Understanding Demographic Characteristics and Trip Patterns of Alternative Automobile Modes

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18 June 2020

ABSTRACT

Automobiles provide better access to opportunities than other modes of transportation. While private vehicles are almost universal in the U.S., there is a large automobility gap between low-income and high-income households. Recent innovations in transportation technology have stimulated the emergence of new automobile modes. Two alternative modes that allow individuals to access automobiles without ownership are taxi and ridehail (e.g. Uber/Lyft) and shared car (e.g. Zipcar) services. Yet we know little about riders of these modes and their trip patterns. The implications of these new services for transportation equity also remain unclear. In this report, I analyze data from the 2017 National Household Travel Survey (NHTS) to explore demographic characteristics and trip patterns associated with taxi, ridehail, and shared car riders, in comparison to private vehicle users.

The results indicate that taxi/ridehail and shared car services have the potential to improve mobility for disadvantaged communities. Carless and car-deficit households tend to experience a boost in automobility by using shared car, taxi, and ridehail services. A large share of taxi and ridehail riders come from low-income households. Moreover, there is a large overlap between frequent taxi and ridehail users and people who state that they are financially burdened by transportation or have low household incomes. Overall, the results indicate a role for taxi, ridehail, and shared car services in promoting mobility for disadvantaged communities. The findings also suggest a role for policymakers and transportation companies in addressing existing barriers to the adoption of these new modes.

Introduction

Automobiles provide better access to opportunities than other modes of transportation. However, low-income households tend to have lower car ownership rates than higher-income households (Pendall et al., 2015; Transportation Research Board & National Academies of Sciences, Engineering, and Medicine, 2005). Several alternative automobile modes predicated on the revolution in transportation technology offer new prospective mobility options. These include ridehail and shared cars. Ridehail connects travelers to drivers to fulfill a point-to-point, on-demand trip, and a shared car enables people to use an automobile for a short period and charges them based on the time and/or mileage driven. By reducing household spending on the purchase and operation of automobiles, these alternative automobile modes can provide low-income households cheaper automobility and promote their access to opportunities.

These alternative modes are revolutionizing the transportation system. However, there is relatively little information on the population groups that are able to access these new modes and, when they do, how they use these unconventional transportation services. In particular, there has been a dearth of research on the equity implications of these modes. To fill this gap, this research draws on data from the 2017 National Household Travel Survey (NHTS) to examine three crucial questions. First, are there differences in the demographic characteristics of shared car, taxi, and ridehail riders compared to private vehicle users? Second, how do the trip characteristics by these modes compare to those of private vehicle trips? Third, are these new modes embraced by disadvantaged communities, such as low-income or car-deficit households, and, consequently, do these modes have the potential to close the automobility gap?

I start by examining Americans' dependency on automobiles and the significance of automobiles in improving access to opportunities. I then review the history of two novel transportation services brought by the revolution in technology: shared car and ridehail services. In the following section, I discuss current knowledge about the adoption and impacts of these two modes. My analysis of survey data from 2017 NHTS shows that shared car and taxi/ridehail users are different from private vehicle users. While the majority of taxi/ridehail and shared car riders tend to be younger, have higher educations, and earn higher incomes than private vehicle users, carless and car-deficit households tend to experience a boost in automobility by using these new modes. Taxi/ridehail services, in particular, have the potential to serve low-income households and enhance their mobility. There are high rates of usage of this service among low-income travelers and a large overlap between frequent taxi users and people who report that they are financially burdened by transportation or have low household incomes. The results suggest a role for taxi/ridehail and shared car services in promoting mobility for disadvantaged communities and a role for policymakers and transportation companies in addressing existing barriers to the adoption and use of these new modes.

Existing Research on Cars and New Transportation Services

Automobility and transportation equity. Americans have grown increasingly dependent on automobiles. Automobile ownership has been steadily rising over the years and it now almost universal in the United States. In 2001, 91.7% of American households owned at least one vehicle; this number climbed to 95.2% in 2017 (Pucher & Renne, 2003). Automobile ownership has increased over time in large part because it is associated with better mobility and accessibility than other modes. For example, a typical carless young person made just two trips

per day and traveled two miles on average, whereas a typical young driver made twice as many trips and traveled twelve times further (Ralph, 2017). Limited mobility associated with the lack of an automobile can greatly reduce individuals' accessibility to employment and essential services. For example, in Los Angeles, within one hour's commute time, workers can reach 75% of the jobs in metropolitan areas with an automobile, but that number drops to five percent with public transit (Owen & Murphy, 2018a, 2018b).

Among low-income households, car ownership is positively associated with better economic outcomes. For example, from 1969-2013, the median income of households that maintained or acquired a car rose 20%, while the median income of carless households declined 34% (King et al., 2019). In addition to economic disadvantages, the lack of an automobile is also a major barrier to gaining health care (Syed et al., 2013) or accessing supermarkets and healthy food (Walker et al., 2010).

The importance of automobiles stems from its flexibility, convenience, and speed, along with the complexity of household travel patterns. For example, traveling by public transit can be especially difficult for a low-income single parent, who has to balance their work trips and daily non-work trips to serve their children and households (Blumenberg, 2004). Public transit or other alternative modes (e.g. walking, biking) are very time-consuming. In contrast, cars provide the flexibility needed for travelers to make stops on their way to and from work. They also make it easier to travel with passengers, transport large parcels (e.g. groceries), and move about at night and on weekends when traveling by other modes may be unsafe.

Automobiles play an increasingly important role in our lives. However, there remains a gap in car ownership rates between low-income and high-income households. As of 2017, around 18% of the households below the poverty line were carless, while more than 98% of households above the poverty line owned at least one private vehicle (Federal Highway Administration, 2017). Car ownership is expensive. Car owners must pay to purchase vehicles and also to operate them. The operating costs include auto insurance, car repairs, vehicle registration, and gas. On average, U.S. car owners spend around $8,400 each year (U.S. Bureau of Labor Statistics, 2016). Also, low-income car owners are particularly burdened by vehicle ownership. Some low-income households have especially high vehicle expenditures and need to allocate a large portion of their incomes to transportation. For example, 1999 – 2001 Consumer Expenditure Survey revealed that 10% of low-income households devoted 35% or more of their spending to vehicles, compared to 16% in higher-income households (Rice, 2004).

Responding to the need to increase access to opportunities among the poor, policymakers have initiated a number of automobile ownership programs. For example, the California Air Resources Board (CARB) provides a Clean Vehicle Assistance Program to help low-income communities purchase clean vehicles through grants and low-interest rate loans.

At the same time, there has been a growth of the concept of "Mobility as a Service" (MaaS), new car-based services that allow households access to automobility without ownership. These include shared car, ridehail, and informal car services. The emergence of this new concept and its associated transportation modes is disrupting the traditional transportation landscape and redefining car access in cities.

Transportation technology revolution. The evolution of MaaS is largely attributed to recent technological advancements in wireless communications, roadmap APIs, GPS, among other technologies. Two especially noteworthy automobile services are shared car and ridehail.

