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To Pool or Not to Pool? Understanding the Time and Price Tradeoffs of OnDemand Ride Users – Opportunities, Challenges, and Social Equity Considerations for Policies to Promote Shared-Ride Services

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RESEARCH REPORT

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To Pool or Not to Pool? Understanding the Time and Price Tradeoffs of On-Demand Mobility Users – Opportunities, Challenges, and Equity Considerations for Policies to Promote Shared-Ride Services

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16. Abstract
On-demand mobility services including transportation network companies (also known as ridesourcing and ridehailing) like Lyft and Uber are changing the way that people travel by providing dynamic mobility that can supplement public transit and personal-vehicle use. However, TNC services have been found to contribute to increasing vehicle mileage, traffic congestion, and greenhouse gas emissions. Pooling rides — sharing a vehicle by multiple passengers to complete journeys of similar origin and destination — can increase the average vehicle occupancy of TNC trips and thus mitigate some of the negative impacts. Several mobility companies have launched app-based pooling services in recent years including app-based carpooling services (e.g., Waze Carpool, Scoop) that match drivers with riders; pooled on-demand ride services (e.g., Uber Pool and Lyft Shared rides) that match multiple TNC users; and microtransit services (e.g., Bridj, Chariot, Via) that offer on-demand, flexibly routed service, typically in larger vehicles such as vans or shuttles. However, information on the potential impacts of these options is so far limited. This research employs a general population stated preference survey of four California metropolitan regions (Los Angeles, Sacramento, San Diego, and the San Francisco Bay Area) in Fall 2018 to examine the opportunities and challenges for drastically expanding the market for pooling, accounting for differences in emergent travel behavior and preferences across the four metropolitan regions surveyed. The travel profiles, TNC use patterns, and attitudes and perceptions of TNCs and pooling are analyzed across key socio-demographic attributes to enrich behavioral understanding of marginalized and price sensitive users of on-demand ride services. This research further develops a discrete choice model to identify significant factors influencing a TNC user's choice to pool or not to pool, as well as estimating a traveler's value of time (VOT) across different portions of a TNC trip. This research provides key insights and social equity considerations for policies that could be employed to reduce vehicle miles traveled and emissions from passenger road transportation by incentivizing the use of pooled on-demand ride services and public transit.

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Table of Contents

Table of Contents

List of Tables

List of Figures

Glossary

App-based carpooling: Also known as dynamic carpooling, a form of ad-hoc carpooling facilitated via a smart-phone application or website that enables users to request or offer a shared ride, coordinate pickup/drop-off details, and make or receive a nominal payment to reimburse the driver for actual travel expenses (e.g., tolls, gas, etc.).

Area-wide congestion pricing: A per-mile congestion charge that applies per mile driven within a charging zone.

Casual carpooling: Also known as slugging, a form of ad-hoc, informal carpooling among strangers in which no money is exchanged or passenger pay a nominal amount to reimburse drivers for actual travel expenses (e.g., tolls, gas, etc.). In some regions, designated casual carpooling locations serve as a meeting point for drivers to pick-up passengers waiting for a shared ride.

Congestion pricing: Pricing policies to improve transportation system performance by charging vehicles for access to roads in designated areas or facilities (e.g., designated lanes on a highway) during congested periods.

Cordon tolls: A congestion charge for entry and/or exit to a charging zone.

Curb access management: The management of access to the curb by people and vehicles including space allocation for specified purposes (e.g., parking, transit, pedestrian), access restrictions (e.g., vehicle loading/unloading zones), and pricing (e.g., metering, permits).

Deadheading: A period in which a vehicle in a mobility service is operating without passengers.

Heavy TNC users: People that use TNCs more than three days per week.

Frequent TNC users: People that use TNCs at least once a week.

Indirect pooled rides: Pooled on-demand rides that require passengers to walk a short distance to/from their pickup/drop-off location as opposed to receiving door-to-door service.

Mobility as a Service (MaaS): A concept envisioning integrated mobility where travelers can access their transportation modes over a single digital interface. MaaS primarily focuses on passenger mobility allowing travelers to seamlessly plan, book, and pay for travel on a pay-as-you-go and/or subscription basis.

Mobility on Demand (MOD): A concept envisioning an interconnected and coordinated mobility ecosystem to meet the needs of all users by providing the safe, reliable, and efficient movement of people and goods upon request. MOD offers users personalized mobility and goods delivery options upon request, matched with coordinated network strategies of service providers and operations managers.

Microtransit: A technology-enabled transit service that typically uses shuttles or vans to provide pooled on-demand transportation with dynamic routing.

Mileage-based road pricing: Encompasses both mileage-based road user fees (MBUF) and area-wide congestion charging in which vehicles are charged a specified fee per mile driven. MBUFs are currently being piloted in select states across the United States including California, primarily as a transportation funding mechanism to replace gas excise taxes.

Ridesharing: The grouping of multiple travelers into a car or van to complete a common trip. Certain terms are sometimes used inconsistently or confusingly to characterize TNCs/ridesourcing/ridehailing. A for-hire vehicle service with one paid driver and one paying passenger is not considered ridesharing (or carpooling). While some TNCs offer shared rides for more than one traveler, these services are referred to as "ridesplitting," "pooling," and "taxi sharing," the latter used to describe sharing a taxi cab.

SB 1014 (Clean Miles Standard): Requires transportation network companies (TNCs) to reach a per-passenger-mile greenhouse gas (GHG) emission level and develop future GHG reduction plans.

Shared micromobility: The shared use of a bicycle, scooter, moped, or other low-speed mode that provides travelers with short-term access on an as-needed basis.

Transportation demand management (TDM): A set of defined strategies aimed at providing travelers with effective choices to improve travel reliability, particularly in relation to work trips.

Transportation network company (TNC, also known as ridesourcing and ridehailing): A service that provides the traveler with pre-arranged and/or on-demand access to a ride for a fee using a digitally-enabled application or platform (e.g., smartphone apps) to connect travelers with drivers using their personal, rented, or leased motor vehicles. Digitally enabled applications are typically used for booking, electronic payment, and ratings.

Executive Summary

Executive Summary

On-demand mobility services including transportation network companies (TNCs, also known as ridesourcing and ridehailing) like Lyft and Uber are changing the way that people travel by providing dynamic mobility that can supplement public transit and personal-vehicle use. However, TNC services have been found to contribute to increasing vehicle mileage, traffic congestion and greenhouse gas emissions, in part due to increased time spent in transit without passengers, known as deadheading. Pooling — the sharing of a vehicle by multiple travelers to complete journeys of similar origin and destination — can increase the average vehicle occupancy of TNC trips and thus mitigate some of the negative impacts. Several mobility companies have launched app-based pooling services in recent years. These include app-based carpooling services (e.g., Waze Carpool, Scoop) that match drivers with riders, pooled on-demand ride services (e.g., Uber Pool and Lyft Shared rides) that match multiple TNC users, and microtransit services (e.g., Bridj, Chariot, Via) that offer on-demand, flexibly routed service, typically in larger vehicles such as vans or shuttles.

The growth of these app-based carpooling, microtransit, and on demand pooled-ride services presents a unique opportunity to limit congestion, energy use, and emissions through increased vehicle occupancy. However, the success of these mobility options will be largely dependent on the decisions of individual travelers to pool or not to pool. It is imperative to develop a deeper understanding of which population segments are most likely to be affected by pricing policies such as congestion charging and mileage-based pricing, which are increasingly under consideration as well as the magnitude of congestion and emission reduction that may be achieved by various strategies.

This research employs a general population stated preference survey of four California metropolitan regions (Los Angeles, Sacramento, San Diego, and the San Francisco Bay Area) in Fall 2018 to examine the opportunities and challenges for drastically expanding the market for pooling, accounting for differences in emergent travel behavior and preferences across the four metropolitan regions surveyed. The travel profiles, TNC use patterns, and attitudes and perceptions of TNCs and pooling are analyzed across key socio-demographic attributes to enrich behavioral understanding of marginalized and price sensitive users of on-demand ride services. This research further develops a discrete choice model to identify significant factors influencing a TNC user's choice to pool or not to pool, as well as estimating a traveler's value of time (VOT) across different portions of a TNC trip. This research provides key insights and social equity considerations for policies that could be employed to reduce vehicle miles traveled and emissions from passenger road transportation by incentivizing the use of pooled on-demand ride services and public transit.

Pooling Defined

Carpooling, also known as ridesharing, is the grouping of multiple travelers into a car or van to complete a common trip. Traditional ridesharing includes acquaintance-based and organization-based carpools (groups of two to six traveling together in a car) and vanpools (groups of seven to 15 commuting together in one van) as well as casual carpooling, also known as "slugging" (Shaheen and Cohen, 2019). Recently, socio-economic forces coupled with technological innovation have given rise to a new wave of pooling enabled by app-based services that reserve, match, and process payments for pooled rides. Several mobility companies have launched app-based services for traditional ridesharing (e.g., Waze Carpool, Scoop), although some pilot projects have been discontinued due to low match rates (e.g., Lyft Carpool) (Shaheen and Cohen, 2019).

Transportation network companies (TNCs), also known as ridesourcing and ridehailing services like Lyft and Uber, also offer pooled on-demand ride options (e.g., Uber Pool and Lyft Shared rides), in which users may choose to share a ride with another passenger or passengers traveling along a similar path for a reduced fare. However, pooled rides are a relatively small fraction of overall TNC ridership, comprising just 20 percent of all Uber rides and 40 percent of Lyft rides in 2017 (Shaheen and Cohen, 2019). Data on matching rates for pooled TNC rides is scarce, although it suggests that so far, the density of pooled ride requests remains insufficient to facilitate a significant increase in TNC vehicle occupancy (Schaller, 2018; CARB, 2019).

In 2017, both major TNC companies launched modified versions of their pooled on-demand ride services, called Uber Express POOL and Lyft Shared Saver, referred to as indirect pooled rides in this report, which require that passengers walk a short distance to/from their pickup/drop-off location (Lyft, 2017; Uber, 2017). These services resemble microtransit, which offers flexible- or fixed-route rides with fixed-schedule or on-demand service in shuttles or vans (Shaheen and Cohen, 2019). This approach could further reduce the cost and duration of pooled rides, potentially increasing their acceptability and use, as well as ameliorating some concerns over traffic congestion from uncontrolled curb use for passenger loading/unloading.

Pandemic Issues

As urban areas prepare to loosen restrictions on daily activities requiring travel, public transit agencies across the globe are considering the development or expansion of microtransit services to provide more flexible, lower-density alternatives to traditional transit in an effort to avoid a dramatic increase in reliance on personal autos due to lingering aversions to high density public transit (Johnson, 2020). Although mobility plans for the recovery phase of the pandemic are still evolving, forecasts of worst-case modal split scenarios show lasting increased individual vehicle use and lower public transit ridership, demonstrating the importance of pooled ride services in providing essential mobility while reducing the prospects of gridlock.[1]

Research Objectives and Results

This research provides key insights into policies that could be employed to reduce vehicle miles traveled (VMT) and emissions from passenger road transportation by incentivizing the use of pooled on-demand ride services and public transit. We employ a general population stated preference survey of Los Angeles, Sacramento, San Diego, and the San Francisco Bay Area conducted in Fall 2018 to examine the opportunities and challenges for drastically expanding the market for pooling, considering the nuances in emergent travel behavior and demand sensitivity for on-demand rides across the four California metropolitan regions studied. We also develop a discrete choice model to investigate the significant factors influencing a TNC user's choice to pool or not to pool, as well as the estimation of a traveler's value of time (VOT) across different time segments of a TNC trip.

