data is subject to change with any variation in Zipcar offerings. Latitudes and Longitudes of Zipcar locations were spatially joined to a U.S. Census Tract map to correlate where Zipcars are located. Some census tracts have multiple Zipcar locations, and a binary variable that denotes the presence of at least one Zipcar in the associated census tract was created. This study simplified the assumption that a Zipcar is close enough to access if it is within the same census tract due to its ease of application on a scope as large as the United States. Table 1 provides information on top ten states and cities based on the number of Zipcar locations.

Table 1: Top 10 states and cities with highest number of Zipcar locations

Rank	Top 10 States	Number of Car-sharing Locations	Top 10 Cities	Number of Car-sharing Locations
1	California	572	San Francisco	239
2	New York	529	Chicago	219
3	Massachusetts	411	New York	208
4	Illinois	250	Washington	192
5	District of Columbia	192	Seattle	146

6	Washington	167	Boston	138
7	Pennsylvania	154	Philadelphia	117
8	Maryland	134	Brooklyn	101
9	Oregon	87	Baltimore	70
10	Virginia	73	Portland	70

Race/ethnicity data was collected by 2016 ACS dataset and estimated for number of people aggregated by census tract. Income data used for analysis is the median household income by census tract.

Statistical Modeling

The second approach investigates the actual Zipcar usages and how this usage relates with sociodemographic profiles of the users. We developed the zero-inflated negative binomial (ZINB) regression model to understand the effects of various socio-economic variables on car-sharing usage using household travel survey, 2017 National Household Travel Survey (NHTS).

The 2017 NHTS data includes various information regarding travel behavior and socio-economic data for individual household, person, vehicle and day trip level. As shown in Table 2, a total of 11 variables (17 including all binary dummy variables) representing transportation options, financial status, and socioeconomic status were selected for the modeling.

Table 2: Description of variables

Category	Variables	Description
Response Variable	CARSHARE	Number of car-sharing usage in past 30 days
Transportation related independent variable	PTUSED	Count of public transit usage
	RIDESHARE	Count of Car share usage
	YEARMILE	Miles personally driven
Financial status related independent variable	WalkorBike	Walk or Bike to reduce financial burden
	Burden	Travel is a financial burden (1: Yes, 0: neutral or no)
	Income_Low	Household income less than $50,000 (used as reference for the modeling)
	Income_Med	Household income more than $50,000 and less than $100,000
	Income_High	Household income more than $100,000
Neighborhood related independent variable	Population Density_Low	0 - 999 (persons per square mile) (used as reference for the modeling)
	Population Density_Med	1,000 - 9,999 (persons per square mile)
	Population Density_High	Over 10,000 (persons per square mile)
Individual related independent variable	AGE	Age
	GENDER	1: Male, 2: Female

	Race-White	Race of respondent (used as reference)
	Race-African American	Race of respondent
	Race-Asian	Race of respondent
	Race-Others	Including American indian, native Hawaiian, and multiple responses

This study used the number of car-sharing usage (e.g., Zipcar or Car2Go) in past 30 days from the date of survey as the response variable. Among the selected ten (16 including binary dummy variables) independent variables, three of them are transportation related, three are financial status related, one is neighborhood related, and three are individual person related variables. The PTUSED variable, for example, is a transportation related variable that shows the number of days the respondent has used public transportation such as buses, subways, streetcars, or commuter trains in past 30 days. The RIDESHARE shows the number of times a respondent have purchased a ride with a smartphone rideshare app (e.g; Uber, Lyft, Sidecar) in past 30 days from the date of survey. The YEARMILE indicates a best guess of number of miles a respondent personally drove during the past 12 months in all motorized vehicles including all miles from work vehicles, rental cars or any other vehicles outside of household. These variables are commonly used ones to represent transportation options, travel behaviors and activities of individuals (Jeong, 2017)

The three financial status related vehicles provide information about respondent's financial situation and perception about financial loss or gain from travelling using different transportation modes. The eleven income ranges in original NHTS survey were merged into three groups, representing the lower income group with less than \$50,000 as an annual earning, the middle income group ranging from \$50,000 to \$100,000 and the higher income group over \$100,000. Various individual and neighborhood related variables including age, gender, race, and population density (neighborhood variable) are also selected. Age, gender, and race show the basic individual socio-demographic status ((De Luca, 2015), (Prieto, 2017), (Kim, 2015)) while population density represents neighborhood land use and urban design (Prieto, 2017)

When sampling for car-sharing usages, zero car-sharing usages were found excessive since car-sharing tends not to be the individuals' major daily mobility option. However, we also found few large values, and this makes the carsharing distribution have a small mode and a median but a long tail, which refers to as an over-dispersion. To properly explain this unique characteristic of carsharing usages (the response variable), this study selected Zero-inflated model. The model consists of two parts- one for the count and another for excessive zeros. Zero-inflated modeling is generated by a binary decision that produces (extra) zeros based on a logit model. The count model that also includes zeros that do not belong to 'absolute' (or excessive) zeros is determined by a count function such as Poisson or Negative Binomial distributions depending on the distribution type of the variable.

Among numerous methods to model count data, ZINB is an advantageous method to capture excessive zero counts such as carsharing usage. There are two type of users contributing zero counts in carsharing. The first type includes people who have membership to car-sharing but did not use the service during the survey period and the second group are those who do not have an access or membership at all. The second group was certain not to use the carsharing service, which would cause excessive zero outcomes in the survey for the car-sharing usage. This group needs to be distinguished from the first group who are in favor but happened not to use the service during the survey period.

Therefore, the zero usage is caused either by a group of people who generally uses car-sharing service but did not use the service during the survey time period or a group who never use or are aware of car-sharing service. The second group results in 'certain' zeros for the car-sharing. The ZINB aims to distinguish the 'certain' zeros from 'non-certain' zeros or non-zeros in order to understand the factors affecting car-sharing service from those who never used the service. At the same time, it develops the relationships between count (non-zeros) response variable and the predictor variables. A traditional count model alone is not able to account for the excess zeros therefore a zero inflated modeling is recommended to understand two different relationships between response and predictor variables.

ZINB captures these two groups by constructing the model into two parts – zero-inflated model and count model – and integrating them as one model. The zero-inflated model analyzes the dataset focusing on the excessive number of zeros to understand who would be in the 'certain' non-users. The count model investigates the car-sharing usage including the first group of people based on the negative binomial distribution. Negative binomial model assumes a generalized format of Poisson regression to relax restrictive assumptions of mean and variance equivalence, which were restricted to Poisson model. Since the negative binomial regression model allows the model to apply Poisson heterogeneity using a gamma distribution, over-dispersion in dataset can be properly captured in the model.

The probability mass functions of the ZIP and ZINB are as follows.