Shared car services enable travelers to use an automobile for a short period of time and charge them based on time and/or mileage driven. Shared car mainly differs from the conventional rental car by allowing travelers to rent vehicles for short time periods. The service is self-accessing, and the rates of shared cars already include gasoline and insurance. Many traditional car rental enterprises are also incorporating this new form of car rentals into their services, such as offering hourly rates (Transportation Research Board & National Academies of Sciences, Engineering, and Medicine, 2005). Ridehail services, also called ridesource, are operated by Transportation Network Companies (TNC) such as Uber and Lyft. They provide for-hire vehicle services and connect travelers to drivers using a smartphone application. This new form of transportation mode is most analogous to taxis. The successful utilization of technologies enables ridehail services to be reliable, affordable, and accountable to travelers; in some cities, ridehail trips can be cheaper and more dependable than taxi trips (A. Brown & LaValle, 2020).

Though relatively new to the U.S. transportation sector, both ridehail and shared car are gaining popularity very rapidly. Comparing to household private automobiles, whose emergence became popular in 1908, carsharing experienced the most drastic growth in the early 2000s, while ridehail services emerged in the U.S. less than a decade ago (S. A. Shaheen et al., 2009; Varone, 2018). Even though these two forms of automobility are quite new, they have expanded significantly since their introduction. Researchers estimate that the global shared mobility market exceeded $50 billion in 2016, with the United States alone contributing $23 billion; the global market was projected to grow annually by 15% (Grosse-Ophoff et al., 2017). In addition, in 2015 about 33% of the Americans had never heard of ridehail services, but by 2018, this percentage dropped to only three percent (Pew Research Center, 2018). Similarly, membership in shared car services in North America grew more than 14 times, from approximately 120 thousand members in 2006 to 1.8 million in 2016 (S. A. Shaheen et al., 2018).

Current Adoption. Along with the growth of innovative automobile modes, there has been a number of studies on the demographic characteristics of shared car users. In general, members of shared car programs tend to be young, highly educated and have middle to high incomes. For example, Clewlow's analysis (2016) in the San Francisco Bay Area suggested that 84% of the shared car members held at least a bachelor's degree and 59% of households had an annual income over $100,000. However, the low participation rate of low-income individuals does not necessarily reflect a disinterest. Kim (2015) utilized vehicle inventory data from Zipcar and found no significant difference in usage rates among residents of low-income and affluent neighborhoods. In fact, on weeknights, shared vehicles were utilized at a higher rate in low-income neighborhoods than in other neighborhoods. Several barriers may impede low-income individuals from using shared cars, including limited access to smartphones or internet access, lack of credit cards, and an insufficient number of stations in low-income communities (Kodransky & Lewenstein, 2014).

In contrast, little is known about ridehail services despite the dazzling growth in riders. Due to the protection of commercial confidentiality and customer privacy, ridehail companies have shared little trip data with scholars and policymakers. Scholars have made many attempts to understand ridehail users, such as utilizing online user surveys or in-car intercept surveys. Current studies show that users are more likely to be younger and have higher educational attainment, but there are mixed results on the association between income and ridehail use. For instance, the Clewlow & Mishra (2017) study of 4,094 residents in major metropolitan regions revealed that 36% of the riders were between 18 to 29 years old, and the adoption rate doubled

among the college-educated (26%) compared to those without a college's degree (13%). This study found that the adoption rate of affluent riders was more than double that of poor riders (15% of the riders had an annual income below $35,000 compared to 33% of riders who had annual income above $150,000). The intercept study conducted by Gehrke et al. (2018) showed a different income distribution of ridehail riders. Among 780 respondents that were surveyed in their vehicles during a four-week period, the greater number were in the lowest income category. Riders with incomes less than $38,000 made up 23% of the ridehail population, compared to 17% among those with annual incomes above $137,000. A recent study by Brown (2018) relied on 3 months of trip data from Lyft, a predominant TNC company in the United States. This study showed an intriguing association between neighborhood income and Lyft users. The findings are based on the neighborhood characteristics of 828, 616 Lyft users as indicated by their billing zip code. The author found that while a larger share of Lyft users lived in high-income neighborhoods, users in low-income neighborhoods made trips more frequently (riders in low-income neighborhoods made 36% more trips per month than those in high-income neighborhoods). The finding suggests that ridehail services have the capability to bolster the mobility of residents living in low-income communities.

Impacts on Trips, Travel Behavior, and the Environment. Access to convenient and cheap ridehail and shared car services can influence individual travel behavior, such as trip frequency, trip length, and mode choices, and consequently, affect the society and environment as a whole. On the financial side, these alternative automobile modes efficiently convert the cost of driving from both fixed costs (e.g. car payment and insurance) and variable costs (e.g. gasoline and parking) to mostly variable costs. The majority of the costs of driving a car can be attributed to fixed cost – 81% for a small car that is driven below 10,000 miles per year (Transportation Research Board & National Academies of Sciences, Engineering, and Medicine, 2005). Car owners assume the full cost of ownership. However, with respect to ridehail and shared car services, the high up-front costs of vehicles are distributed across a large customer base, with each passenger contributing a small per-trip payment (A. E. Brown, 2018). Therefore, shared cars and ridehail could render automobility more affordable, particularly for lower-income travelers. For example, a survey of PhillyCarShare Program members showed that 40% of the member had saved money since joining the shared car program, with an average saving of $2,509 annually (Lane, 2005).

The reduced travel costs associated with shared car and ridehail use could, in turn, lead to changes in mode choice and vehicle ownership. The relationship between these new modes and transit is a hotly debated topic, and it remains uncertain. Studies have found that these modes could both compete with or be a complement to transit services, the latter by providing first- or last-mile service to/from transit stations. Additionally, many users of ridehail and shared cars reported a decrease in vehicle ownership, either avoiding the purchase of a car or forgoing a second or third car. A study that looked at fourteen shared car programs in North America found that on average, 21% of the shared car members gave up a vehicle after joining the program (Transportation Research Board & National Academies of Sciences, Engineering, and Medicine, 2005).