[1] In 2020, several pooled on-demand ride services were suspended due to public health concerns during the COVID-19 pandemic (Etherington, 2020). Some app-based ride services have continued to operate with a limit of one person per row of seats and other precautions following public health guidelines (Salzberg, 2020).

Pooling demand sensitivity varies significantly across trip contexts, metropolitan regions, socio-demographics, travel behavior, and attitudes and perceptions toward sharing. We estimate the time and price tradeoffs in choosing between ride alone and pooled on-demand service options, finding significant differences across values that travelers place on each component of travel time (wait, access/egress walking, and in-vehicle time) by geography and income level.

We examine which groups may be the most likely to engage in pooling, and therefore may be encouraged to increase their use in the future, including to access public transit. The results of this study demonstrate that TNCs present a significant opportunity to expose travelers to ridesharing and shift captive high-frequency TNC users to higher-occupancy rides. While monthly carpool/vanpoolers comprise just 10 to 15 percent of the population across all metropolitan regions surveyed, active TNC users make up about 45 to 55 percent of the populations in these regions. Frequent TNC users — those that use TNCs once a week or more — are more likely to consider pooling when using TNCs than less frequent users and engage in more multimodal travel behavior than other travelers, including higher rates of carpooling/vanpooling and public transit use. However, we observed that about a third of weekly TNC users consider pooling less than half the time they use TNCs and although public transit use is greatest among frequent TNC users, the majority of weekly TNC users are not using TNCs to access public transit.

We identify a sizable opportunity to increase pooling rates among *heavy* TNC users — those using TNCs more than three days per week — who are disproportionately low income, more likely not to own or lease a car, and more likely to use TNCs for essential trip purposes than less frequent users. Heavy TNC use also varies notably across race and ethnicity, reflecting differences in socio-economic disparities across racial and ethnic groups in each metropolitan region studied. In particular, heavy TNC use among young people reflects higher usage among: 1) higher income young Caucasian/Non-Hispanics and 2) lower income African Americans. Although heavy TNC users constitute a relatively small portion of the overall population across the four metropolitan regions surveyed, they represent a cohort of TNC users that will be among the most impacted by transportation demand management (TDM) policies, as they have incorporated on-demand ride services into their weekly routine beyond just weekend travel and are likely to consider on-demand rides in their mode choice decisions on a daily basis. Moreover, a majority of daily TNC users make more than one TNC trip per day, across all of the regions surveyed.

Based on heavy TNC users' greater propensity to use TNCs for essential trips as well as the significance of trip purpose in the sensitivity of their demand for pooled rides, they are most likely to respond to promotional offers (such as free or discounted rides) for pooling to public transit stations, employment centers, and healthcare services. There is also tremendous untapped potential to increase the market share of pooling among commuters as the likelihood to pool is greatest for work trips in all metropolitan regions studied except for the San Francisco Bay Area, where trips to public transit have a slightly higher likelihood for pooling. The results also suggest that, by converting waiting time to walking time and reducing in-vehicle time, indirect pooled rides can be a significantly more attractive ride option with co-benefits for society and the environment.

Policy Options

We conclude with a discussion of the potential to leverage these insights to develop policies that reflect the geospatial and socio-demographic differences across regions to encourage pooling and more efficient TNC routing that reduces deadheading and excess VMT:

- In residential and commercial zones, **dedicated pickup and drop-off locations** for on-demand rides can aid in aggregating demand for pooled ride services, while providing a mechanism for pricing and enforcement of desirable curb access restrictions. In a dynamic curb access management system, differentiated pricing could incentivize pickups and drop-offs at designated locations that minimize disruption to traffic flow and improve safety, while imposing a premium on door-to-door services.

- In particularly congested conditions that arise frequently in central business districts during peak commute hours, the combination of **mileage-based congestion charging** with **time-sensitive curb access restrictions** could offer a promising strategy to manage congestion from on-demand rides while incentivizing pooling. As congestion charging policies are being investigated and developed in many metropolitan regions including San Francisco and Los Angeles, consideration of area-wide schemes in which vehicles are charged per mile driven within a charging zone is recommended to provide an additional financial incentive to reduce VMT and increase pooling during peak periods. Restricting TNC curb access to strategically placed pickup/drop-off locations during peak periods can further incentivize pooling by shifting wait times to walking time and increasing matching rates. Existing activity data reporting requirements for TNCs in California under the California Public Utilities Commission (CPUC) Decisions D.13-09-045 and D.16-04-041 and SB 1014 (also known as the Clean Miles Standard) would facilitate the enforcement of such policies.

- **Subsidized pooled rides** for travelers that are low-income, unemployed, or have a medical condition/ handicap could greatly increase mobility and accessibility for these groups. Such programs may be modeled after shared micromobility low-income membership programs (e.g., Bikeshare for All), which determine eligibility by verifying participation in local, state, or federal aid programs such as CalFresh or Medicaid. In addition, **level of service regulations or incentives** analogous to shared micromobility permit programs are recommended to ensure a minimum level of travel time reliability for particular geographic regions or user groups. For example, activity data reported to the CPUC could be leveraged to audit TNC wait times for targeted communities.

- **Simple promotions** can also provide effective incentives for pooling. Offering a discount off of a future ride in return for choosing a pooled ride can be a particularly impactful strategy for reducing VMT during periods of peak or abnormal congestion, such as during rush hour or a major event. Travelers can also be given incentives to pool across multiple trips by offering a free ride in return for taking a specified number of pooled rides.

- Finally, offering **discounts on public transit fares** in return for pooling to a public transit station could be a strategy for increasing public transit ridership through pooled first/last mile connections. It may be particularly beneficial to target public transit discounts toward marginalized communities to alleviate the cost burden of heavy TNC use that may arise from poor reliability or limited access to public transit while promoting pooling. Mobility as a service (MaaS) or mobility on demand (MOD) strategies can be leveraged for this purpose by providing eligible travelers with discretionary subsidies for a suite of mobility services with an integrated trip planning, reservation, and payment system.

Contents

Introduction

In recent years, the transportation ecosystem in most urban areas across the globe has expanded to include a suite of technology-enabled, shared mobility services such as carsharing, bikesharing, scooter sharing, and transportation network companies (TNCs), also known as ridesourcing and ridehailing services like Lyft and Uber. These innovative services are changing the way people travel by providing dynamic, on-demand mobility that can supplement public transit and personal-vehicle use. There is, however, growing evidence that TNCs are contributing large sums of additional vehicle miles traveled (VMT) in large dense metropolitan areas of the United States (Schaller, 2017; SFCTA, 2017; Schaller, 2018), with an estimated 20 to 45 percent of TNC VMT consisting of "deadheading" miles — miles driven without a passenger in the vehicle (Henao and Marshall, 2019; Cramer and Krueger, 2016; SFCTA, 2017; Schaller, 2017).[2]

Pooling rides — the shared use of a vehicle by multiple passengers to complete journeys of similar origin and destination — can increase the average vehicle occupancy of TNC trips and thus reduce VMT, energy use, and greenhouse gas (GHG) emissions (Viegas et al., 2016; WEF and BCG, 2018; Greenblatt and Saxena, 2015). Yet, there is limited understanding of the sensitivity for pooling demand, particularly within the context of on-demand ride services.

Traditional ridesharing, or carpooling, has a long history as a transportation demand management (TDM) tool in North America, with large employers historically playing a central role in the incentivization and facilitation of commuter carpooling programs. In addition, casual carpooling, in which strangers share rides through informal regional systems has thrived for decades in the metropolitan regions of Houston, Texas, Washington, D.C. and Northern Virginia, and the San Francisco Bay Area. Participation in casual carpooling is driven by significant driver and passenger travel-time savings from gaining High Occupancy Vehicle (HOV) lane access as well as passenger cost savings and perceived convenience over driving alone and public transit options (Shaheen and Cohen, 2019). Recently, socio-economic forces coupled with technological innovation have given rise to a new wave of pooling enabled by app-based services that reserve, match, and process payments for pooled rides on-demand. However, the broader impacts of these innovative mobility services are highly uncertain and largely dependent on the ubiquity of riders willing to share their rides.

Several mobility companies have launched app-based ridesharing services (e.g., Waze Carpool, Scoop), although some pilot projects have been discontinued due to low match rates (e.g., Lyft Carpool) (Shaheen and Cohen, 2019). Some TNCs offer pooled on-demand ride options (e.g., Uber Pool and Lyft Shared) in which users may choose to share a ride with another passenger traveling along a similar path for a reduced fare. However, in 2017, just 20 percent and 40 percent of all Uber and Lyft rides, respectively, were pooled rides (Shaheen and Cohen, 2019). In New York City, where data on matching rates are available, only about 22 percent of requested Lyft Line (now Lyft Shared) rides and 23 percent of Uber Pool rides in 2018, resulted in matched trips (Schaller, 2018).

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[2] The increasing popularity of TNCs also threaten to worsen congestion and inconvenience drivers and pedestrians with impromptu pick up and drop off of passengers, besides drawing riders away from public transit. Several strategies to mitigate the negative impacts of TNC use have emerged across North America at both the state and local levels. These include vehicle and driver licensing and registration fees, access fees and restrictions to specific pickup or drop-off locations (e.g., airports, stadiums, etc.) or areas (e.g., downtown zones) and pricing policies that apply a flat, percentage-based, or per-mile surcharge to TNC trips within a jurisdiction

In 2017, both major TNC companies launched modified versions of their pooled on-demand ride services, called Uber Express POOL and Lyft Shared Saver, which require that passengers walk a short distance to/from their pickup/drop-off location (Lyft, 2017; Uber, 2017). These "indirect pooled" ride services resemble microtransit services, which offer flexible- or fixed-route rides with fixed-schedule or on-demand service in shuttles or vans (Shaheen and Cohen, 2019).

In some cases, jurisdictions have addressed the negative impacts of TNCs by imposing surcharges on rides while providing discounts for pooled TNC trips that can help reduce VMT. Examples include the: 1) New York State Congestion Surcharge, which applies a $2.75 fee to all ride-alone TNC trips but only $0.75 to all pooled TNC trips that start, end, or pass through Manhattan south of 96th Street; 2) San Francisco Rideshare Tax, which applies a 3.25 percent surcharge to all ride-alone trips but a 1.5 percent surcharge to pooled TNC trips that start in San Francisco; and 3) City of Chicago congestion pricing, which applies a $3 surcharge to all ride-alone TNC trips but a $1.25 surcharge to pooled trips that start or end in a designated downtown zone during weekday peak hours (between 6 AM and 10PM) and applies a $1.25 surcharge on all other ride-alone trips but a $0.65 surcharge to pooled TNC trips. The disposition of funds from state and local TNC taxes and fees includes general funds, 'congestion mitigation' funds, and even public school funds. However, it remains to be seen whether the effects of these pricing policies are distributed equitably across the population. It is imperative to develop a deeper understanding of which population segments are most likely to be affected by pricing policies as well as the magnitude of VMT and emission reductions that may be achieved by various strategies.