ZIP:

$$\Pr(Yi = yi \mid \mu i, \omega i) = \begin{cases} \omega i + (1-\omega i)\exp(-\omega i), & yi = 0 \\ (1-\omega i)\dfrac{\mu i^{yi}}{yi\,!}\exp(-\mu i), & yi > 0 \end{cases}$$

Where, $0 \leq \omega i < 1$ and μi is a non-negative number and $\mu_i > 0$. The expected value for the ZIP is $E(Y_i) = (1-\omega i)\mu i$ and the variance is $Var(Y_i) = E(Y_i)(1 + \omega i \mu i)$

ZINB:

$$\Pr(Yi = yi) = \begin{cases} \omega i + (1-\omega i) g(y_i = 0) & yi = 0 \\ (1-\omega i) g(y_i), & yi > 0 \end{cases}$$

$$g(y_i) = \Pr(Y = y_i \mid \mu i, \omega i) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(\alpha^{-1})\, \Gamma\, (y_i + 1)} \left(\frac{1}{1 + \alpha \mu i}\right)^{\alpha^{-1}} \left(\frac{\alpha \mu i}{1 + \alpha \mu i}\right)^{y_i}$$

Where $0 \leq \omega i < 1$ and μi is a non-negative number $\mu_i > 0$. The expected value of ZINB is same as ZIP, $E(Y_i) = (1 - \omega i)\mu i$ and the variance is $Var(Y_i) = E(Y_i)(1 + k\, \mu_i + \omega i \mu i)$.

From the probability mass function of ZINB, it can be inferred that the model structures have similar properties as the negative binomial distribution when $\omega i = 0$ and similar to ZIP when k=0. Hence the ZINB can handle both the zero inflation and over-dispersion caused by K>0 and $\omega i > 0$ in the variance equation for the count data.

5.2. COMMUNITY ENGAGEMENT WITH QUALITATIVE APPROACH

Recognizing the unique history of public transit infrastructure within DFW, TX, the study sought input from the community directly in order to develop strategies that best address their needs and concerns towards carsharing operation. We conducted Focus group through a broader regional study assessing transportation needs among environmental justice (EJ) populations during the summer 2018. Following university institutional review board (IRB) approval, participants (n=28) were recruited to participate in one of seven focus groups using purposive sampling methods. Members of a community advisory board, comprised of 14 individuals representing social workers, civil engineers, and public planners, provided contact information of professionals who were either in organizations, which provided transportation resources to EJ populations, or were civil engineers working for local governments who had knowledge of transportation inequities. The purpose of the focus groups was to collect data about who is most affected by transportation inequities, how and why they are, and what potential solutions may increase transportation equity. The final question specifically inquired about the use of car-sharing as a resource for promoting transportation equity and meeting the needs of EJ populations.

Participants received an email with information about the purpose of the focus groups, which were held online using an online meeting software called Zoom. To participate, participants accessed the meeting with their phone or computer using a link provided in an email. When it was time for the focus group, a lead research team member opened the Zoom meeting and began recording. The lead researcher followed a semi-structured interview guide, and at least one other research team member was present to take notes. The focus groups lasted approximately one hour, and participants received $10 gift cards for their time. Approximately 3-4 participants attended each focus group.

Digital recordings from the focus groups were professionally transcribed. One research team member analyzed the data using Atlas.ti following an open coding and basic content analysis approach (Elo, 2008) to identify key themes around the feasibility of car-sharing for EJ populations. A second research team member read through half of the transcripts randomly and checked the themes for consistency. In the event that the researchers disagreed, they discussed the discrepancies until they had reached consensus on the meanings.

6. FINDINGS

6.1. QUANTITATIVE ANALSIS

Spatial analysis of car-sharing location

We analyzed the spatial distributions of Zipcar operation in the US. This analysis provides the overall spatial patterns of Zipcar location, rather than an analysis on spatial distribution of actual users. The premise of this study is that the location of carsharing service is an important factor that determines potential users, therefore determining equitable location should be the first step for carsharing operator or policy makers to achieve social justice in the service. We investigated the number of people who would have access to Zipcar location in the US and how differently this access is shown by race and income characteristics of the neighborhoods where Zipcar is operating.

Table 3 compares the access to the Zipcar by race and ethnicity. In 2016, almost 330 million people lived in the United States. An estimated 61% of the U.S. population in 2016 is non-Hispanic White alone, 12% non-Hispanic Black alone, 0.6% non-Hispanic American Indian or Alaskan Native alone, 5% non-Hispanic Asian alone, 0.2% non-Hispanic Hawaiian or Pacific Islander alone, and 18% Hispanic alone. Almost 5% of the U.S. Population has access to at least one Zipcar in their census tract. Similarly, White, Black, Hawaiian or Pacific Islander, and Hispanic populations have between 3% and 5% access to Zipcars. The Asian population has the highest access to Zipcars at 13%, while the American Indian or Alaskan Native population has the lowest access to Zipcars at 2%. Black population has fairly good access with 4.8%, compared to the US average (4.74%).

Table 3: Zipcar by Race/Ethnicity (2016 5-year ACS, Zipcar API)

	Total	**White**	**Black**	**American Indian**	**Asian**	**Pacific Islander**	**Hispanic**
Number of People (million)	328.9	201.2	39.8	2.1	17.6	0.52	59.5
% of U.S. Population	100.00%	61.20%	12.10%	0.60%	5.40%	0.20%	18.10%
Number of People with Access To At Least One Zipcar* (million)	15.6	8.5	1.9	0.039	2.2	0.016	2.2
% of population with Access To At Least One Zipcar in corresponding race category*	4.74%	4.25%	4.83%	1.88%	12.87%	3.21%	3.79%

*Zipcar location in the same census tract

Table 4 shows the spatial distribution of Zipcar by different income categories. It is shown that 13% of census tracts with median income less than $10,000, 9% of census tracts with median income between $10,000 and $20,000, 6% of census tracts with median income between $80,000 and $90,000, and 7% of census tracts with median income between $90,000 and $100,000 having access to at least one Zipcar. By comparison, less than 3% of census tracts with median income between $30,000 and 60,000 have access to at least one Zipcar. While census tracts with median income greater than $100,000 shows almost 10% access to at least one Zipcar.

Figure 1 illustrates Zipcar access with the income distributions for the five major cities in the US. It was shown that local geography seems to have a bigger influence on where Zipcars are located than income distribution although Zipcars are clustered in either highest or lowest income neighborhoods. It also should be noted that this study only considers the number of population in Census Tract where Zipcar is operating rather than the actual users of the service, to evaluate spatial access to the service. Future study should consider the number of employees particularly low wage workers for the analysis since many Zipcar operations are located in the business districts.