As a result of shifts in travel behavior, shared car and ridehail use can have significant impacts on automobile trip frequency, vehicle miles driven (VMT), and subsequently, the environment. On the one hand, empirical studies found that many travelers drove less due to the emergence of shared cars and ridehail. The survey on San Francisco ridehail users revealed that

40% drove less due to ridehail (Rayle et al., 2016). On the other hand, new shared transportation services also induce more trips and increase VMT. For example, the Clewlow & Mishra (2017) study found that 22% of the trips might have not been made at all if ridehail services had not been available. The authors argued that induced trips might bring more motorized vehicles onto the road. Nonetheless, increased vehicles do not necessarily lead to harmful impacts on the environment, because many of these vehicles have high occupancy. As shared rides become more widespread, multiple travelers could share the vehicle through services like carpooling. Lyft trip data in Los Angles suggested that a quarter of the Lyft trips were shared Lyft Line trips (A. E. Brown, 2018). In this sense, by choosing a shared car and ridehail, travelers could have a smaller carbon footprint than driving alone without reducing their travel plans and decreasing their mobility. It appears that whether shared car and ridehail services facilitate changes in VMT is complicated and depends on a plurality of factors. One possible factor is vehicle ownership. The evaluation of the Carsharing Portland program conducted by Cooper et al. (2000) showed that while members who did not have access to cars increased personal VMT by 22.3%, members who owned cars decreased personal VMT by 24.9%. The changes in VMT were not statistically significant, but the trends were suggestive. In general, the adoption of these alternative automobile modes is found to have a positive impact on the environment by encouraging travelers toward a cleaner transportation mode. Martin & Shaheen (2011) conducted an online survey on shared car members in North America and the findings indicated a reduction in greenhouse gas emission of 0.58 tons per household.

Methodology

Ridehail and shared car services are distinct from all other modes. In this study, I focus on their potential to be an alternative to private automobiles. I term taxicabs and ridehail as "taxi/ridehail," and traditional car rentals and shared car as "shared car." Taken together, I refer to taxi/ridehail and shared car as "alternative automobile modes."

I explore the current usage of alternative automobile modes with particular attention to the adoption of these modes among low-income households. I analyze data from the 2017 NHTS, conducted by the Federal Highway Administration (FHWA). The 2017 NHTS is the eighth and most recent national travel survey in a series that dates back to 1969. The dataset includes demographic, attitudinal, and travel behavior data collected in two phases. In the first phase of the study, participants were prompted to complete a survey about household, personal, vehicle, and general trip patterns. In the second phase, participants of the survey were assigned a particular travel day between April 19 to April 25, 2017. On the designated travel date, the respondent was instructed to keep a detailed travel diary of all the trips he/she made from 4 a.m. to 3:59 a.m. of the following day, and each trip record should include trip origination, destination, start time, end time, means of transportation, and trip purposes, among others.

The 2017 NHTS includes several changes in survey methodology, and the improvements in sample design are especially worth mentioning. The sampling method used by previous NHTS surveys, the Random Digit Dial telephone sampling method, had suffered from many criticisms, such as the undersampling of low-income households without telephones and the exclusion of the increasing number of households with only cellular phones but no landlines (Clewlow & Mishra, 2017). The previous surveys partially addressed these criticisms by weighting the survey responses of underrepresented populations. The 2017 NHTS resolves this problem by introducing a new sampling method: Address-based Sampling (ABS). The sampling frame

consists of all residential addresses on a frame originated from the U.S. Postal Service (USPS) Computerized Delivery Sequence file (CDS), and then the addresses are randomly selected based on Metropolitan Statistical Area designations. Hence, households without telephones are included as well.

The 2017 NHTS includes four data files: the household file, personal file, vehicle file, and trip file. Each data file contains socioeconomic attributes associated with either trip characteristics or household vehicle information. In this study, I conduct statistical analyses only on the trip file and household file. I analyze data from the trip file to understand the differences in the demographic and trip characteristics of travelers who use the three automobile modes – private car, taxi/ridehail, and shared car.[1] I analyze the socio-economic characteristics of each trip to produce an aggregate demographic distribution of users by my three modes of interest. The 2017 NHTS includes 923,572 daily trips. There are a total of 799,982 trips (86% of the total trips) via private car (795,163), taxi/ridehail (2,813), and shared car (2,006) (see Figure 1).

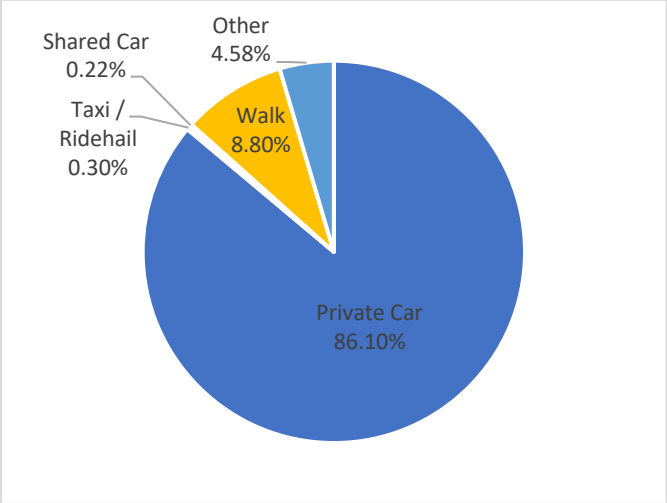

Figure 1. Mode of transportation.

The household file includes survey results from 129,696 households. I explore the attitudinal attributes of low-income automobile users. This file contains several variables that offer insight into the possible determinants of transportation mode choice. For example, high cost is arguably a major obstacle to driving and could be examined using the question that asks respondents whether they believe travel to be a financial burden.

Results

Comparison of Demographic Characteristics. The majority of taxi/ridehail and shared car users have high incomes. Forty-five percent of taxi/ridehail and 58% of shared car users have annual incomes above $100,000, compared to 35% of private car users. In contrast, around 21% of taxi/ridehail riders have household incomes below $25,000. This number is only 12% for private cars and four percent for shared car users (see Figure 2).

[1] Concerning the NHTS mode categories, the private car includes cars, vans, sport utility vehicles (SUV), and pickup trucks; taxi/ridehail refers to "taxi/limo (including Uber / Lyft)," and shared car refers to "rental car."

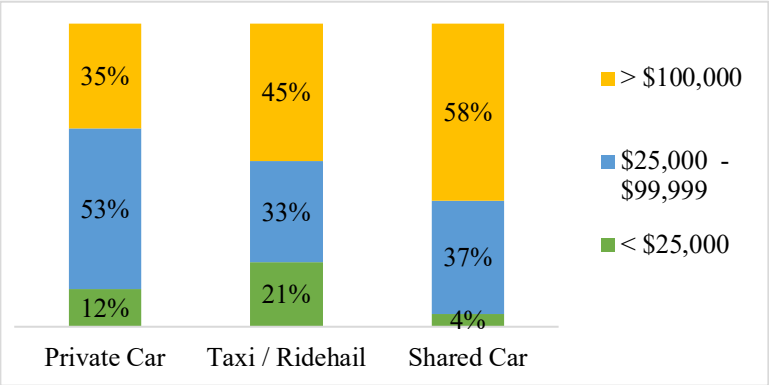

Figure 2. Distribution of users by income

The gender distributions of private cars and taxi/ridehail users are the same, with more female users than male users. Shared cars, in contrast, have more male than female riders (see Figure 3). The sex compositions of these three modes are comparable to the general U.S. population, which consists of 51% females and 49% males (U.S. Census Bureau, 2017).