Although there is a growing literature focused on characterizing the socio-demographics, travel behavior, and mode shifts of TNC users in general, there remains a limited understanding of the differences between pooled and ride-alone TNC demand. Nor is it clear whether the strategies enacted so far to encourage pooling provide efficient disincentives to curb TNC use nor whether the established discounts are sufficient to incentivize pooling. Knowledge of individual travel behavior and decision-making processes for choosing between the growing number of on-demand mobility services is critical for devising equitable and effective incentives for increasing vehicle occupancy while maintaining the affordability and mobility provided by such services.

As urban areas prepare to loosen restrictions on daily activities requiring travel, public transit agencies across the globe are considering the development or expansion of microtransit services to provide more flexible, lower-density alternatives to traditional public transit in an effort to avoid a dramatic increase in reliance on personal autos due to lingering aversions to high density public transit (Johnson, 2020). Although mobility plans for the response and recovery phases of the pandemic are still evolving, forecasts of worst-case modal split scenarios showing increasing individual vehicle use and lower public transit ridership demonstrate the importance of both public and private pooled shared-ride services in providing essential mobility while reducing the prospects of gridlock.[3]

This report investigates the opportunities and challenges for expanding the market for pooling by incentivizing TNC users to pool. Using a stated preference survey of the general population in Los Angeles, Sacramento, San Diego, and the San Francisco Bay Area conducted in 2018, we examine the nuances in travel behavior and demand sensitivity for on-demand rides in general and pooled ride options in particular. Frequent TNC users — those that use TNCs at least once a week — pose a notable opportunity to increase pooling, as they are more likely to consider pooling and already engage in more multimodal travel behavior than other travelers. However, we observe that the most captive and price sensitive TNC users

[3] In 2020, several pooled on-demand ride services were suspended due to public health concerns during the COVID-19 pandemic (Etherington, 2020). Some app-based ride services have continued to operate with a limit of one person per row of seats and other precautions following public health guidelines (Salzberg, 2020).

are often among marginalized populations in as much as heavy TNC users — those using TNCs more than three days per week — are disproportionately low income, more likely not to own or lease a car, and more likely to use TNCs for essential trip purposes than are less frequent users.

A discrete choice analysis of stated preferences across ride alone, door-to-door pooled (e.g., Lyft Shared rides, Uber Pool), and indirect pooled (e.g., Uber Express POOL, Lyft Shared Saver) rides reveals that females, travelers aged 18 to 30 years old, travelers with an annual income less than $35,000, car owners/leasers, and public transit users are among the most likely to share an on-demand ride with others. Moreover, the likelihood to share varies significantly by the origin, destination, and time sensitivity of a trip. For example, the relative demand sensitivity to estimated wait times, in-vehicle times, and walking access/egress times reveals significant opportunities to shift deadheading and passenger vehicle miles to walking miles by incentivizing indirect pooled rides. In addition to direct price incentives and indirect operational incentives that reduce wait times and in-vehicle times, we quantify the impact that promotional offers can have on a traveler's choice to pool or not to pool.

This report is organized into five key sections. First, the authors present literature and prior research on pooling. The survey design and methodology for discrete choice analysis are presented next, followed by a presentation of results. Finally, the authors discuss the broader implications of the study and provide policy recommendations and conclusions.

Background

Pooling exists in numerous forms today. From traditional ridesharing (e.g., carpooling and vanpooling) to on-demand ride services such as microtransit, taxi sharing and pooled ride TNC services, pooling offers travelers a cheaper alternative to ride-alone, or single occupant vehicle (SOV) use that generates important societal and environmental benefits through the reduction of VMT and GHG emissions. In this section, we provide an overview of the state of the knowledge of different forms of pooling.

Traditional Ridesharing (Carpooling and Vanpooling)

Traditional ridesharing includes acquaintance-based and organization-based carpools (groups of two to six traveling together in a car) and vanpools (groups of seven to 15 commuting together in one van) as well as casual carpooling, also known as “slugging” (Shaheen and Cohen, 2019). Ridesharing can be recognized by many names, including liftsharing or car sharing in the UK, and carpooling or vanpooling in North America. However, it differs from for-hire vehicle services such as taxis, jitneys, and TNC services in that ridesharing payments, when collected, are not intended to result in financial gain and typically only partially cover the driver’s cost (Chan and Shaheen, 2011). In addition, ridesharing drivers share a common origin and/or destination with their passengers.

Ridesharing has a long history as a transportation demand management (TDM) tool in North America. It first emerged in the U.S. during World War II as a result of a 1942 federal regulation that sought to conserve rubber for the war effort (Chan and Shaheen, 2011). Carpooling and eventually, vanpooling, have since continued to have a role in congestion and parking supply management, particularly at large employment sites and during periods of economic stress. High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes have historically encouraged the adoption of ridesharing in regions where they provide significant time and cost savings (Neoh et al., 2015; Shirgaokar and Deakin, 2005). The phenomenon of casual carpooling, or slugging, began in the 1970s and has maintained prominence in the regions of Houston, Texas, Washington, D.C. and Northern Virginia, and the San Francisco Bay Area, where participation is driven by significant driver and passenger travel-time savings from gaining access to HOV lanes, as well as passenger cost savings and perceived convenience over driving alone or taking other alternative transportation modes (Shaheen and Cohen, 2019).

While individuals’ likelihood to carpool has been found to increase for lower income groups, younger age groups, and minority groups (typically Hispanics and African Americans), these factors are all highly correlated with a lack of car ownership, the strongest internal predictor of carpooling (Correia and Viegas, 2011; Neoh et al., 2015, Shaheen and Cohen, 2019). Attitudinal factors, such as perceptions of the convenience and reliability of ridesharing, coupled with situational factors influencing the: 1) quality of public transit alternatives to driving, 2) flexibility of work schedules, and 3) availability of workplace incentives have a stronger positive influence on the propensity to rideshare than do socio-demographic factors (Neoh et al., 2015; Vanoutrive et al., 2012; Koppelman et al., 1993). In the San Francisco Bay Area and Washington, D.C., casual carpooling is most heavily used during the morning commute, as many passengers opt to use public transit for their commute home when there is generally more travel-time flexibility (Shaheen and Cohen, 2019).

The commute mode share of ridesharing in the U.S. has declined over the past decade, from 10.4 percent in 2007 to 8.9 percent in 2017 (U.S. Census Bureau, 2018a). In California, the commute mode share of ridesharing has declined as well, from 11.9 percent in 2007 to 10 percent in 2017. The nation’s most populous metropolitan regions have also experienced declines in ridesharing commute mode share, although many saw a lower rate of decline than the national average, particularly between 2015 and 2017. Although a new era of smartphone-enabled ridesharing emerged in North America during this period, it is yet to be determined whether this has had an impact on ridesharing rates. Several mobility companies have launched app-based ridesharing services including: Waze Carpool, Scoop, Carzac, and Ride (Shaheen and Cohen, 2019). In March 2016, Lyft piloted a traditional ridesharing service in partnership with the Metropolitan Transportation Commission in the San Francisco Bay Area, but the project was discontinued after six months due to low match rates (Shaheen and Cohen, 2019).

Pooled On-Demand Ride Services

On-demand ride services provide for-hire rides to travelers through smartphone applications that facilitate reservations, driver dispatching, and payment. They include TNC services, which offer both ride-alone (e.g., uberX, Lyft Classic) and pooled ride options (e.g., Uber Pool, Lyft Shared rides), also known as ridesplitting. Ridesplitting also encompasses taxi sharing services, which enable multiple unacquainted users with similar routes to split the fare of a shared ride in a taxi (Shaheen and Cohen, 2019). Lastly, on-demand transit services, called microtransit, frequently provide rides in a van or bus with flexible service in terms of pickup and drop-off times and/or locations.

Pooled TNCs

Pooled TNC services are typically provided within the same smartphone app-based user interface as ride-alone TNC options, allowing passengers to choose to share their ride with a stranger traveling along a similar path. TNC users are usually quoted a discounted price and a longer estimated total travel time for a pooled ride compared to the ride-alone option. When Lyft and Uber first launched in 2012 and 2013, respectively, only private on-demand ride services were offered (Shaheen and Cohen, 2019). Both TNCs introduced their pooled-ride services in August 2014, (originally called Uber Pool and Lyft Line). As of December 2017, 20 percent of all Uber rides and 40 percent of Lyft rides, were pooled rides (Shaheen and Cohen, 2019). In 2017, both TNC companies started piloting modified versions of their pooled on-demand ride services, called Uber Express POOL and Lyft Shared Saver, which require that passengers walk a short distance to/from their pickup/drop-off location (Lyft, 2017; Uber, 2017). This newest iteration of pooled on-demand ride services resembles microtransit services, which offer flexible- or fixed-route rides with fixed-schedule or on-demand service in shuttles or vans (Shaheen and Cohen, 2019).

Microtransit

The recent growth in microtransit service is in part a renewal of the core pooled service provided by jitneys that have offered rail feeder, circulator, and high-frequency areawide service in metropolitan regions such as the San Francisco Bay Area, San Diego, Atlantic City, and Miami (Cervero, 1997). Chariot, which launched in San Francisco in 2014 offered rides in 14-person passenger vans along fixed routes that were ‘crowdsourced’ by users in Austin, Columbus, London, New York City, San Antonio, San Francisco, and Seattle (Shaheen and Cohen, 2019). Another microtransit service called Bridj emerged in 2014, which promised on-demand, flexibly routed service similar to the indirect pooled rides offered by Uber Express POOL and Lyft Shared Saver, through 14-seater passenger vans. A study during six months of a pilot project of Bridj in Kansas City found that the majority of riders used the service to commute and for work-related travel, with price affordability and convenience being the key motivating factors for use (Shaheen et al., 2016). While both Bridj and Chariot ended their operations in 2017 and 2019, respectively, a third prominent microtransit service called Via operates in

Arlington (Texas), Chicago, London, New York City, Washington D.C., West Sacramento, and Los Angeles (Shaheen and Cohen, 2019).

Early Understanding of Pooled On-Demand Ride Services

Overall, TNC users tend to be younger and more highly educated than the general population (Rayle et al. 2016; Smith 2016; Henao and Marshall, 2019; Clewlow and Mishra 2017; Gehrke et al. 2018; Circella et al. 2018; Schaller, 2018). Findings on the income and racial/ethnic distributions of TNC users have been mixed, with some studies suggesting that TNC users have higher incomes (Clewlow and Mishra 2017; Schaller, 2018) and are more likely to be white/Caucasian (Henao and Marshall, 2019; Hampshire et al. 2017), while others have found that these distributions of TNC users are closely aligned with those of the general population in the study area (Rayle et. al 2016; Feigon and Murphy 2018; Gehrke et al. 2018). Brown (2019) found that, on average, Lyft users living in low-income neighborhoods in Los Angeles County make more trips per capita, and are more likely to pool than those living in neighborhoods with higher median income.[4] She also found that users living in majority-black and majority-white neighborhoods of Los Angeles County take more trips and are less likely to pool than those living in more diverse neighborhoods.