Table 4: Zipcar by Income (2016 5-year ACS, Zipcar API)

	Median Income					
	Total	<10,000	10,000 to 20,000	20,000 to 30,000	30,000 to 40,000	40,000 to 50,000
Number (%) of Census Tracts (CT)	74,962 (100%)	916 1.20%	2,062 2.80%	6,265 8.40%	11,508 15.40%	13,467 18.00%
Number (%) of CT with Access To At Least One Zipcar*	3,209 4.28%	120 13.10%	186 9.02%	254 4.05%	302 2.62%	312 2.32%
	Median Income					
	50,000 to 60,000	60,000 to 70,000	70,000 to 80,000	80,000 to 90,000	90,000 to 100,000	> 100,000
Number (%) of Census Tracts (CT)	11,890 15.90%	8,691 11.60%	5,822 7.80%	4,261 5.70%	3,004 4.00%	7,064 9.40%
Number (%) of CT with Access To At Least One Zipcar*	319 2.68%	282 3.24%	284 4.88%	253 5.94%	211 7.02%	683 9.67%

*Zipcar location in the same census tract

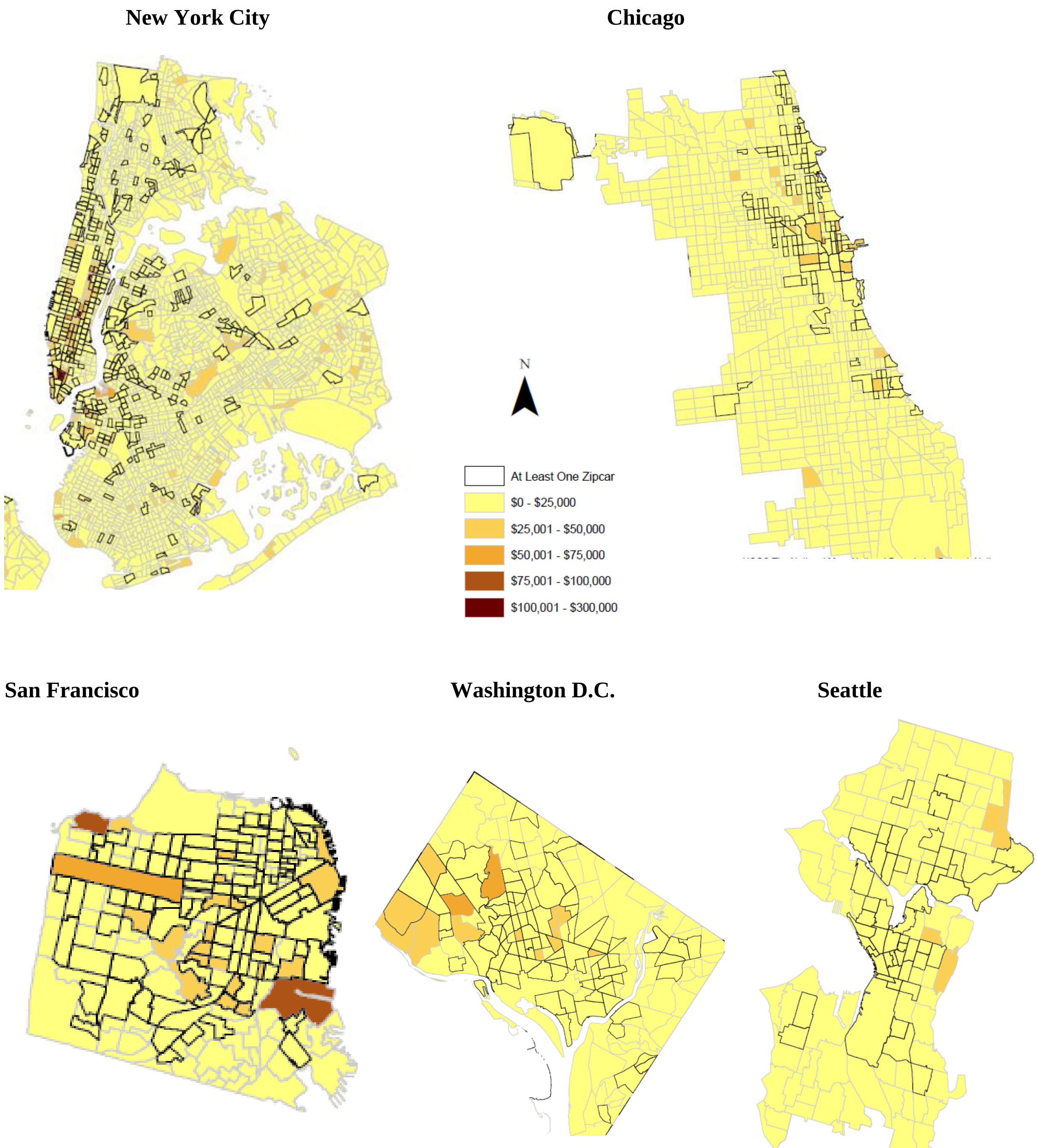

Figure 1: Zipcar Access with income distribution map

Zero Inflated Negative Binomial Regression Model

A total of 134,250 NHTS survey responses were used in this study for ZINB modeling. Table 5 provides the summary statistics of the response and predictor variables. The response variable CARSHARE is a numerical variable with the minimum of 0 and the maximum of 40. The average number 0.02 indicates that there are lots of zeroes in the dataset that make the average be close to zero. The financial status related variables are binary variables. For example, Burden could be either 0 or 1 where 1 indicates travelling as financial burden. It was shown that 36 percent of the survey population considers travelling as financial burden.

Table 5: Summary descriptive statistics for modeling variables

Category	Variables	Mean	Min	Max	Std
Response Variable	CARSHARE	0.02	0	40	0.39
Transportation related independent variable	PTUSED	0.92	0	240	4.43
	RIDESHARE	0.29	0	99	1.70
	YEARMILE	10.36	0	200	11.90
Financial status related independent variable	WalkorBike	0.11	0	1	0.31
	Burden	0.36	0	1	0.48
	Income_Low	0.22	0	1	0.41
	Income_Med	0.45	0	1	0.50
	Income_High	0.34	0	1	0.47
Neighborhood related independent variable	Population Density_Low	0.40	0	1	0.49
	Population Density_Med	0.53	0	1	0.50
	Population Density_High	0.07	0	1	0.25
Individual related independent variable	AGE	53.24	16	92	18.54
	GENDER	0.48	0	1	0.52
	White	0.84	0	1	0.36
	African American	0.06	0	1	0.24
	Asian	0.04	0	1	0.20
	Others	0.05	0	1	0.23

Table 6 shows the number of carsharing usage. As expected, zero counts are dominant while 40 is the maximum carsharing usage in the dataset. Table 7 compares the number of vehicles owned and income in household level. Income is categorized into three groups, as discussed in Chapter 5 (less than $50,000 as low, over 10,000 as high). While 12% of lower income group do not own a vehicle while 44% owned one car. However, only 1% and 8% of higher income group population has zero and one car, respectively.