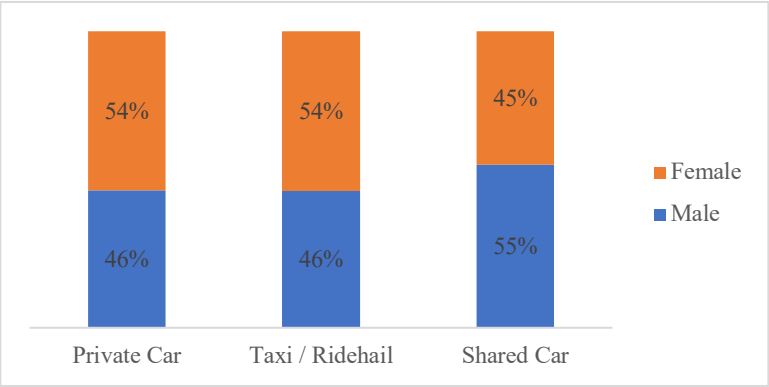

Figure 3. Distribution of users by gender

The predominant race of users for all three modes is non-Hispanic white. Passengers of the automobile modes are representative of the general U.S. population, of which approximately 61% are non-Hispanic white (U.S. Census Bureau, 2017). Yet taxi/ridehail riders are more diverse than riders of the other two modes. For example, around 10% of taxi/ridehail riders are black or African American, while that number is six percent for both private cars and shared cars (see Figure 4).

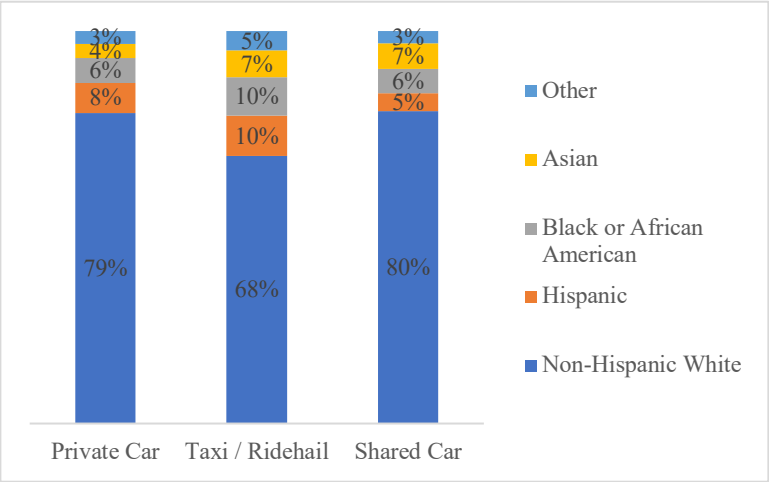

Figure 4. Distribution of users by race

Similar to private car users, most taxi/ridehail and shared car riders tend to have at least some college or bachelor's degree. The distribution by education for taxi/ridehail riders roughly resembles that of private car users, except that a higher percentage of taxi/ridehail users have a graduate degree or higher. Shared car riders are especially highly educated: 92% of riders have a college degree or higher (see Figure 5).

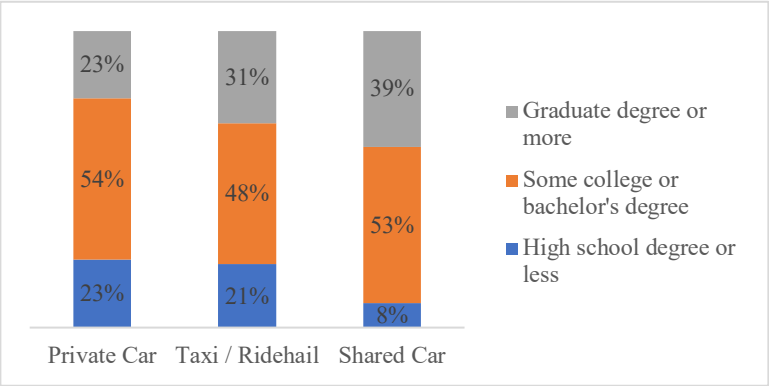

Figure 5. Distribution of users by education

The majority of all three automobile mode users are 31- to 55-year-old. Private cars and shared car users tend to have a similar age distribution; half of the users are above 55 years old and less than 15% of users are below 31 years old. In line with previous studies, I find that taxi/ridehail riders tend to be younger in general; sixty-eight percent are below 56 years old, including 25% of passengers who are between 16 to 30 years old (see Figure 6).

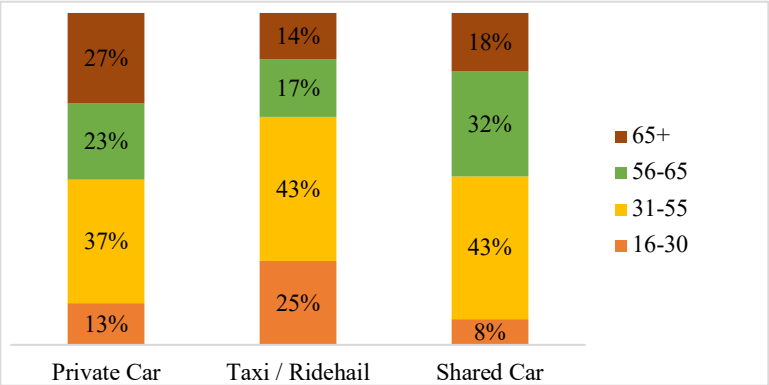

Figure 6. Distribution of users by age

Taxi/ridehail and shared car users include a higher proportion of workers than private cars, but the majority of riders are workers for all three automobile modes. While 59% of private car users are workers, that number increases to 67% and 65% for taxi/ridehail and shared car, respectively (see Figure 7).

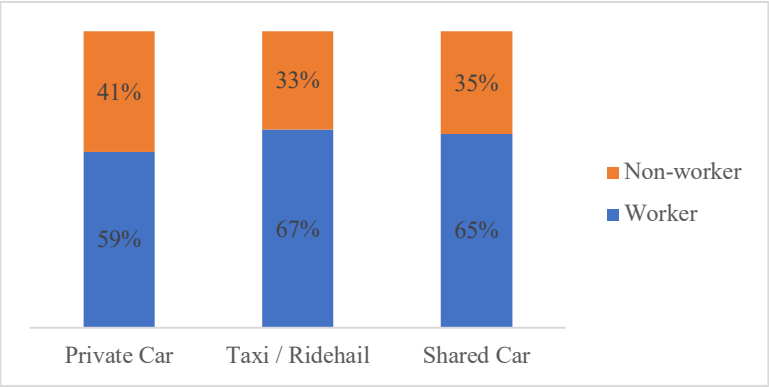

Figure 7. Distribution of users by worker status

Twenty-three percent of all private car trips take place in rural areas. However, taxi/ridehail and shared car services tend to be overwhelmingly urban in nature. Ninety-three and 86% of taxi/ridehail and shared car riders, respectively, are in urban areas. This number is substantially higher than the percentage of private car trips in urban areas (77%) (see Figure 7).