TNC services have been found to contribute large sums of additional VMT in large dense metropolitan areas of the U.S. (Schaller, 2017; SFCTA, 2017; Schaller, 2018). The total VMT produced by TNCs includes the miles driven by drivers en route to their market of choice, as well as those driven while roaming and unreserved, driving to pick up a passenger, and driving with a passenger in tow. The former three phases of service represent 'deadheading' or miles driven without a passenger in the vehicle. Studies estimating the percent of VMT caused by deadheading typically focus on miles driven while awaiting a ride request and driving to the passenger pickup point. These studies have estimated that 20 to 45 percent of miles driven by TNC vehicles are accounted for by deadheading (Henao, 2017; Cramer and Krueger, 2016; SFCTA, 2017; Schaller, 2017; CARB, 2019).

To the authors' knowledge, there are six studies of TNC services that measure vehicle occupancies, five of which explicitly consider pooled-ride services. An intercept survey used to gather information directly from TNC users in San Francisco prior to the launch of pooled rides found that half of ride-alone TNC trips had more than one passenger, with an average occupancy of 2.1 passengers per trip (Rayle et al., 2016). Intercept surveys conducted in Denver, Colorado during Fall 2016 and Boston, Massachusetts during Fall 2017 observed average occupancies of 1.36 and 1.52 passengers per trip, respectively (Henao and Marshall, 2019; Gherke et al., 2018). The Boston study found that pooled rides comprised about a fifth of trips surveyed, while in the Denver study, about 13 percent of all rides were requested as pooled services, about 85 percent of which were not matched with another rider. A survey distributed across California in 2018 found that the average occupancy of respondents' most recent trips was about 1.9 passengers per trip, with lower occupancy observed on weekends and greater occupancy observed during nighttime trips (Circella et al., 2019). The California Air Resources Board (CARB) analyzed records from trip diaries collected from 31 TNC drivers in Spring 2019, finding time-weighted occupancies of 1.57 for pooled rides and 1.54 for non-pooled rides.[5] About 15 percent of trips from the 2018 California studies and 12 percent of those from 2019 were pooled trips. Finally, using a dataset of all Lyft trips, Brown (2019) found that Lyft Line was

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[4] Due to data limitations, the findings by Brown (2019) are based on the census tract median household income corresponding to the zip code of residence for the rider of each trip.
[5] The CARB study concluded that the differences in vehicle occupancies across pooled and non-pooled trips were insignificant (CARB, 2019).

used for 29.2 percent of all Lyft trips in Los Angeles County from September to November 2016 and 32 percent of all peak-hour trips during that period.

As with traditional ridesharing, a critical mass of ridership is necessary to facilitate efficiency gains from pooled on-demand ride services. Based on data from TNC trips in New York City in February 2018, only about 22 percent of requested Lyft Line and 23 percent of Uber Pool rides, actually resulted in a matched trip (Schaller, 2018). In contrast, about 60 percent of Via trips in New York City are shared (Schaller, 2018). Simulation-based studies focused on shared automated vehicle (SAV) fleets have projected the impacts of on-demand pooling, finding that the potential of SAVs to reduce VMT is highly dependent on the percent of trips that are shared and the rate of replacement of single occupant trips by pooled trips (Viegas et al., 2016; WEF and BCG, 2018; Greenblatt and Shaheen, 2015; Greenblatt and Saxena, 2015).

Methodological Overview

This study analyzes data from a general population stated preference (SP) online survey of residents from Los Angeles, Sacramento, San Diego, and the San Francisco Bay Area conducted from August to December 2018. The survey design and analysis were informed by a large body of literature on travel demand modeling (Ben-Akiva and Lerman, 1985: Train, 2009), particularly for estimation of the value of time (VOT) and a traveler's willingness to pay for travel time reductions (Brownstone and Small, 2005; Wardman, et al., 2016; Zamparini and Reggiani, 2007). VOT is calculated as the ratio of the sensitivity of demand to a particular travel time component (e.g., walking time to/from a pickup/drop-off location, waiting time, in-vehicle time) to the sensitivity of demand to travel cost. Estimates of VOT for driving vary from about 50 to 100 percent of the mean hourly wage for the population of interest (Brownstone and Small, 2005; U.S. DOT, 2016; Wardman, et al., 2016; Zamparini and Reggiani, 2007). While previous VOT waiting time estimates for public transit have varied from about 1.5 to 2 times the VOT for in-vehicle time, a recent SP survey of Dutch citizens regarding pooled on-demand ride services similar to microtransit found that the VOT for waiting was about 1 to 1.5 times the VOT for in-vehicle time (Alonso-Gonzalez, et al., 2020). While this SP survey stipulated a constant one-minute walk time estimate, our study includes walking time as an additional travel time component.

This study estimates a discrete choice model for the choice of TNC ride options to enable the investigation of the significant factors influencing a TNC user's choice to pool or not to pool, as well as the explicit estimation of a traveler's VOT across different time segments of a TNC trip. In addition, we explore the regional variation in travel behavior and demand sensitivity for on-demand rides across the four California metropolitan regions studied. This section details the methods used for data collection, survey analysis, and discrete choice analysis.

Survey Design

The online survey included multiple-choice questions regarding respondents' socio-demographic characteristics, travel profiles, typical TNC use, attitudes and perceptions toward TNCs and pooling, and a series of four to five stated preference, mode-choice experiments.

Upon confirmation of consent to participate in the Institutional Review Board (IRB)-approved survey, respondents were asked to identify their metropolitan region of residence, gender, age, income, highest level of educational attainment, and racial/ethnic background. Responses to this preliminary set of questions determined respondents' eligibility to participate in the survey. Respondents under the age of 18 and those living outside of the four target metropolitan regions were thanked and excused from the study. Additional respondents were released based on the adherence to the existing survey sample to target distributions of all five socio-demographic variables listed above, which were determined from the U.S. Census Bureau's 2017 American Community Survey (ACS) 5-year estimates.

Stated Preference Experiments

The second portion of the survey consisted of four to five stated preference experiments. Respondents were first asked to indicate their familiarity with TNC services such as Lyft and Uber. Respondents who had never used TNCs were presented with a brief explanation of such ride services. All respondents were then provided instructions explaining that the following set of questions would present hypothetical travel scenarios in which the respondent would be asked to choose a transportation option based on the information. Respondents were asked to imagine that they were traveling alone and could choose from the following options, as presented:

- **Ride alone TNC:** a service such as uberX/ Lyft Classic where you request a direct, door-to-door ride for yourself.
- **Door-to-door shared ride (TNC):** a service such as Uber Pool/ Lyft Shared rides (formerly Lyft Line) where a traveler requests a door-to-door ride for themself and your route may deviate to pick up or drop off one to three additional passengers riding along a similar route.
- **Indirect shared ride (TNC):** a service such as Uber Express POOL that is identical to the door-to-door shared ride, except the traveler is assigned pickup and drop-off locations that might require him/her to walk several minutes to and from the origin and destination locations designated in the ride request. Indirect shared rides may have one to five additional passengers.
- **Public bus:** a public bus service.
- **Rail:** a light rail, subway, or rapid public transit service.
- **Personal Vehicle:** drive alone in your own personal vehicle with potential costs incurred from tolls and/or parking.[6]

In each of the first four scenarios, respondents were asked to imagine that they were making a trip with a specified context provided by the trip origin, destination, and a time constraint. The trip purpose was indicated by the destination, which was selected randomly from the following possibilities: home, a restaurant/bar, an event (e.g., sports event, theater, concert), the airport, a recreational/social activity (e.g., a park, the beach, etc.), or a public transit station. Further context regarding the location in which the hypothetical mode choice occurred was randomly generated to be either from home, or from somewhere other than home. Finally, the time constraint was randomly generated to provide the context that the trip would be made with plenty, some, or no time to spare.

Respondents that self-identified as being employed (either full- or part-time) or a student were presented with a fifth scenario, in which they were asked to consider that they were planning a commute trip to work (or school). This scenario was designed identically to the first four scenarios but with two additional transportation options available, as applicable:

- **Carpool/vanpool as a passenger**: a service such as Waze Carpool, 511 RideMatch, or Scoop, in which a traveler requests a ride to work within a given reservation window (e.g., one hour in advance, 12 hours in advance, etc.) and are matched to a driver who is also traveling along a similar route to work (or school). The route may deviate to pick up or drop off additional passengers, and the traveler may be asked to walk several minutes to/from pickup/drop-off locations.
- **Carpool/vanpool as a driver:** a service such as Waze Carpool, 511 RideMatch, or Scoop, in which you offer rides to work to strangers within a given reservation window (e.g., one hour in advance, 12 hours in advance, etc.) and are matched to passengers who travel along a similar route to work as you. Your route may deviate to pick up/drop off additional passengers.

[6] The personal vehicle option was only made available to respondents that had self-identified as owning/leasing one or more vehicles.

Each scenario consisted of two parts, representing a nested mode-choice structure. In the first part, respondents were asked to choose their preferred travel option for the specified trip context from among the three TNC options. In the second part, respondents were asked to choose from among a new set of options that included the TNC option they chose in the first part as well as the public bus, rail, and personal vehicle, as applicable. This report presents the results from the first part of the stated preference experiments: the choice between TNC options.

As shown in Figure 1 (below), the alternative-specific attributes for each transportation option were presented in a table format including the: 1) estimated wait time, 2) estimated walking time to or from the pickup or drop-off locations, 3) estimated in-vehicle time, 4) estimated total time, 5) estimated cost, and 6) expected range of additional passengers. Only the indirect shared-ride and public transit options included the estimated walking access/egress time attribute, as the other ride options provide door-to-door service. As with a typical shared TNC ride quote, respondents were not given an estimate of the exact number of additional passengers that may join the ride. The indirect pooled ride was specified to include up to five additional passengers to account for a ride experience similar to dynamic microtransit in which a larger vehicle, such as a van or shuttle, may be used for this service type, whereas the door-to-door pooled ride was specified to include up to three additional passengers to differentiate it as a trip that would typically be served by a smaller vehicle, such as a sedan.

Imagine you are making a trip **from somewhere other than home** to **a restaurant/bar** with **some time to spare.**

Please carefully review the transportation options available to you for this trip.

	Ride Alone	Door-to-Door Shared Ride	Indirect Shared Ride
Estimated wait time	9 minutes	6 minutes	2 minutes
Estimated walking time to/from pickup/dropoff	-	-	7 minutes
Estimated in-vehicle time	28 minutes	48 minutes	48 minutes
Total estimated time	37 minutes	54 minutes	57 minutes
Estimated total cost	$18	$11.7	$9.6
Additional passengers	0	1 to 3	1 to 5

Which of these choices would you prefer for a trip from somewhere other than home to a restaurant/bar with some time to spare?