Table 6. Carsharing Usage

Car-share usage	0	1	2	3	4	5-10	11-40
Counts	133479	384	168	50	50	87	32

Table 7. Relationships between Number of vehicles owned and Income distribution

		Number of Vehicle Owned				
		0	**1**	**2**	**more than 3**	**Total**
Income Level	**Low**	3637 (12%)	12966 (44%)	8437 (19%)	4176 (14%)	29216 (100%)
	Medium	666 (1%)	13746 (23%)	26855 (45%)	18631 (31%)	59898 (100%)
	High	241 (1%)	3651 (8%)	20858 (46%)	20386 (45%)	45136 (100%)

ZINB model was developed using the statistical software R. As mentioned earlier, the ZINB provides two modeling outcomes from a negative binomial count model and a zero-inflation model. The first count model accounts for the actual car-sharing usages to focus on car-sharing usages reported from those who had access to car-sharing regardless of their travel with car-sharing during the survey period. However, the second outcomes from the zero inflated model discusses excessive zeroes from the individuals who did not have access at all to car-sharing. The carsharing usages included two types of zeros: one from the group who frequently uses the carsharing but did not use the service during the survey. The second group is those who do not have access to Zipcar at all. As discussed earlier, ZINB modeling captures those two zero components through separate modeling with logit (excessive zero) and negative binomial (count) modeling structures. Researchers are flexible to choose explanatory variables in each component and this study used the same explanatory variables to understand how the effects of variables vary in two carsharing usage behaviors. All the predictor variables were checked for multi-collinearity and all of them resulted in a VIF value close to 1.

Table 7: Estimation Results for the (a) Count and (b) Zero-inflation Models

Count Model						
Category	**Variables**	**Coefficient**	**Std. Error**	**z value**	**Pr(>|z|)**	**Significance**
Intercept	Intercept	-3.426	0.281	-12.186	2E-16	***
Transportation related independent variable	PTUSED	0.002	0.005	0.386	7E-01	
	RIDESHARE	0.112	0.018	6.36	2E-10	***
	YEARMILE	-0.006	0.004	-1.39	2E-01	
Financial status related independent variable	WalkorBike	0.321	0.156	2.064	4E-02	*
	Burden	0.479	0.130	3.697	2E-04	***
	Income_Med	0.086	0.168	0.511	6E-01	
	Income_High	0.191	0.167	1.143	3E-01	
Neighborhood related independent variable	Population Density_Med	-0.160	0.156	-1.026	3E-01	
	Population Density_High	-0.263	0.209	-1.258	2E-01	
Individual related independent variable	AGE	0.006	0.003	1.872	6E-02	.
	GENDER	0.082	0.108	0.761	4E-01	
	African American	0.444	0.192	2.308	2E-02	*
	Asian	0.580	0.223	2.601	9E-03	**
	Others	0.003	0.222	0.013	1E+00	
ZINB Model						
Category	**Variables**	**Coefficient**	**Std. Error**	**z value**	**Pr(>|z|)**	**Significance**
Intercept	Intercept	2.15E+00	3.60E-01	5.987	2.14E-09	***
Transportation related independent variable	PTUSED	-9.78E-01	1.86E-01	-5.263	1.42E-07	***
	RIDESHARE	-2.24E+01	1.06E+03	-0.021	0.983189	
	YEARMILE	-1.77E-02	7.03E-03	-2.517	0.011836	*
Financial status related independent variable	WalkorBike	-2.14E-01	2.18E-01	-0.981	0.326621	
	Burden	2.94E-01	1.62E-01	1.81	0.070278	.
	Income_Med	3.35E-01	1.98E-01	1.695	0.09006	.
	Income_High	6.90E-01	2.20E-01	3.131	0.001742	**
Neighborhood related independent variable	Population Density_Med	-6.37E-01	1.73E-01	-3.678	0.000235	***
	Population Density_High	-6.96E-01	3.28E-01	-2.125	0.033606	*
Individual related independent variable	AGE	1.01E-02	4.31E-03	2.354	0.018595	*
	GENDER	-2.00E-01	1.50E-01	-1.336	0.181658	
	African American	-1.16E+00	2.50E-01	-4.633	3.60E-06	***
	Asian	-8.48E-01	2.95E-01	-2.879	0.003987	**
	Others	-6.54E-01	3.06E-01	-2.138	0.032555	*
Goodness of Fit						

Log-likelihood: (full model)	*-5466 on 31 Df*
Log-likelihood: (null model)	5e-275 *31 Df*
Vuong Test	Z statistics 12.3 (p value <0.0000000000000002)
	BIC corrected z statistics 9,4 (p value <0.0000000000000002)

. Significance at 10%. * Significance at 5%. ** Significance at 1%. *** Significance at 0.1%.

Overall, the goodness-of fit results indicate that the developed model is statistically significant. This is first shown based on the log-likelihood comparisons between full and null (i.e., intercept only) model where the null model is estimated without predictors using chi-squared test. The Vuong test is also used to confirm that the zero-inflated negative binomial model improves the statistical fitness over a standard negative binomial model. The Z statistics and p value suggest that zero inflated model is a significant improvement over a standard model.

The count model shows that people who use rideshare likely to use carsharing as well. For example, the expected number of carsharing for a group who use ridesharing would increase by a factor of exp (0.1112) = 1.12. In addition, two financial status variables, walk or bike and burden show the positive relationships to the car sharing usages. In other words, the group that has financial burden or choose to walk or bike to reduce financial burden tend to more use car sharing service. Compared to White, African American and Asian have higher likelihood in using car-sharing. Density is not chosen as a significant variable, which is potentially because Zipcar locations are concentrated in high-density locations thus provide small variation in population density across census tracts. This finding is supported by the results of the zero-inflation model as high-density area likely include frequent carsharing users (negative coefficients in ZINB model shows the negative association to the excessive zero group).

It is natural to show opposite signs and trends between the count and zero-inflation model because two models explain the opposite target behaviors. While the count model accounts the number of carsharing usages, the logit component (Zero-inflation model) treats the excessive zero as a target outcome. In the zero-inflation model, PTUSED and YEARMILE show negative relationships with the carsharing. If a group were to increase its PTUSED value by one, the odds that it would be in the excessive zero group would decrease by a factor of exp (-0.978) = 0.376. Therefore, if more public transit users in a group, less likely the group include a member with certain non-access (excessive zero) for carsharing. Similarly, if more long-distance drivers are included in a group, the group less likely include a member without access to the carsharing. However, income shows the positive relationship to carsharing in an excessive zero modeling, which indicates that higher income population more likely include excessive zero or individuals without any access to carsharing. Compared to White, African American and Asian are less likely included in the group without access to carsharing. These findings infer that higher income and White population more likely have access to their own individual vehicle and consequently less use the carsharing service, which is shown in Table 8 where higher income population have more vehicles owned than lower income counterparts. The results from the population density variables are intuitive. Lower population density neighborhood would highly likely include a group without access to car-sharing. Note that the household income less than $50,000 (Income_Low) and population density less than 1000 persons per square mile are used as reference categories for the modeling, as discussed in Table 2.