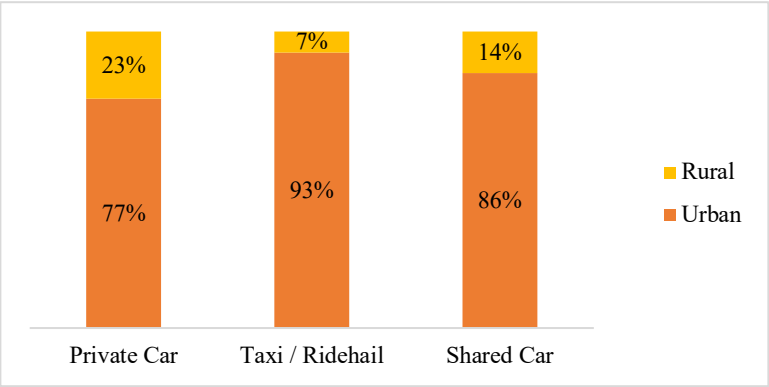

Figure 8. Distribution of users by urban-rural classification

A substantial proportion of taxi/ridehail trips come from travelers who live in zero-vehicle or auto-deficit households, while shared car trips display a similar vehicle ownership pattern as private car trips. Auto-deficit households are households with less than one car per driver. Twenty-five percent of taxi/ridehail trips are taken by those in zero-vehicle households, and another 12% come from trips made by those in auto-deficit households. In contrast, only four percent of shared car use trips are taken by those with zero-vehicles in their households and 11% from auto-deficit households. Eight percent of trips in private cars are made by those in auto-deficit households.

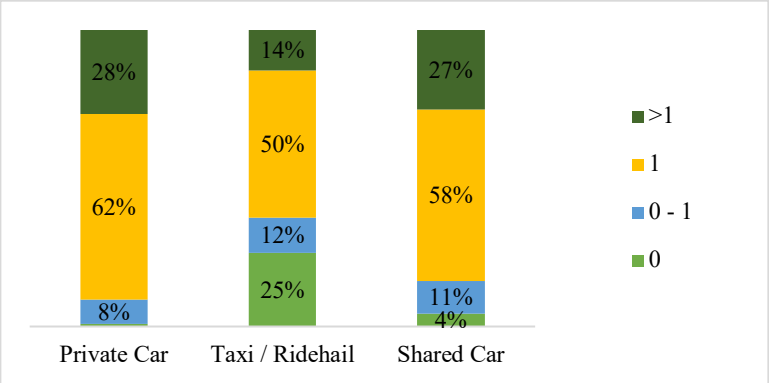

Figure 9. Distribution of users by vehicle/driver ratio

Comparison of Trip Characteristics. A plurality of trips made by taxi/ridehail and shared car is for social or work-related purposes. Travelers often use alternative automobile modes for social or recreational purposes, such as visiting relatives, or going to restaurants and bars. Only 26% of trips in private cars are made for this purpose compared to 37% in taxi/ridehail and 44% in shared car. Furthermore, data suggest that travelers use these alternative modes for work trips at a similar rate as private cars. Taxi/ridehail trips even have a slightly higher proportion of work-related trips than private car trips (21% and 19%, respectively). Finally, while 21% of private car trips are for shopping and 30% are for family/personal businesses (e.g. going to the dentist, cleaning garments, and haircuts); very few of these trip types are made using the other two modes (see Figure 10).

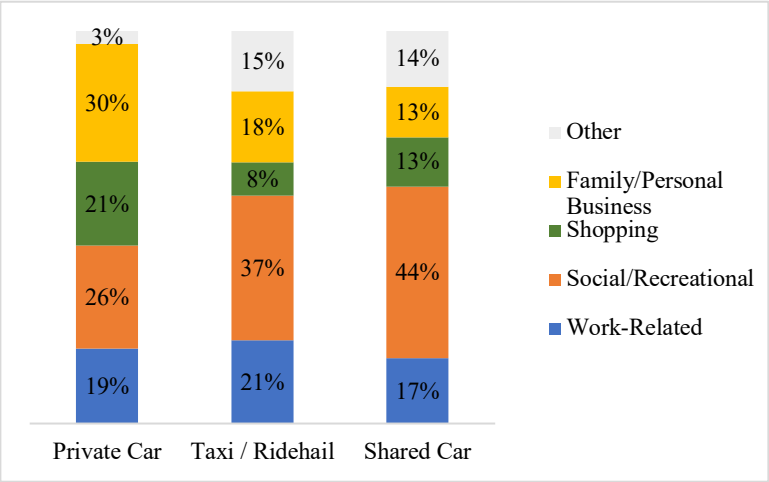

Figure 10. Distribution of trips by trip purposes (1990)

The trips made by alternative automobile modes are typically longer in duration. The median trip duration of taxi/ridehail and shared car trips is 5-6 minutes longer than private car trips (see Figure 11). The distance of the trips made by taxi/ridehail is slightly shorter than that of private cars, but the median trip miles of shared car trips are much longer than private cars (see Figure 12). A t-test shows that the differences in trip duration and trip miles between modes are statistically significant.

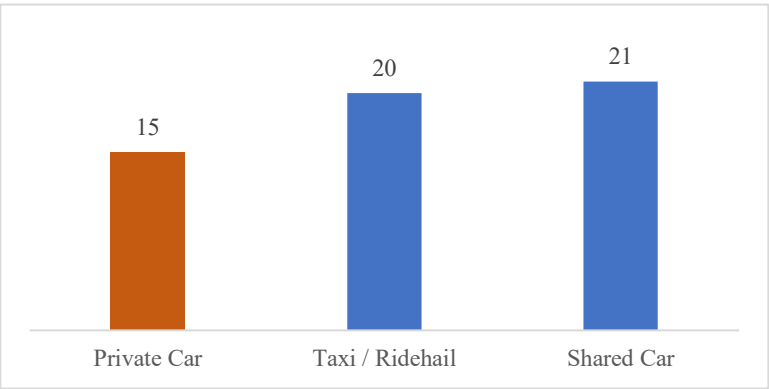

Figure 11. Median trip duration (in minutes)

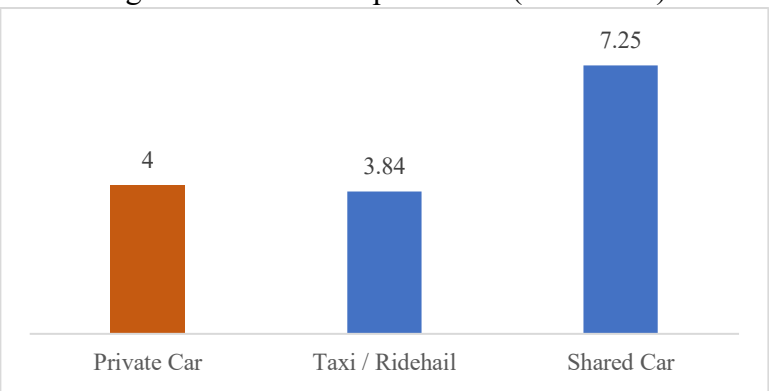

Figure 12. Median trip miles (in miles)

Characteristics of low-income households. To further understand the feasibility of alternative automobile modes in bridging the automobility gap and improving transportation equity, in this section, I focus on the characteristics of low-income households, especially those with zero-vehicles. I define low-income households as households with annual incomes below $25,000; this household income threshold approximates the bottom income quintile.