Ride Alone

Door-to-Door Shared Ride

Indirect Shared Ride

Figure 1a. Part 1: TNC Mode Choice

Now, consider that you have the following options **for the same trip (traveling from somewhere other than home** to **a restaurant/bar** with **some time to spare)**.

Please carefully review the transportation options available to you for this trip.

	Ride Alone (TNC/Ridesourcing)	Personal Vehicle	Public Bus (e.g., MTS buses)	Rail (e.g., San Diego Trolley)
Estimated wait time	9 minutes	-	6 minutes	14 minutes
Estimated walking time to/from pickup/dropoff	-	-	7 minutes	2 minutes
Estimated in-vehicle time	28 minutes	28 minutes	35 minutes	1 hour 8 minutes
Total estimated time	37 minutes	28 minutes	48 minutes	1 hour 24 minutes
Estimated total cost	$18	$5 (parking and tolls)	$9	$2.5

Which of these choices would you prefer for a trip from somewhere other than home to a restaurant/bar with some time to spare?

Ride Alone (TNC/Ridesourcing)

Personal Vehicle

Public Bus

Rail

Figure 1b. Part 2: General Mode Choice

Figure 1. Example Stated Preference Experiments

All other alternative-specific attributes were generated randomly from pre-specified distributions of discrete values that were purposefully chosen to represent a range of possible scenarios.[7] The estimated wait times for each shared-ride option and the estimated walking times for indirect pooled rides and public transit were independently and randomly generated. The estimated in-vehicle times and costs of each alternative were generated in a cascading fashion, starting with the randomly generated estimate of in-vehicle time for the ride-alone TNC and drive-alone options, which were assumed to travel the most direct path among all options. The range of possible values of the estimated in-vehicle times for door-to-door pooled rides were specified to be greater than or equal to that of the ride-alone option to allow for the possibility that the rider is at best the last to be picked up and first to be dropped off in the pooled ride. For the indirect pooled ride, the range of possible in-vehicle times also included values that were slightly faster than the ride-alone option to reflect the potential efficiency gains from dispatching rides for passengers that do not have to be directly picked up or dropped off from their requested origin and destination. In order to constrain the scope of the experiments to trip distances for which most people would not choose to walk or bike, the minimum estimated in-vehicle time across all scenarios and transportation options was seven minutes.

The estimated total cost for the travel options were also chosen based on the estimated in-vehicle time of the ride-alone TNC option to reflect the time- and distance-based pricing of TNC services (Uber, 2018; Lyft, 2018). The range of cost estimates was amplified to test the sensitivity of respondents to prices that may be cheaper or more expensive than contemporary TNC pricing. In doing so, the SP experiment design and resulting discrete choice analysis enables consideration of policy scenarios in which the proliferation of SAV ride services have drastically reduced on-demand ride prices, as well as scenarios in which pricing policies are enacted to increase the prices of certain on-demand services. The estimated costs for the door-to-door shared TNC were randomly generated from values ranging from 90 to 65 percent of the ride-alone cost. The estimated cost for the indirect shared TNC was then randomly generated from values ranging from 90 to 65 percent of the door-to-door shared TNC cost.

In the third and fourth scenarios, a promotional offer was included as an additional alternative-specific attribute for the shared TNC options, as demonstrated by the example in Figure 2 below. Three types of promotions were tested, one of which would only appear if the randomly generated trip destination was "to a public transit station," while the other two were eligible to appear for any trip purpose. The public transit-focused promotion stated: "Take a door-to-door (indirect) shared ride to public transit and get $2 (or $5 or $7) off your public transit fare," where the transit discount offered was randomly generated from those three values. The second promotional type offered: "Take 2 (5, 7, or 10) door-to-door (indirect) shared rides and get one door-to-door (indirect) shared ride free." Finally, the third promotion offered: "Take one door-to-door (indirect) shared ride and get 5% (7%, 10%, 12%, 15%, or 20%) off your next door-to-door (indirect) shared ride." The promotional values for each of the two latter offers were also randomly generated from the values listed.

[7] The distributions of the time and cost attribute levels are presented in Table A1. All other attributes levels were generated using a uniform distribution.

Imagine you are making a trip to **your home** with **some time to spare.**

Please carefully review the transportation options available to you for this trip.

	Ride Alone	Door-to-Door Shared Ride	Indirect Shared Ride
Promotion	-	Take a door-to-door shared ride and get 10% off your next door-to-door shared ride	Take an indirect shared ride and get 5% off your next indirect shared ride
Estimated wait time	2 minutes	6 minutes	9 minutes
Estimated walking time to/from pickup/dropoff	-	-	5 minutes
Estimated in-vehicle time	28 minutes	36 minutes	36 minutes
Total estimated time	30 minutes	42 minutes	50 minutes
Estimated total cost	$52	$42.6	$34.9
Additional passengers	0	1 to 3	1 to 5

Which of these choices would you prefer for a trip to your home with some time to spare?

- Ride Alone
- Door-to-Door Shared Ride
- Indirect Shared Ride

Figure 2b. Part 1: TNC Mode Choice

Now, consider that you have the following options **for the same trip (traveling** to **your home** with **some time to spare)**.

Please carefully review the transportation options available to you for this trip.

	Door-to-Door Shared Ride	Personal Vehicle	Public Bus (e.g., MTS buses)	Rail (e.g., San Diego Trolley)
Promotion	Take a door-to-door shared ride and get 10% off your next door-to-door shared ride	-	-	-
Estimated wait time	6 minutes	-	14 minutes	9 minutes
Estimated walking time to/from pickup/dropoff	-	-	5 minutes	10 minutes
Estimated in-vehicle time	36 minutes	28 minutes	57 minutes	45 minutes
Total estimated time	42 minutes	28 minutes	1 hour 16 minutes	1 hour 4 minutes
Estimated total cost	$42.6	$16.6 (parking and tolls)	$9	$9

Which of these choices would you prefer for a trip to your home with some time to spare?

- Door-to-Door Shared Ride
- Personal Vehicle
- Public Bus
- Rail

Figure 2b. Part 2: General Mode Choice

Figure 2. Example Stated Preference Experiments with Promotional Offers

Survey Analysis

In total, 2,538 respondents completed the survey. A number of response quality checks were applied to filter out incomplete responses, resulting in a final sample size of 2,434. The survey results were analyzed for the purposes of understanding the socio-demographic and travel profiles of California residents that use TNC services, the nature of TNC use, and the extent to which TNC users share their rides. Furthermore, the analysis focuses on characterizing high frequency TNC users to provide insights into which population segments represent the most captive demand for TNCs and other on-demand ride services, including app-based carpooling and future SAV services. When applicable, analysis of the response from both TNC users and nonusers are provided.

The primary test of significance used in the analysis is the two-proportions z-test in which the null hypothesis is that two proportions are equal. Unless otherwise noted, all results that are stated to be 'significant' have failed the null hypothesis of the two-proportions z-test at a 99 percent significance level.

Discrete Choice Analysis

In order to investigate the significant factors in an individual's choice to pool when using TNC services, a discrete choice analysis (DCA) was performed using the SP survey data. DCA is a method used to model the choice from an exhaustive, finite set of mutually exclusive alternatives, based on the principles of utility maximization (Ben-Akiva and Lerman, 1985; Train, 2009). The objective is to estimate a parameterized random utility model for each of the alternatives, composed of a deterministic and a random component. As defined in Equation 1, the utility of alternative j to individual n, denoted as U_{nj}, is the sum of the linear combination of observable independent variables, X_{nj}, multiplied by corresponding coefficients, β_{nj} (the deterministic component), plus an error term representing unknown factors, ε_{nj} (the random component).

Equation 1. A Random Utility Model

$$U_{nj} = \beta_{nj} X_{nj} + \varepsilon_{nj}$$

The probability that a particular individual chooses any one of the alternatives, defined by the logit model in Equation 2, is the probability that the chosen alternative provides that individual with the greatest utility across all available alternatives. In the multinomial logit model, the scale parameter μ is conveniently constrained to a value of one, following the assumption that the variances of the error terms are homoscedastic (Ben-Akiva and Lerman, 1985). More refined models, such as the nested multinomial logit, relax this assumption by allowing different scale parameters across alternatives. The maximum likelihood approach for estimating the parameters is used (Ben-Akiva and Lerman, 1985).

Equation 2. The Probability That Decision Maker n Chooses Alternative j

$$P_{nj} = Prob\left(U_{nj} > \max_{i \in C_n, i \neq j} (U_{ni})\right) = \frac{e^{\mu \beta_{nj} X_{nj}}}{\sum_{i \in C_n} e^{\mu \beta_{ni} X_{ni}}}$$

A total sample of 10,912 SP choice experiments from 2,398 individual respondents was included in the DCA to produce a TNC mode choice model that predicts the preferred ride option of a particular traveler in a given trip context. Responses to multiple SP choice experiments from each respondent are included as independent observations in the model.

TNC Mode Choice Model Estimation

The TNC choice model is a multinomial logit model estimated from the responses to the SP choice experiments, in which respondents indicated which one of three TNC-ride options they preferred given the trip context and attributes of each alternative. The model was specified using a backward elimination procedure. Table 1 below provides the full list of variables considered as candidate model parameters. All trip context and alternative-specific attributes were included in the candidate parameter set. An additional set of individual characteristics, including socio-demographic, travel profile, and attitudinal variables were chosen as candidates for the model based on the survey analysis. Ordinal variables (e.g., education and all attitudinal variables) were treated as continuous variables for model simplicity.

In addition, a nested multinomial logit specification was estimated to test for correlation between the shared-ride options. The estimated nest-scale parameter failed the null hypothesis of being equal to one with a 90 percent confidence level. Moreover, the model was rejected by the likelihood ratio test with a 90% confidence level.

Table 1. Candidate Parameters for DCA

Contextual Variables	Alternative-Specific Attributes	Individual Characteristics
Origin	Estimated wait time	Metropolitan region
Destination (purpose)	Estimated in-vehicle time	Gender
Time sensitivity	Estimated walking time	Age
	Estimated cost	Education
	Promotion: % off next pooled ride	Racial/Ethnic group
	Promotion: number of pooled rides to get one free	Employment
		Income
	Promotion: $ off of public transit fare	Medical condition/handicap
		Car ownership
		TNC tenure (years since started using)
		TNC trip frequency
		Drive-alone trip frequency
		Public bus trip frequency
		Rail trip frequency
		Carpool/Vanpool trip frequency
		Shared micromobility trip frequency
		Comfortable being driven
		Comfortable sharing rides
		Enjoy chatting with driver
		Enjoy chatting with passengers
		Believe pooled rides are more environmentally friendly than ride-alone TNCs

With the exception of the estimated cost parameter, all parameters were initially specified as alternative-specific, with the ride-alone TNC option as the base. In other words, the initial model specification included separate coefficients for the door-to-door pooled rides and indirect pooled rides for each alternative-specific parameter. The first step in the backward elimination involved consolidating parameters using the likelihood ratio test to determine if a significant[8] improvement in the goodness-of-fit of the model could be achieved by restricting each parameter from two alternative-specific parameters (one for each shared-ride option) to one generic parameter for both shared-ride options. First, the parameters for which the confidence intervals of the unrestricted parameters overlapped were tested for consolidation, which was followed by the remainder of the parameters in order of decreasing p-value. As a result, only parameters with a significant difference in their relationship to the likelihood that an individual chooses one shared-ride option over another remained as two separate model parameters. In the next step of the backward elimination, parameters were tested for removal from the model specification (in order of decreasing p-value), again using the likelihood ratio test for improvement in goodness-of-fit with a significance level of 95 percent.