6.2.QUALITATIVE ANALYSIS

The results of the focus groups highlighted participants' knowledge and characterization of car-share programs. Overall, results indicating that participants were relatively unfamiliar with car-share programs. Consequently, the researchers found it valuable to compare participants' perspectives on car-share programs to their perspectives on ride-share programs. Within this comparative framework, the researchers identified four key themes: familiarity, affordability, convenience, and technological barriers.

(Lack of) Familiarity

In general, participants in the focus groups expressed little knowledge of carsharing programs. Many participants stated they were unaware of the existence of a carsharing program and those that knew of the services has never used it. In fact, when initially asked about car sharing programs, many participants talked about ridesharing services. Another participant said, "I know they have ride share, but I haven't heard car share." In one of the focus groups, the facilitator clarified that she was referring to carshare programs, specifically, and a participant replied, "With car shares, I don't know…In the city of Dallas, I'm not even aware that we have those. I probably should be if we do." This participant went on to explain, erroneously, that the City of Dallas has a bike share program, but not a car share program. "We don't have cars, but we've got bike share."

Participants also expressed hesitancy about using carshare programs. One participant said, "Have a shared a ride? Many times, and more than happy to do so. But, have I shared a car? I don't think I'm there yet." Overall, participants were more familiar with ride-share programs and would use ride-share programs more readily and frequently. Car-share programs were not on the participants' radar.

In contrast, participants in the focus groups were quite familiar with ride-share programs. Participants spoke of experiences with different types of services such as Uber, Lyft, Via, and Paratransit. Several participants compared ride-share programs to a taxi services due to the availability and fees. Participants also commented on the amount of times they used ride-share programs. One participant said, "I mean I obviously take ride-share at least like eight times a week probably. It just depends on the week." One participant had been a driver for Uber and recalled his experience saying, "I've actually been an Uber driver for the last year. I've done I think about 1,620 trips over the last year, so Dallas is definitely an Uber town. Every hour of the day there's Uber rides out there and everything. I mean, you're busy all day long." Overall participants expressed a positive opinion of ride-share services and recalled several successful experiences accessing different programs. However, two participants felt ride-share programs were not safe. One participant said, "I wouldn't use it. Because number one they're supposed to be very dependable and things like that. But with the, and I know that the security and stuff, but I wouldn't want to call a stranger in their own car, not knowing what kind of car they have, if it's going to break down at 10 o'clock at night because I've got to go to work and then depend on that."

Affordability

Participants commented frequently on the cost of rideshare and carshare programs. Perspectives on car-share costs were mixed and seemed to suggest that car-sharing is associated with a higher-income rider. As one participant explained, "But getting private rides and things like that, it's so costly, and these people don't have the money to pay for private rides and things like that." Related to the affordability, one participant seemed to associate car-share programs with more upper-income communities and business travel. As she said, "these folks [individuals living in higher-income suburban communities] aren't going to have a problem with public transportation as far as their daily needs, but there may be that opportunity there for something like a train to the airport or the Zipcar things. That's something that business travelers are interested in and I think we have more of that coming." Another participant also found some value to car-sharing when associated with business travel. She explained, "[Zip car] sounds pretty cool because as an alternative to having to go to a city and rent a car somewhere. You just use it when you need it rather than having to rent it for three days and pay $100 a day…it would be much more, I think, practical as far as cost goes."

Due to their relative lack of familiarity with car-share programs, though, they were more expressive about the costs related to ride-share programs, particularly as they relate to EJ populations. Participants even noted the city sponsored programs which offered rides at a lower fee, such as Via in Arlington and Paratransit in Dallas, were too costly simply because the people accessing those services had very limited financial resources. One participant said, "Most of the people that need rides don't have the money." Private ride-share programs, such as Uber and Lyft, were too expensive. Another participant commenting on Uber said, "I have only heard about the expense of Uber up in Grayson county and to go from Ben Austin to Sherman, which is probably like a 15-mile jaunt, it cost a woman $50. I don't know why. That's just what I heard so I really hate to say anything but it's a financial reason why Uber would not be used by my students." Participants also compared the fees of ride-share programs to a taxi service. One participant said, "I find them becoming more and more like a taxi service, and the longer they're in business their fees and their rates tend to be like a taxi service rates. Even though, in essence, run independently. They're all independent operators. And so, I don't find it convenient. I mean, just like right now, if I wanted to take a taxi to DFW, it'd cost me 30 or 40, maybe even 50 dollars, just staying here in downtown Arlington." In terms of car-sharing programs, participants also felt that is the programs were available, they would also be too costly given their similarity to ride-share programs.

Perceived (In)Convenience Due to Misconceptions

Participants described carsharing services as inconvenient, but often their descriptions seemed to suggest that they thought that carsharing works similarly to bus services where people would need to get to the central hub in order to pick up a car. One participants said, “I don't know if I will ever opt for Zip car because I would have to go pick up the car first. Then share it with people which is not going to happen at all.” Another participant, perhaps not fully understanding how car-sharing programs operate, commented, “Yeah, it’s hard whenever you don’t have a centralized point.” Overall, participants explained that getting to the car may pose an additional challenge and may be associated with an additional cost which would be inconvenient and discourage use.

Additionally, participants seemed to conflate “sharing a ride with someone” with “car sharing”. As one participant said, “I haven’t used that [Zip Car] but, personally, I have been mindful with my buddies and with my colleagues where we are going…We either share rides. Then you know, like individual person go in a single car.”

In contrast, participants commented frequently on the convenience of ride-share programs over traditional means of public transportation. One participant said, “And if that ride for hire, your Ubers, your Lyfts, can provide that flexibility of kind of getting from point A to point B that a typical, fixed route transit service would provide, doesn't provide.”