Low-income households tend to have lower car ownership rates than higher-income households. Among low-income households, 18% of households are zero vehicles and seven percent are auto-deficit households, having less than one car per driver. In contrast, only one percent of households with annual income above $100,000 are carless (see Figure 13). Among carless households, 73% are low-income; while within fully equipped households (households with at least one car per driver), less than 15% are low-income. In other words, the majority of households with sufficient cars have higher incomes (see Figure 14).

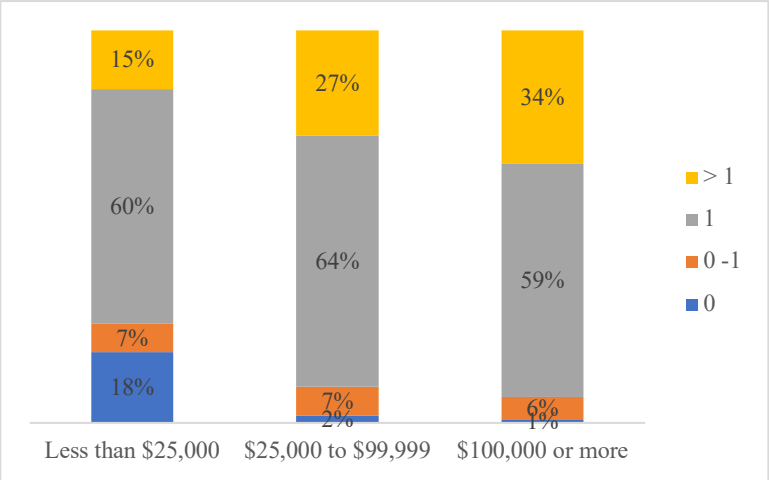

Figure 13. Vehicle ownership distribution, by income

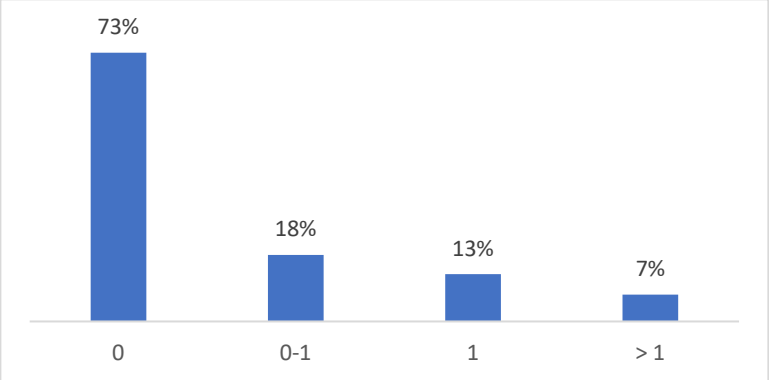

Figure 14. Rate of low-income households, by vehicle ownership

A large proportion of taxi/ridehail trips are made by carless low-income households, around 20%. In contrast, this percentage is less than one percent of the private car and shared car trips (see Figure 15).

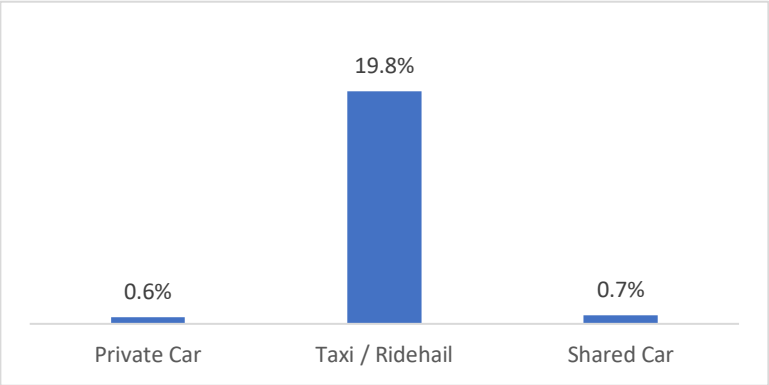

Figure 15. The proportion of trips made by zero-vehicle low-income households, by transportation mode

Trip lengths also vary by household income. Regardless of mode, increasing household income tends to be associated with higher median trip miles. The median trip miles of low-income individuals are below the median trip miles of the general population in their mode group. The median trips miles of taxi/ridehail riders with low-income are the shortest among the three automobile modes, and low-income shared car users travel the longest distances. Nonetheless, there is not much difference in trip travel time across income groups for private car and taxi/ridehail riders. Shared car users with incomes between $25,000 - $99,000 do not have the highest median trip miles but have the highest median trip duration compare to the other two income groups (see Figure 16 & Figure 17).

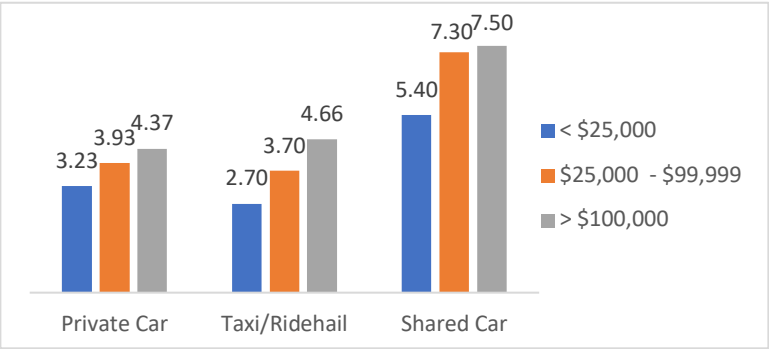

Figure 16. Median trip miles (in miles) of riders by mode and income

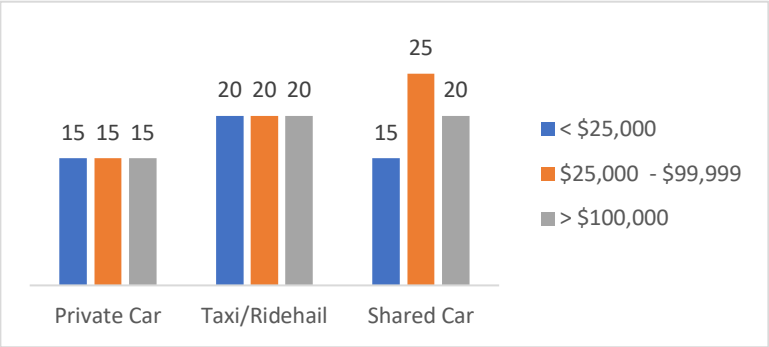

Figure 17. Median trip duration (in minutes) of riders by mode and income

I analyze respondents' self-reported frequency of taxi/ridehail use with regard to their income. The results showed that a higher percentage of frequent taxi/ridehail users have lower incomes than those who barely use taxis or ridehail. Almost half (48%) of the daily taxi/ridehail users have household incomes below $25,000.