Next, variables were tested for their correlation to the metropolitan region of the decisionmaker's residence. Naturally, each metropolitan region surveyed has unique cultural, land use, and geographic characteristics that can influence the significance of various factors in an individual's transportation mode choices. While specification of four separate region-specific models was an undesirable final outcome of the DCA due to the necessary sacrifice in predictive power from reduced sample sizes, four such models were estimated as an intermediary step in the model specification process to identify parameters that could improve the core model by being specified for each metropolitan region. Parameters for which the confidence intervals of the estimated coefficients overlapped across multiple region-specific models were then interacted in the full model and tested using the likelihood ratio test with a significance level of 95 percent. Following this process, the resulting region-specific parameters were tested once more on the basis of improvement in goodness-of-fit from either the generic or alternative-specific specification. For example, although the final model estimation suggests a significant difference in the relationships between the utility of door-to-door pooled rides and indirect pooled rides for weekly TNC users in the San Francisco Bay Area, there is no such difference in utilities across the two pooled ride options for weekly TNC users in the remaining three metropolitan regions. Finally, the same process was undertaken for socio-demographic variables to check for the significance of additional interactions.

Study Limitations

This study focuses on the self-reported socio-demographics, travel behavior, attitudes and perceptions, and stated preferences of a sample of residents from four California metropolitan regions. The survey sampling strategy was designed to capture a representative sample from each metropolitan region surveyed based on regional univariate distributions of each socio-demographic variable (see Table 2 and Table A2). Some of the socio-demographic targets were relaxed during the survey distribution process in order to reach the sample target size, resulting in differences of about 10 percent between the sample income distribution and the population across the four metropolitan regions surveyed. Analyses of TNC travel behavior and demand sensitivity are disaggregated by income to explicitly account for this small discrepancy in the socio-demographic representativeness of the study sample. Moreover, we note that the multivariate distributions of

[8] A significance level of 95% was used in for the likelihood ratio test.

socio-demographic variables were not explicitly accounted for, further limiting the similarity between the sample and the population in any particular region.[9]

While all four metropolitan regions examined reside in California, there are distinct differences in the land use, culture, and transportation systems that are reflected in the survey results. All survey analysis results are disaggregated by metropolitan region and the significance of findings are noted separately for each region, when applicable. Since the sample from the Los Angeles region is about five times the size of the other three regions, the margin of error for results from Los Angeles is about 2 percent, while the margin of error of the remaining regions is about 6 percent. In addition, the TNC choice model produced by the DCA includes region-specific parameter estimates, which reflect the heterogeneity in demand sensitivity across the regions.

Both TNC users and nonusers are included in the DCA. As a result, the TNC choice model may be used to understand demand sensitivity with respect to TNC-ride options across the full population in any of the metropolitan regions studied, both at present and in hypothetical scenarios in which various circumstances (e.g., the proliferation of SAVs, fuel price changes, etc.) or policies (e.g., TNC surcharges, road pricing, targeted subsidies, etc.) have an impact on the price and time tradeoffs in choosing between TNC-ride options. However, it is important to note that the TNC mode choice model alone does not predict the likelihood that an individual will choose to use a TNC over other modes — it merely predicts which TNC-ride option would be preferred in the event that a traveler is considering using a TNC for a particular trip.

Finally, we note that SP surveys are limited in their ability to predict the actual choices of individuals in their day-to-day travel. In the absence of reservation-level data from on-demand mobility providers or costly travel diary survey data, SP surveys provide a means of understanding individuals' choices through controlled experiments. The trip context and alternative-specific variables in the SP experiments were designed to control for as many pertinent factors in the decision-making process of choosing between on-demand ride options as possible. With the exception of the attitudes and perception variables, all parameters in the model are routinely captured by household travel surveys, which are commonly used for regional travel demand modeling.

[9] The correlations between socio-demographic variables are presented in the Appendix, in Table A2.

Respondent Demographics

In this section, we compare the distributions of sociodemographic characteristics of the survey sample to those of the population in each metropolitan region, as reported by the 2017 five-year ACS estimates (see Table 2). In addition, we compare the distributions of each characteristic among respondents that have used TNCs (e.g., Lyft, Uber) in their metropolitan region at least once in the year prior to being surveyed to those that have not. Henceforth, we refer to these groups as TNC users and nonusers, respectively. Figure 3 below displays the distribution of TNC users and nonusers among respondents in each metropolitan region, revealing that active TNC users comprise just over one half of the population in all metropolitan regions except in Sacramento, where only 44 percent of the population has used TNCs locally in the past year.

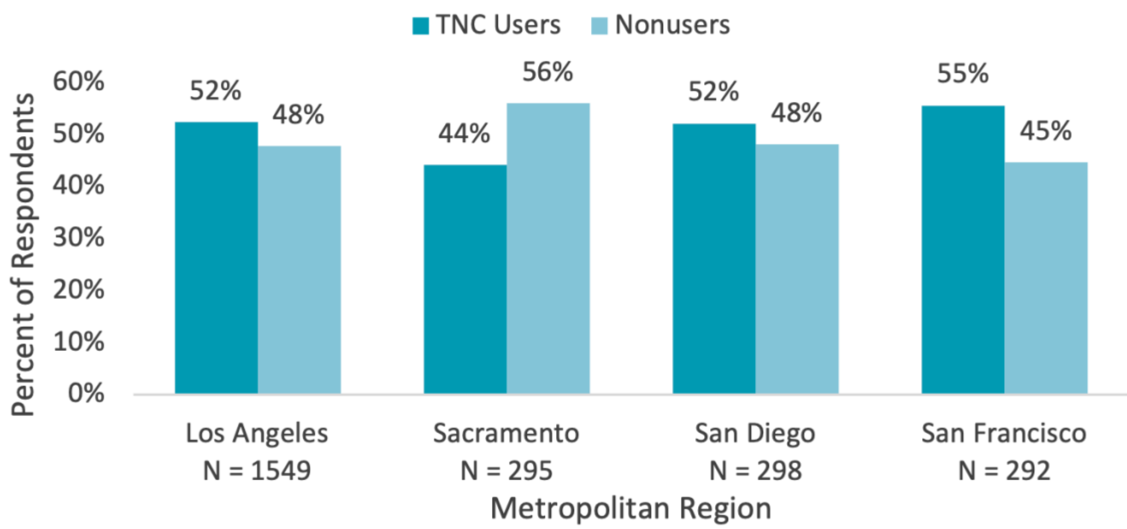

Figure 3. Distribution of TNC Users and Nonusers by Metropolitan Region

By design, the survey sample is close to socio-demographically representative of the populations in the Los Angeles, Sacramento, San Diego, and San Francisco Bay Area metropolitan regions. As shown in Table 2 below, the sample distributions of gender and age most closely match those of the general population, across all metropolitan regions surveyed. Across all of the regions, the lowest and highest income groups are over- and under-sampled, respectively, with respondents earning less than $35,000 annually making up about 6 to 10 percent more of the sample than the population and those earning $100,000 or more annually making up about 6 to 12 percent less than the population. The sample distributions of educational attainment and race/ethnicity (see Table A2) are similar to those of the general population, with a few exceptions: 1) the respondent samples from the Los Angeles metropolitan region with less than a high school degree and those with a Bachelor's degree are under-sampled, while the remaining two educational attainment groups are oversampled, and 2) White/Caucasian respondents are oversampled by up to 8 percent compared to the population across the Sacramento, San Diego, and San Francisco Bay Area metropolitan regions.

Table 2. Distribution of Socio-Demographics of the Population and the Survey Sample by Metropolitan Region

	LOS ANGELES			SACRAMENTO			SAN DIEGO			SAN FRANCISCO BAY AREA		
GENDER	Population[a] N=10,271,191	Survey N=1,541	TNC Users n=808	Population[b] N=1,300,405	Survey N = 294	TNC Users n=128	Population[c] N=2,555,203	Survey N=297	TNC Users n=155	Population[d] N=6,026,055	Survey N=292	TNC Users n=162
Male	49%	49%	47%	48%	46%	47%	50%	50%	47%	49%	47%	46%
Female	51%	51%	53%	52%	53%	52%	50%	50%	53%	51%	52%	54%
Other	n/a	0.3%	0.1%	n/a	0.7%	1.5%	n/a	0%	0%	n/a	0.7%	0.6%
AGE (years old)	N=10,271,191	N=1,549	n=810	N=1,300,405	N=295	n=130	N=2,555,203	N=298	n=155	N=6,026,055	N=292	n=162
18 to 29	23%	26%	31%*	24%	22%	23%	25%	22%	26%	20%	23%	31%*
30 to 49	36%	40%*	42%	35%	30%	40%*	35%	39%	45%	37%	31%	39%*
50 to 69	29%	26%	22%*	30%	36%	32%	29%	29%	23%	31%	33%	22%*
70 and over	11%	8%*	4%*	11%	13%	5%*	11%	10%	6%	12%	13%	8%*
INCOME	N=4,315,854	N=1,505	n=793	N=604,895	N=289	n=127	N=1,112,851	N=294	n=153	N=2,700,986	N=281	n=156
Less than $35,000	28%	36%*	35%	29%	36%	33%	24%	34%*	25%*	20%	26%	27%
$35,000 - $99,999	40%	42%	41%	43%	41%	40%	41%	44%	47%	34%	39%	36%
$100,000 - $199,999	23%	18%*	19%	22%	18%	20%	25%	19%	23%	29%	26%	24%
$200,000 or more	10%	5%*	5%	6%	4%	7%	9%	4%*	5%	18%	9%*	13%
EDUCATIONAL ATTAINMENT	N=10,271,191	N=1,536	n = 804	N=1,300,405	N=291	n=129	N=2,555,203	N=296	n=155	N=6,026,055	N=287	N=159
High School Diploma or less	40%	33%*	32%	36%	32%	30%	33%	32%	32%	29%	26%	29%
Some College/ Associate's Degree	30%	36%*	36%	36%	41%	40%	33%	35%	37%	28%	32%	31%
Bachelor's Degree	20%	15%*	15%	18%	17%	15%	21%	21%	19%	26%	24%	19%
Graduate/ Professional Degree	10%	16%*	17%	10%	11%	15%	12%	11%	12%	17%	17%	20%