Accessibility

However, participants noted that shared transport may not be accessible for everyone, particularly those with physical disabilities. One participants said, “One of the things I've noticed, and that would need to be added to, as it were, Uber and Lyft is right now I can go out and be an Uber driver, but my vehicle is not capable of hosting somebody in a wheel chair.” One participant also commented on the inconvenience of a public ride-share services called Paratransit saying, “Unless you live in the specific area where you have the on-call service, you cannot use Paratransit. If I want to go to the store right now, I can't do that. I can't call Paratransit and say, "I need a ride" like an Uber or a Lyft, I have to schedule my appointment the day before, or two days before, because of the area that I live in, and I've been told that they don't have on-call in the area where I live.” Participants also felt that individuals experiencing homelessness may experience discrimination in attempting to use ride-share programs due to their outward appearance. One participant said, “My concern would be whether or not they would be accepted as participants in a ride share program, based on stereotypes, would be my biggest concern.” Overall the majority of participants recognized that certain populations may experience challenges attempting to access services.

Technological Barriers

The participants highlighted that technology is an important factor when using ride-share and car-share programs. Many felt that the technological resources to use ride-share and car-share programs are barriers to access, particularly for EJ population members and individuals who may be unbanked. One participant said, "Yeah, you have to have a credit card, you have to have a smart phone, you have to know how to use the app, which there is a big technological barrier there." Participants also felt that the technological *knowledge* required to utilize certain services would present a barrier to certain populations. One participant said, "I don't think that the elderly are as unfamiliar with technology now as they have been in the past 20 years it's being getting bigger. Because we see people come in all the time, they're using tablets and smart phones. They're just fine with it. I don't think it's a valid assertion that all elderly folks can't use the technology. But several can't or don't have it or don't want to, and so that would definitely be a problem with something like that. They would have to have a lot of training, and even we see with training sometimes that doesn't even bridge that." Overall, participants expressed the sentiment that older adults who are less familiar with emerging technologies, as well as individuals who may have a cognitive developmental disability may struggle with some of the technological aspects of shared transport.

7. CONCLUSION

Car-sharing continues to transform its technology to be a fast, cost-effective, and environmentally-sustainable option by adopting autonomous shared use programs. With declining federal funding for public transit, carsharing services would also become a more important transportation mode that fills the gap in providing mobility for low-income communities. As the shared use field continues to expand and adopt new technology driven solutions, the need to explore their current and potential role in providing service equity for all communities appears particularly timely.

As carsharing offers mobility without vehicle ownership, it has been shown to complement or supplement the current public transit ridership. To respond to the positive aspects of shared mobility, governments have implemented pro-carsharing policies including allocating more parking zones in cities for car-sharing operators, giving start-up funds to establish programs, and allowing DOT to use car-sharing for work activities. Not only carsharing users but policy makers consider carsharing to be an efficient, economical, and environmentally sustainable transportation alternative which can replace personal automobiles and promote sustainable transportation options. In this regard, carsharing would be an attractive option for communities that have low vehicle ownership and remain dependent on public transit. However, not much attention has been given to lower-income communities when starting carsharing programs or to providing incentives to the operators if they provide fair accessibility and sufficient opportunities to achieve social equity.

This study applied mixed methods to understand viability of carsharing as a mobility option. The study first identified the current implementation patterns of car-sharing in the five major US cities. The spatial analysis studying the relationships between Zipcar parking locations and income level of the neighborhoods showed that ZipCar is prevalently implemented in these major Cities and does not disproportionately serve particular population group such as high-income groups. The mathematical model based on Negative Binomial Regression approach showed the important sociodemographic and travel behavior variables that affect car-sharing usage. Ride-share and public usage are shown to complement car-sharing. Financial status also affects to car-sharing where people who choose to walk of bike to reduce financial burden tend to use more car-sharing.

As a qualitative analysis, focus groups was designed to learn key factors of feasibility, accessibility, affordability, and willingness to use the car-sharing technology. Individuals representing social workers, civil engineers, and public planners were selected as participants. Perhaps the key result to emerge from the qualitative data was the general lack of familiarity about regional car sharing among transportation professionals and those working with EJ population members. In fact, participants confused car sharing with ride sharing, and even bike sharing, at times. This lack of knowledge among transportation professionals and social workers will certainly present a barrier to encouraging car sharing use among EJ population members. The participants also identified that affordability and technological barrier besides a lack of familiarity and consequence misconception as the potential causes of the lack of awareness or willingness to use car-sharing service.

The demographic usage patterns may suggest that car sharing companies like Zip Car may need to offer lower prices, or create sliding scale fees, in order for EJ population members to use their services. In addition, it may be effective for MPOs and communities to subsidize car sharing services for individuals who are lower income. Moreover, car share companies need to consider how accessible their cars are for individuals with physical disabilities. They ought to maintain fleets of cars that have wheelchair accessibility. Related to this recommendation, car share companies should advertise their accessibility features and educate transportation professionals so that people are aware of these features.

Finally, the technological barriers that focus group participants identified suggest that there may be potential riders who just need to *know* how to ride. This would include many EJ population members who are less familiar with emerging app-based technologies. Such potential riders would benefit from transportation navigators who would show riders how to use car sharing apps for the first few rides before they are confident using car sharing independently.

Overall, this study investigates if the car-sharing could fill as a feasible and socially equitable transportation option, particularly in transit-dependent transportation disadvantaged populations. Although the mathematical modeling found that the individuals experiencing financial burden used the carsharing service as their alternative mobility, the focus group showed the general lack of familiarity of the service. This study could find great potential of the carsharing as the mobility option for lower income or EJ population from the overall trends in the US; however, the general understanding of the service in local area (DFW in Texas) is still limited due in part to less popularity and limited operation of the carsharing in the area.

Communities may benefit from increased transit resources that help individuals without personal vehicles access jobs, healthcare, education, and food. This study found one lower-cost, innovative option may be carsharing since it allows individuals to select and rent a vehicle on a trip basis at their selected locations, affording them on-demand and independent mobility without the expense of owning a vehicle.

Based on the research findings, this study suggests three recommendations for active implementation. First, target low-income populations because research and pilot programs have shown that low-income earners would adopt carshare technology if they are aware of the service. Those who use traditional transit are at a significant disadvantage as opposed to those with access to automobiles (Sullivan, 2003). Studies show that lack of vehicle ownership prevents individuals from jobs options, contributes to absenteeism, and is a barrier for low-income earners to shift from welfare to work (Sullivan, 2003). The purpose of carsharing is to afford its members with on-demand, independent access to vehicles. These vehicles would allow residents flexibility and allow transit-dependent populations to consider job options that traditional-mass transit methods may not reach. With carsharing, low-income earners who previously lacked access to vehicles would be provided an avenue to automobiles, and in turn, carsharing would open up new employment options.

Second, offer a variety of service to accommodate diverse needs from various population such as round-trip and free-floating services. The round-trip method requires that a transaction is completed only when the car returns to its original location. Round-trip carsharing would benefit low-income populations because it grants them access to frequently unplanned and quick travel needs such as shopping (i.e. groceries, clothes, and school supplies), as well as healthcare appointments, and job interviews. Round-trip carsharing is not feasible for commuting to work as users would pay extra hours until return, a new method that would allow individuals to use carsharing for their work commute (i.e., free-floating carsharing) can be also considered. In free-floating carsharing, the company allows the car to be parked anywhere within a given area, the vehicle does not need to be returned to its original location to complete a transaction (Schmöller, 2015).