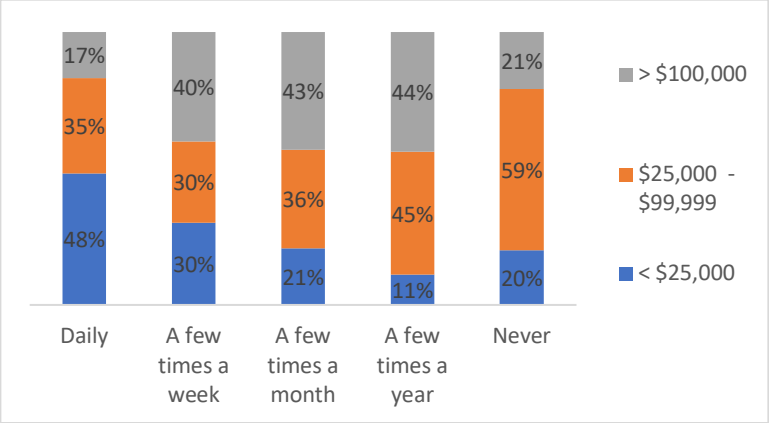

Figure 18. Distribution of taxi/ridehail use frequency, by income

Studies suggest that taxi/ridehail will reduce travel costs and hence have the potential to increase the mobility of low-income households. To examine this statement, I analyze responses to four questions about finance and travel from the household file. These four questions ask whether the respondents believed travel is a financial burden and whether they walk/transit/bike to save money. I then examine the association between frequent taxi/ridehail users and the distribution of responses to these questions.

Among daily taxi/ridehail users, 56% agree that travel is a financial burden, including 26% of the people who strongly agree with the statement. These percentages suggest that there is a large overlap between frequent taxi/ridehail riders and people who suffer from a heavy transportation financial burden. Similarly, 47% - 48% of daily taxi/ridehail users agree that they would walk or use transit to save money. The analysis of these two questions suggests that daily taxi/ridehail users might tend to prioritize price when making mode choice. And their choice to use taxis or ridehail daily also suggests that the price of a taxi/ridehail is ideal for their travels. Daily taxi/ridehail users who also bike, in contrast, appear to show a different reason for biking. Around 59% of the respondents do not agree that the reason for their biking is to save money.[2]

[2] Interestingly, among respondents who are daily taxi/ridehail users and do not bike to save money, 16% have annual incomes below $25,000, while 30% have incomes above $100,000; additionally, approximately 90% of them have at least one car per driver in their household, compared to only three percent households who are carless. It should also be noted that the sample size of this population is 180. See Appendix 2.

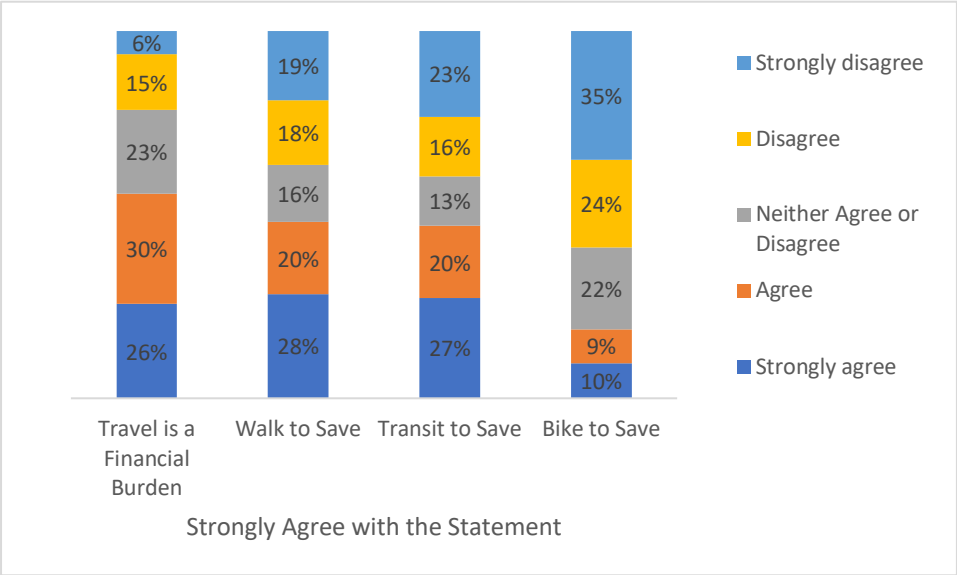

Figure 19. Distribution of daily taxi users, by statements

Discussion

While innovative transportation modes such as shared car and ridehail services provide new alternative automobile modes and have revolutionized the way people gain access to automobiles, relatively little is known about who and how people are using these modes and whether the population of users differs from the traditional private vehicle riders. In particular, there is limited literature on low-income households' access to these modes. I explore three questions in this study using 2017 NHTS data: First, what are the demographic characteristics of riders of alternative automobile modes and how do they differ from that of private vehicles? Second, what are the trip patterns of alternative automobile modes users, and are they different from private vehicle trips? Third, do low-income travelers use automobile modes differently than travelers in other income groups?

The demographic compositions of taxi/ridehail and shared car are different from that of private cars. First, my findings on taxi/ridehail users are consistent with previous studies that the majority of riders are young, well-educated, have higher incomes, and live in urban areas. However, this finding does not necessarily suggest that people with low-income are excluded from this mode. Compared to private vehicle users, taxi/ridehail services serve a higher proportion of low-income travelers (12% vs. 21%). In addition, a quarter of taxi/ridehail riders are carless households and another 12% are auto-deficit; only eight percent of private car users are auto-deficit. These differences may reflect the demand for taxi/ridehail among people with low-income and indicate that taxi/ridehail could be a viable service to facilitate automobility access without necessarily adding more personal vehicles. Second, the rider population of shared car is different from users of private vehicles, but there are many nuances to this finding. Shared car use tends to be more popular among travelers with high income and high education levels, compared to both private vehicles and taxi/ridehail. Shared car contributes positively to automobility among car-deficit households. Fifteen percent of shared car users are car deficit compared to eight percent of private car users. This finding perhaps echoes studies that found many households who gave up their second or third alternative vehicle due to the convenience of shared cars (Cervero et al., 2003; Lane, 2005).