	LOS ANGELES			SACRAMENTO			SAN DIEGO			SAN FRANCISCO BAY AREA		
RACE/ ETHNICITY	N=13,261,538	N=1,532	n = 800	N=1,708,005	N=296	n=128	N=3,283,665	N=295	n=155	N=4,641,820	N=292	n=162
Caucasian/Non Hispanic	30%	29%	25%*	46%	54%*	54%	46%	53%	48%	40%	45%	38%*
African American	6%	7%	7%	9%	5%	7%	5%	5%	4%	6%	9%	10%
Asian	16%	16%	16%	15%	11%	12%	11%	8%	8%	25%	21%	24%
Hispanic	45%	45%	50%*	24%	24%	23%	33%	32%	36%	24%	20%	23%
Two or more	1%	2%*	1%	5%	2%	2%	0%	3%*	0%	4%	0%*	0%
Other	2%	1%*	2%	2%	5%*	2%	2%	1%	4%	1%	4%*	4%
VEHICLE OWNERSHIP	N=4,320,174	N=1,549	n=810	N=604,895	N=295	n=130	N=1,111,739	N=298	n=155	N=2,700,986	N=292	n=162
0	8%	11%*	12%	7%	10%	10%	6%	12%*	8%	10%	15%*	15%
1	33%	41%*	41%	34%	43%*	45%	31%	40%*	40%	31%	38%	38%
2	37%	34%	35%	37%	35%	33%	40%	38%	38%	36%	32%	32%
3	14%	8%*	8%	15%	9%*	8%	16%	8%*	9%	15%	8%*	7%
4 or more	8%	5%*	5%	7%	3%	5%	8%	2%*	5%	8%	7%	7%

Asterisks in the: 1) survey and 2) TNC users columns denote a 99% confidence level in the difference in proportions of each socio-demographic variable between the: 1) population and survey sample and 2) survey sample and TNC users, respectively.

a. Los Angeles-Long Beach-Anaheim, CA Metro Area

b. Sacramento and Yolo Counties, CA

c. San Diego-Carlsbad, CA Metro Area

d. Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma Counties, CA

Few differences are observed in the socio-demographic makeup of TNC users and nonusers. Most significantly, TNC users tend to be younger than nonusers, particularly in the Los Angeles and San Francisco Bay Area regions where the proportions of TNC users in the 18 to 29 years old age group are significantly larger than in the survey samples in those regions. The distributions of income and educational attainment among TNC users are not significantly different from those of nonusers, with the exception of the San Diego metropolitan region in which TNC users are significantly less likely to be in the lowest income group (earning less than $35,000 annually) compared to the survey sample in that region. TNC users in the Los Angeles, San Diego, and San Francisco metropolitan regions are less likely to be Caucasian and more likely to be Hispanic than nonusers in their respective regions. In addition, there is a larger proportion of Asian TNC users than there are nonusers in the San Francisco Bay Area. The distributions of race/ethnicity among TNC users and nonusers in the Sacramento metropolitan region are generally similar, with the exception of a slightly greater proportion of African American respondents in the TNC user group than in the nonuser group. Finally, we observe that the distribution of vehicle ownership among TNC users and nonusers is generally very similar across all metropolitan regions.

Respondents were asked whether they have a medical condition or handicap that makes it difficult to travel outside of the home and if so, to indicate what types of walking assistance (e.g., cane, walker) they employ, if any to travel outside of the home. This group comprises about 10 to 12 percent of the sample across all of the metropolitan regions. About 85 percent of all respondents with a medical condition/handicap use some form of walking assistance; about one third use a cane, and another third use a walker.

Respondents with a medical condition/handicap are significantly less likely to be active TNC users in the Los Angeles and Sacramento metropolitan regions, while they are slightly more likely to be active TNC users in the San Francisco Bay Area, where 60 percent of respondents with a medical condition/handicap are active TNC users.

Respondent Travel Profiles

The following analysis of trends in respondent travel profiles seeks to understand the breadth of transportation options being used by travelers in each metropolitan region, as well as the degree of multimodality in the travel profiles of TNC users. The analysis aids in understanding the interdependence of travel demand across multiple modes and provides insight into the possible impacts of on-demand mobility on systemwide mode share as well as the potential modal shifts of particular socio-demographic groups.

General Mode Use and Trip Frequency

The travel profiles of respondents vary significantly across the regions surveyed, reflecting regional differences in the availability of public transit and shared mobility services. The distributions of a selection of modes used by respondents in their metropolitan region at least once per month are shown in Figure 4. Across all metropolitan regions, drive alone is by far the most ubiquitous mode, with about 76 to 84 percent of respondents that drive alone in a personal vehicle at least once per week in their region.

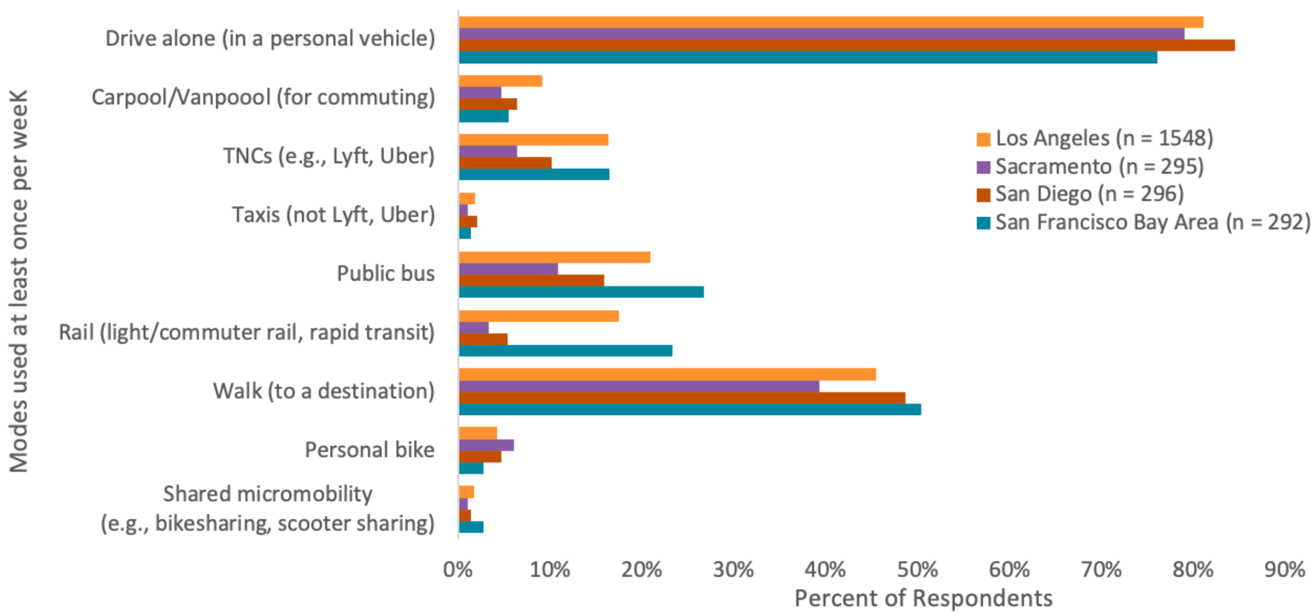

Figure 4. Distribution of Modes Used Locally at Least Once per Week by Metropolitan Region

About 10 percent of respondents in the Sacramento, San Diego, and San Francisco Bay Area regions carpool and/or vanpool once a month or more, while about 15 percent of respondents from the Los Angeles metropolitan region do so. Figure 5 displays the distribution of carpool/vanpool options used by these respondents. Just over half of the respondents that carpool/vanpool once a month or more organize their own carpools without the use of a third-party service (e.g., Waze Carpool, Scoop) across all metropolitan regions except for Sacramento. Interestingly, 80 percent of such respondents selforganize their carpools. This likely reflects the high percentage of individuals working for governmental agencies in the state's capital.

Regional services — such as 511 RideMatch in the San Francisco Bay Area, RideMatch and Metro Vanpool programs in the Los Angeles metropolitan region, the San Diego Association of Governments (or SANDAG) Vanpool program, and the Transportation Management Association (TMA) Vanpooling program and Sacramento Region Commuter Club — facilitate carpooling and/or vanpooling for commuters. These regional services are used by about one quarter of monthly carpool/vanpool travelers in the Los Angeles and Sacramento regions and approximately 16 percent in the San Diego region and 12 percent in the San Francisco Bay Area. Additionally, about one third of monthly carpool/vanpool riders in the San Francisco Bay Area use casual carpooling — an informal regional system with designated meeting locations that facilitate the formation of carpools during commuting hours. About 20 percent of monthly carpool/vanpool commuters in the Los Angeles and San Francisco Bay Area metropolitan regions, 16 percent in the San Diego region, and 8 percent in the Sacramento region have used app-based carpooling services, such as Scoop and Waze Carpool.

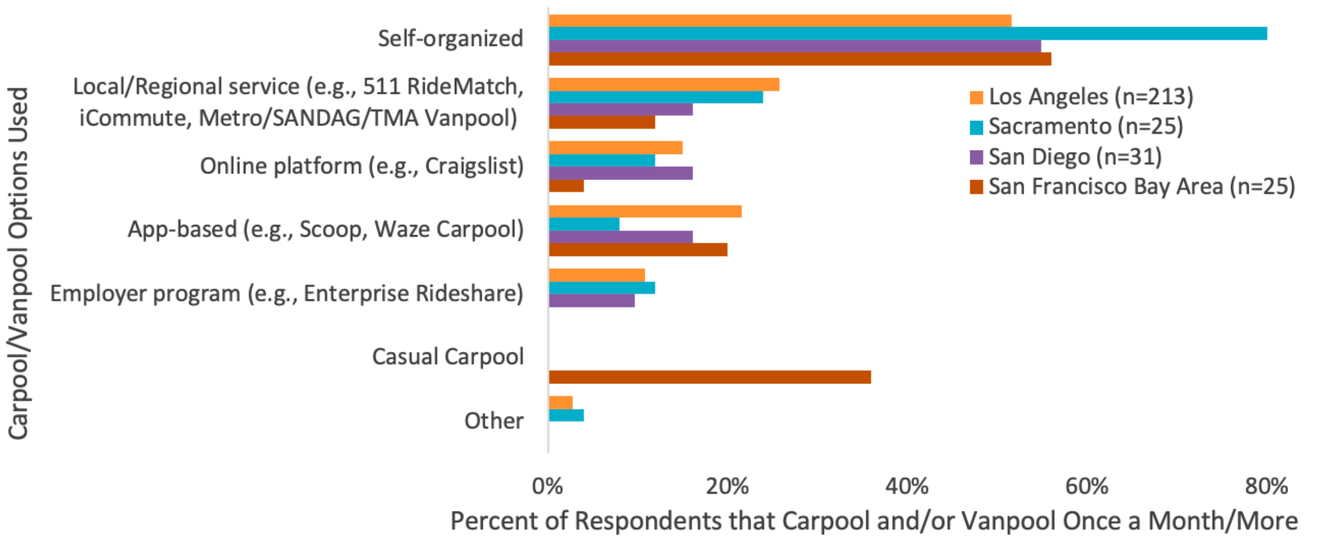

Figure 5. Distribution of Carpool/Vanpool Options Used by Respondents Who Carpool and/or Vanpool Once a Month or More by Metropolitan Region

Public transit use is highest in the San Francisco Bay Area, where about one third of all respondents use some form of public transit once a week or more. In contrast, only one quarter of residents in the Los Angeles metropolitan regions and only about 15 percent of respondents in the Sacramento and San Diego regions use public transit on a weekly basis. Both the San Francisco Bay Area and the Los Angeles metropolitan region have rapid transit systems (e.g., Bay Area Rapid Transit (BART) District, Los Angeles Metro Rail Purple and Red lines) in addition to light rail systems, which are available in all four of the regions studied. While about 5 percent of respondents use their local light rail system on a weekly basis across all regions, about 15 percent of respondents in the Los Angeles region use Metro Rail rapid transit (Red and Purple Lines) and 20 percent in the San Francisco Bay Area use BART. Only about one percent of respondents in the Los Angeles, San Diego, and San Francisco Bay Area regions use their local commuter rail systems (e.g., Metrolink, COASTER, Caltrain, Amtrak) on a weekly basis, while there were no weekly commuter rail users among the respondents from the Sacramento region. The rate of public bus use follows a similar trend to that of rail, with weekly bus users making up about 27 percent, 20 percent, 16 percent, and 11 percent of respondents in the San Francisco Bay Area, Los Angeles, San Diego, and Sacramento metropolitan regions, respectively.