Third, subsidize parking spaces for carshare companies and implement Electric-Vehicles in order to incentivize carshare use, reduce parking congestion and reduce car emissions. An important consideration is environmental impacts as carshare services can combat the negative effects of air pollution by possibly reducing vehicle ownerships or trip length (Nijland, 2017). Estimates show that one carshare vehicle can remove about 13 vehicles from the road (NewYork, 2018). Cities also incentivize carshare use by subsidizing public parking spaces for carshare vehicles (NewYork, 2018). This investment reduces the amount of congestion in roads and parking garages and encourages individuals to adopt carshare. Another method which carshare companies have combated environmental issues is their investment in Electric Vehicles (EV's). Research shows that EV's have a significant positive environmental impact (Helmers, 2012). In London, the carsharing company, Zipcar, offers over 300 EV's (Manthey, 2019). Cities that desire to offer EV's have two options for fueling. If the city subsidizes parking spots, the city can place a fueling station with each parking spot for convenience. If the city lacks the infrastructure to implement charging stations, they could utilize a wireless method of free wire mobile chargers (Cuff, 2018).

The assessments and feedback from this study would bring broad impacts to prepare for the autonomous vehicle era as various shared transportation options including free-floating car-sharing, shared autonomous vehicles, ridesharing, and demand transit will be implemented in the near future. Based on the outcomes from this study, a more comprehensive follow-up study should be conducted, using a quantitative survey, to examine various transportation options in terms of their economic feasibility and compatibility with current transportation needs for diverse populations, such as lower-income individuals, those with disabilities and older adults.

8. REFERENCES

(AMPO), A. o. (2011). *More Than Mobility: Examining the impacts of EJ Populations.* Retrieved July 15, 2018, from https://www.nctcog.org/nctcg/media/Transportation/DocsMaps/Quality/Environ/More41than-Mobility.pdf.

(NCMM), N. C. (2014). *Making First/Last Mile Connections to Transit: How Carsharing and Bikesharing Programs are Improving Connectivity.* National Center for Mobility Management (NCMM). Retrieved from https://nationalcenterformobilitymanagement.org/wp-content/uploads/2013/11/Info-Brief-Shared-Use-and-Transit.pdf

(TUS), T. U. (2013). *How to start a car sharing coop.* Retrieved July 2018, from http://www.uwcc.wisc.edu/pdf/HowTo_StartACarSharingCoop_v1.0.pdf

(USDOT), U. D. (n.d.). *Environmental Justice Title VI, Nondiscrimination, and Equity.* Retrieved March 20, 2018, from https://www.fhwa.dot.gov/environment/environmental_justice/equity/

Bullen, A. (2016). *Nonprofit Carsharing Offers Unique Benefits*. Retrieved June 2018, from eGo Carshare Blog: http://carshare.org/nonprofit-carsharing-offers-unique-benefits/

Cuff, M. (2018, November 15). *Zipcar to trial mobile electric vehicle charging in London.* Retrieved from https://www.businessgreen.com/bg/news/3066348/zipcar-to-trial-mobile-electric-vehicle-charging

Dave. (2018, April). *Carsharing Portland Timeline.* Retrieved July 2018, from carsharing.us: http://carsharingus.blogspot.com/,

De Luca, S. a. (2015). Modelling user's behavior in inter-uran carshring program: A stated preference approach. *Transportation Research Part A: Policy and Practice, 71*, 59-76.

Doherty, M. J. (1987). Public use of autos: mobility enterprise project. *Journal of transportation engineering 113.1* , 84-94.

Donald Erdman, L. J. (2008). Zero-Inflated Poisson and Zero-Inflated Negative Binomial Models Using the COUNTREG Procedure. *SAS Global Forum 2008, Paper 322-2008.*

Elo, S. &. (2008). The qualitative content analysis process. *Journal of Advanced* , 107-115.

Ferrero, F. P. (2018). Car-sharing services: An annotated review. 501-518. doi:10.1016/j.scs.2017.09.020

Glaeser, E. L. (2001). Decentralized employment and the transformation of the American city. *National Bureau of Economic Research*. doi:10.3386/w8117

Glaeser, E. L. (2008). Why do the poor live in cities? The role of public transportation. *Journal of urban Economics 63.1* , 1-24. Retrieved from https://doi.org/10.1016/j.jue.2006.12.004

Helmers, E. &. (2012). Electric cars: Technical characteristics and environmental impacts. *Environmental Sciences Europe, 24(1).* doi:10.1186/2190-4715-24-14

Jeong, K. H. (2017). Influence of personal concerns about trael on travel behavior. *Proceedings of the annual Meeting of the Transportation Research Board*.

Kim, K. (2015). Can carsharing meet the mobility needs for the low-income neighborhoods? Lessons from carsharing usage patterns in New York City. *Transportation Research Part A: Policy and Practice*, 249-260.

Kneebone, E. a. (2015). *The growing distance between people and jobs in metropolitan America.* The Brookings Institution.

Kodransky, M. a. (2014). *Connecting Low-Income People to Opportunity with Shared Mobility.* Living Cities. New York, NY: Institute for Transportation & Development Policy .

Lovejoy, K. H. (2013). *Impacts of carsharing on passenger vehicle use and greenhouse gas emissions.* Policy Brief, California Air Resources Board, Sacramento, California.

Manthey, N. (2019, January 24). *London: Electric car club Zipcar delivers e-Golf data.* Retrieved from https://www.electrive.com/2019/01/24/london-electric-car-club-zipcar-delivers-e-golf-data/

Martin, E. a. (2016). *Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities.* Transportation Sustainability Research Center (TSRC), UC Berkeley. Retrieved from http://innovativemobility. org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016. pdf

McLaren, D. &. (2015). *Sharing cities: A case for truly smart and sustainable cities. Cambridge, MA.* Cambridge, MA: MIT Press.

Minneapolis, C. o. (2016). *Car Share policy.* Retrieved from http://ci.minneapolis.mn.us/www/groups/public/@publicworks/documents/webcontent/wcmsp-194728.pdf

Movmi, m. S. (2018, February). *Understanding the car sharing business model and how to build yours.* Retrieved July 2018, from movmi Shared Transportation Services Inc.: http://movmi.net/car-sharing-business-model/

NewYork, T. o. (2018, May 31). Retrieved from https://www1.nyc.gov/office-of-the-mayor/news/278-18/mayor-de-blasio-expanded-access-carshare/#/0

Nijland, H. a. (2017). Mobility and environmental impacts of car sharing in the Netherlands. *Environmental Innovation and Societal Transitions*, *23*, 84-91.