A large proportion of taxi/ridehail and shared car trips serve social/recreation and work-related purposes. As previous survey research revealed, many drivers chose to use alternative automobile modes instead of driving alone because they wanted to avoid driving when they might have alcohol, such as going out to bars or parties (Clewlow & Mishra, 2017). Yet, previous studies neglected the use of these alternative modes to fulfill work-related trips. An even higher share of taxi/ridehail trips is work-related compared to private cars. Planning for these new modes could include how best to integrate taxi/ridehail and shared car with transit for the commute. For example, the CarLink program, a car sharing model in San Francisco, provides employers with shared vehicles to drive between transit stations and their work sites in suburban locations. This design not only promotes transit use but also reduces VMT and vehicle ownership (S. A. Shaheen & Rodier, 2005). Moreover, the median trip length of taxi/ridehail trips is shorter than private vehicle trips, while shared car is used for substantially longer trips. The trip duration of both taxi/ridehail and shared car is longer than that of private cars.

There is an association between households with low-incomes and households with car deficiencies. Taxi/ridehail is a promising mode to enhance automobility for those who need it the most. Exploring the relationship between vehicle ownership and income, I find that low-income households are more likely to be carless or car-deficit than higher-income households. For example, 73% of zero-vehicle households are low-income. Taxi/ridehail services have a high potential to close this income-based automobility gap. Roughly 20% of the taxi/ridehail trips are taken by individuals from zero-vehicle and low-income households. Also, almost half of daily taxi users have incomes below $25,000. Furthermore, a large proportion (56%) of daily taxi/ridehail users agree that travel is a financial burden to them. And there is a large overlap between daily taxi/ridehail users and people who choose to walk or use transit for the sake of saving money. For these users, the choice to use taxi/ridehail may imply that taxi/ridehail is a cost-effective mode. These findings suggest that low-income households need automobiles and that, at least, some of this need can be fulfilled by taxi/ridehail services.

These results suggest an opportunity to expand the use of alternative automobile modes by initiating programs specifically for low-income households. Many organizations have already incorporated low-income-specific programs in their models. For example, the California Air Resources Board (CARB) is cooperating with BlueLA Carsharing to subsidize the use of shared electric vehicles for low-income travelers in Los Angeles. Policymakers may consider expanding subsidies to taxi/ridehail and other shared car organizations. In particular, collaboration with services that use clean vehicles can boost automobility among disadvantaged communities at the same time as they also reduce greenhouse gas emissions.

Despite the potential of these alternative modes to improve transportation equity, there are many barriers that prevent those in need from accessing these services. For example, most ridehail and shared car services require the use of smartphones. However, while smartphones have become more prevalent among Americans, 41% of low-income households never use a smartphone to access the Internet, compared to only six percent in high-income households (see Appendix 3). Another challenge is that these online transportation applications often require the use of bank accounts to fulfill payments. Yet the 2017 National Survey of Unbanked and Underbanked Households showed that 26.9% of households were either unbanked or underbanked, suggesting that approximately one in four households would encounter difficulties in hailing a ride or using a shared car (Apaam et al., 2018).

Some companies have already attempted to tackle these challenges. For example, in 2017, Uber launched a feature to let users book rides for someone other than themselves. This

feature can help travelers without smartphones get rides by letting their families and friends book rides for them (Lien, 2017). Moreover, several TNCs allow users to hail a ride by talking with operators via landlines, such as GoGoGrandparent and RideWith24.

Taxi/ridehail and shared car services offer novel methods for travelers to gain automobility without vehicle ownership. Although they face many challenges, these two alternative automobiles have the potential to improve mobility, especially for low-income, carless, or car deficit households. Planners and policymakers should continue to investigate approaches to better involve disadvantaged communities in using these new transportation modes as a means to enhance both mobility and equity.

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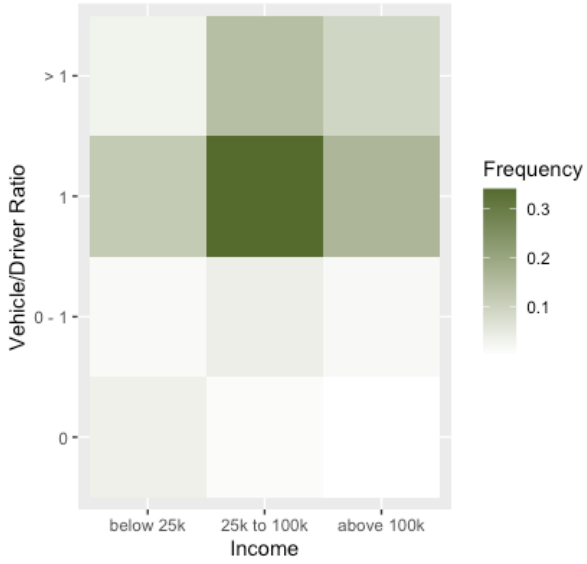
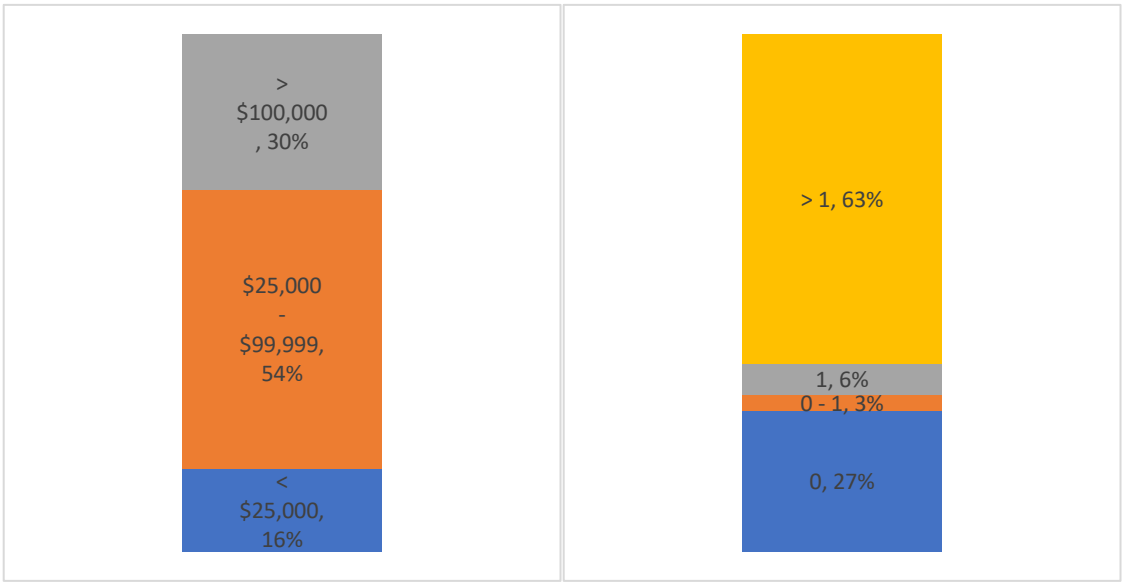
Appendix

Appendix 1. Two-way frequency of income level and vehicle-to-driver ratio



Appendix 2. Distribution of daily taxi users who do not agree they bike to save money, by income (left) and vehicle ownership (right)



Appendix 3. Proportion of the population that never uses a smartphone to access the internet