Parzen J., F. T. (2015). *Shared use mobility reference guide.* Retrieved June 2018, from http://sharedusemobilitycenter.org/wp-content/uploads/2015/09/SharedUseMobility_ReferenceGuide_09.25.2015.pdf

Prieto, M. B. (2017). Carsharing adoption itention in urban areas: what ae the key sociodemographic drivers? *Tranportation Research Part A: Policy and Practice, 101*, 218-227.

Schmöller, S. W. (2015). Empirical analysis of free-floating carsharing usage: The Munich and Berlin case. *Transportation Research Part C: Emerging Technologies, 56*, 34-51. doi:10.1016/j.trc.2015.03.008

SFMTA, S. F. (2013). *Car Sharing Policy and Pilot Project.* Retrieved from https://www.sfmta.com/sites/default/files/projects/SFMTA%20Car%20Sharing%20Policy_MTAB_20130716.pdf

Shaheen, S. A. (1999). A Short History of Carsharing in the 90's. *The journal of world transport policy & practice , 5*, 18-40.

Shaheen, S. E. (2010). Impact of Carsharing Household Vehicle Holdings. *Journal of the Transportation Research Board* , 150-158. Retrieved from https://doi.org/10.3141/2143-19

Silverman, Z. (2012). Locating Environmental Justice Populations: A Method for Identifying Vulnerable Populations in Massachusetts. Retrieved July 15, 2018, from http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1947&context=theses

Statista. (2018). *Households with customers of Zipcar in the U.S. 2018*. Retrieved July 2018, from The Statistics Portal: https://www.statista.com/statistics/295919/zipcar-customers-usa/

Sullivan, K. (2003). *Transportation and Work: Exploring Car Usage and Employment Outcome in LSAL Data.* NCSALL Occasional Paper. Psyc EXTRA Dataset. doi:10.1037/e370552004-001

Tomer A., K. E. (2011). *Missed opportunity: transit and jobs in metropolitan America.* Brookings. Retrieved from https://www.brookings.edu/research/missed-opportunity-transit-and-jobs-in-metropolitan-america/

Bardhi, F., & Eckhardt, G. M. (2012). Access-Based Consumption: The Case of Car Sharing: Table 1. *Journal of Consumer Research*, *39*(4), 881–898. https://doi.org/10.1086/666376

Belk, R. (2007). Why Not Share Rather Than Own? *The ANNALS of the American Academy of Political and Social Science*, *611*(1), 126–140. https://doi.org/10.1177/0002716206298483

Burkhardt, J. E., & Millard-Ball, A. (2006). Who is Attracted to Carsharing? *Transportation Research Record: Journal of the Transportation Research Board*, *1986*(1), 98–105. https://doi.org/10.1177/0361198106198600113

Chen, Y. U. (2008). Possession and Access: Consumer Desires and Value Perceptions Regarding Contemporary Art Collection and Exhibit Visits. *JOURNAL OF CONSUMER RESEARCH, Inc. •*, *35*. https://doi.org/10.1086/593699

Environmental Justice and Transportation Planning. (2003). Retrieved from https://www4.uwm.edu/cuts/utp/justicet.pdf

Fraiberger, S. P., & Sundararajan, A. (2015). Peer-to-Peer Rental Markets in the Sharing Economy. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2574337

Frei, F. X., & Rodriguez-Farrar, H. (2005). *Zipcar: Influencing Customer Behavior*. Retrieved from https://www.hbs.edu/faculty/Pages/item.aspx?num=31929

GARASKY, S., FLETCHER, C. N., & JENSEN, H. H. (2006). Transiting to Work: The Role of Private Transportation for Low-Income Households. *Journal of Consumer Affairs*, *40*(1), 64–89. https://doi.org/10.1111/j.1745-6606.2006.00046.x

Lane, C. (2005). PhillyCarShare. *Transportation Research Record: Journal of the Transportation Research Board*, *1927*(1), 158–166. https://doi.org/10.1177/0361198105192700118

Levine, M. (n.d.). *Share My Ride - The New York Times*. Retrieved from https://www.nytimes.com/2009/03/08/magazine/08Zipcar-t.html

Martin, E., Shaheen, S. A., & Lidicker, J. (2010). Impact of Carsharing on Household Vehicle Holdings. *Transportation Research Record: Journal of the Transportation Research Board*, *2143*(1), 150–158. https://doi.org/10.3141/2143-19

Mitchell, G. (2018). Environmental Justice: An Overview. *Reference Module in Earth Systems and Environmental Sciences*. https://doi.org/10.1016/B978-0-12-409548-9.11227-8

Paundra, J., Rook, L., van Dalen, J., & Ketter, W. (2017). Preferences for car sharing services: Effects of instrumental attributes and psychological ownership. *Journal of Environmental*

Psychology, *53*, 121–130. https://doi.org/10.1016/J.JENVP.2017.07.003

Poverty USA. (n.d.). Retrieved June 24, 2019, from https://www.povertyusa.org/facts

Prieto, M., Baltas, G., & Stan, V. (2017). Car sharing adoption intention in urban areas: What are the key sociodemographic drivers? *Transportation Research Part A: Policy and Practice*, *101*, 218–227. https://doi.org/10.1016/J.TRA.2017.05.012

Watson, R. T., Boudreau, M. C., Chen, A. J., & Sepúlveda, H. H. (2011). Green projects: An information drives analysis of four cases. *Journal of Strategic Information Systems*, *20*(1), 55–62. https://doi.org/10.1016/j.jsis.2010.09.004

Zhou, J. (2012). An analysis of university employee car-sharers in Los Angeles. *Transportation Research Part D: Transport and Environment*, *17*(8), 588–591. https://doi.org/10.1016/J.TRD.2012.07.003

Center for Transportation Equity, Decisions & Dollars

The **Center for Transportation, Equity, Decisions and Dollars (CTEDD)** is a USDOT University Transportation Center, leading **transportation policy research** that aids in **decision making** and **improves economic development** through **more efficient, and cost-effective use of existing transportation systems,** and offers **better access to jobs and opportunities.** We are leading a larger consortium of universities focused on **providing outreach** and **research to policy makers**, through **innovative methods** and **educating future leaders of the transportation field.**

University of Texas Arlington

Cal Poly San Luis Obispo

Georgia Tech

USF University of South Florida

Wisconsin University of Wisconsin–Madison

C-TEDD@UTA.EDU | CTEDD.UTA.EDU | @UTACTEDD | @ C__TEDD | @ CENTER FOR TRANSPORTATION, EQUITY, DECISIONS AND DOLLARS | 817.272.5138