Taxi use is low compared to TNC use (e.g., Lyft, Uber), with no more than 10 percent of respondents, across all regions, taking taxis locally in the past year, 4 percent or less using taxis locally once a month or more, and 2 percent or less using them on a weekly basis across all metropolitan regions. For comparison, about 15 percent of respondents in Los Angeles, 10 percent in the San Francisco Bay Area, and about 5 percent of respondents in the San Diego and Sacramento regions use TNCs once a week or more. Shared micromobility services, including docked and dockless bikesharing, dockless scooter sharing, and moped sharing, are used once a week or more by no more than 3 percent of the sample in any region. Walking as a transportation mode is least popular in the Sacramento region, where about 40 percent of respondents walk once a week or more compared to 45 percent in the Los Angeles region and about 50 percent in the San Diego and San Francisco Bay Area regions.

Mode Use Among Frequent TNC Users

Across all metropolitan regions surveyed, frequent TNC users reflect more multimodal travel behavior than other respondents. Table 3 below presents the distribution of transportation modes used at least once a week by respondents that use TNCs once a month to once every other week (monthly TNC users) and those that use TNCs at least once a week (weekly TNC users) in each of the four metropolitan regions. It is important to note that these results do not imply causality between increased TNC use and the use of other modes or vice versa.

Table 3. Distribution of Transportation Modes Used at Least Once a Week by TNC Trip Frequency and Metropolitan Region

	LOS ANGELES		**SACRAMENTO**		**SAN DIEGO**		**SAN FRANCISCO BAY AREA**	
	Monthly TNC Users n=258	Weekly TNC Users n=252	Monthly TNC Users n = 45	Weekly TNC Users n=19	Monthly TNC Users n = 60	Weekly TNC Users n=30	Monthly TNC Users n = 41	Weekly TNC Users n=48
Drive alone	83%	84%	82%	74%	92%*	87%	78%	69%
Carpool/ Vanpool	9%	25%***	9%	21%	3%	17%**	10%	17%
Public bus	16%**	55%***	16%	42%**	10%	40%***	29%	69%***
Rail	14%*	49%***	9%**	16%	10%*	7%	32%	52%*
Walk (to a destination)	50%	73%***	62%***	74%	60%**	77%	63%*	71%
Personal bicycle	5%	6%	11%	5%	5%	3%	2%	4%
Shared micromobility (i.e., shared bikes and scooters)	2%	5%**	0%	0%	0%	10%**	0%	17%***

Asterisks in the 1) Monthly TNC Users and 2) Weekly TNC Users columns denote a significant difference in the proportions of weekly mode use between: 1) monthly TNC users and respondents that use TNC less than once a month and 2) monthly and weekly TNC users, respectively.

* : p-value < 0.1; ** : p-value < 0.05; *** : p-value < 0.01

While there is little to no significant difference in the weekly drive alone rate across respondents with varying TNC use frequencies, weekly TNC users are significantly more likely than monthly TNC users to use the public bus and shared micromobility (i.e., shared docked and dockless bikes and scooters) on a weekly basis across all four of the metropolitan regions except Sacramento, where there were no weekly shared micromobility users among monthly and weekly TNC users. Only about one to three percent of all respondents in each metropolitan region used shared micromobility services on a weekly basis, and in the Sacramento region, all weekly shared micromobility users were using the JUMP dockless electric bikesharing system. Shared dockless electric scooters, which were not available in the Sacramento region at the time of the survey, accounted for about 40 percent of weekly shared micromobility use in the San Francisco Bay Area and about 50 percent in the Los Angeles and 75 percent in the San Diego metropolitan regions. Again, it is important to note that weekly shared micromobility use is quite low among total respondents, at just one to three percent in each of the four metropolitan areas surveyed. Taxi use was similarly low across all metropolitan regions, with weekly taxi users making up less than two percent of all respondents and about six to ten percent of weekly TNC users.

Across all metropolitan regions, weekly public transit users are significantly more likely to use TNCs on a weekly basis than are less frequent public transit users. About 40 percent of weekly public transit riders in the San Francisco Bay Area and Los

Angeles regions use TNCs on a weekly basis, while only about 25 percent of those in the Sacramento and San Diego regions do so. Interestingly, the rate of weekly TNC use is about the same across weekly riders of bus and rail systems, with the exception of weekly light rail riders in the San Francisco Bay Area, who are significantly less likely than weekly bus and rapid transit riders to use TNCs on a weekly basis. These results are consistent with the findings from previous research using a convenience sample of public transit riders of four agencies, including BART, which found that about half of weekly TNC users also rode public transit on a weekly basis (Feigon and Murphy, 2018).

Finally, we observe that in the Los Angeles and San Diego regions, weekly TNC users were significantly more likely than monthly TNC users to carpool/vanpool on a weekly basis. With the exception of the Los Angeles region, the weekly carpool/vanpool rates in the respondent samples were about 50 percent lower than the corresponding ACS 2017 estimated ridesharing commute mode shares for the study regions (U.S. Census Bureau, 2018a). Interestingly, we observe significantly higher rates of weekly carpool/vanpool use among weekly TNC users across all regions, with about half of weekly TNC users in the Los Angeles and San Francisco Bay Area metropolitan regions carpooling/vanpooling on a weekly basis and about 30 percent of weekly TNC users in the Sacramento metropolitan region but only 25 percent in the San Diego region.

TNC Use Patterns

In this section, we explore TNC usage by analyzing the frequency and purpose of TNC trips, along with the prospect of users considering pooled TNC rides. An understanding of who is using TNCs, at what frequency, and for what trip purposes is essential to developing policies that effectively mitigate negative TNC impacts while ensuring that the cost burden and resulting levels of accessibility across the transportation system are equitable. We investigate the trends in TNC use across age groups in order to provide insight into generational differences in usage patterns, as well as the potential rate of continued expansion and adoption of such patterns that can be expected as increasingly digitally-adept cohorts come of age. In addition, we examine TNC trends across gender, income groups, race/ethnicity, vehicle ownership, and physical ability to enrich behavioral understanding of marginalized and price sensitive users.[10] Finally, we examine the propensity of TNC users to pool rides by analyzing how often users consider pooled ride options when using TNCs.

TNC Trip Frequency

Heavy TNC users — those that use TNCs more than three times per week — pose the largest opportunity for achieving policy objectives through TDM strategies that incentivize pooling. Although heavy TNC users constitute a relatively small portion of the overall population across the four metropolitan regions surveyed (see

below), they represent a cohort of TNC users that will be among the most impacted by any such policies, as they have incorporated on-demand ride services into their weekly routine beyond just weekend travel and are likely to consider on-demand rides in their mode choice decisions on a daily basis. In particular, a majority of daily TNC users are making more than one TNC trip per day, across all of the regions surveyed.

[10] Analysis by level of educational attainment was also conducted; the results support the findings of analysis by other socio-demographic variables due to the correlations across metropolitan regions of educational attainment with other socio-demographic variables (see Table A2).

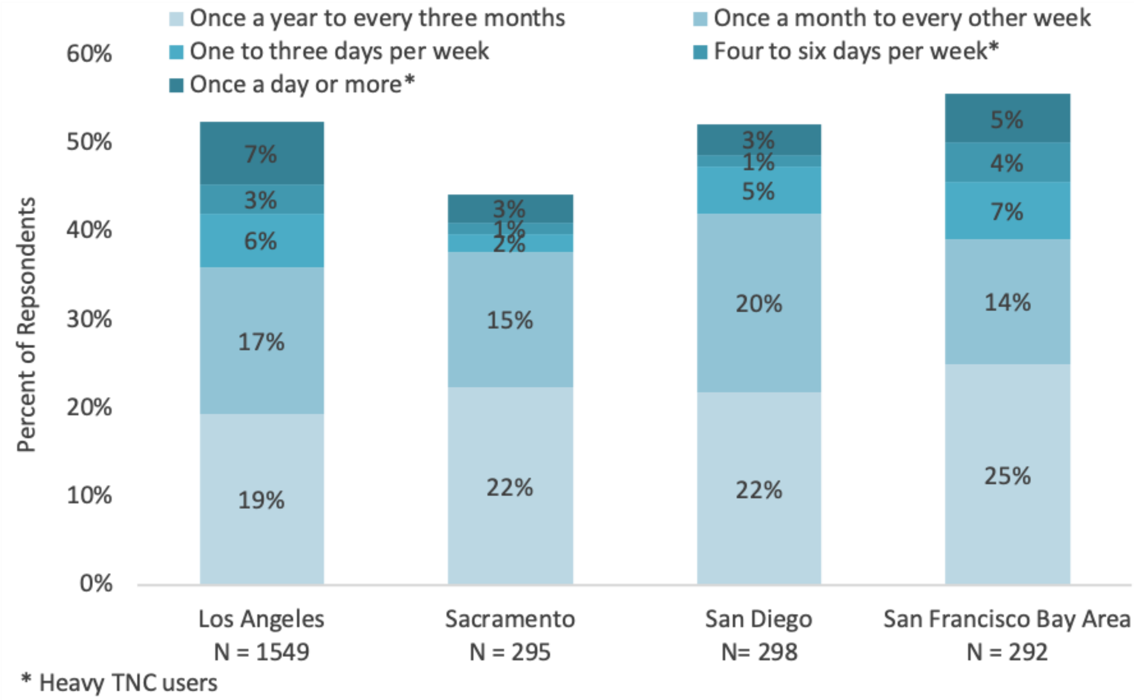

Figure 6. Distribution of TNC Trip Frequency by Metropolitan Region

Heavy TNC users are disproportionately young, low income, and are more likely to not own or lease a car. Figure 7 below shows the percent of respondents in different age groups that use TNCs one to three days a week, four to six days a week, and once a day or more in each metropolitan region. The heavy TNC user segment is particularly young in the San Francisco Bay Area, where roughly one in four respondents under the age of 30 use TNCs more than three days a week, while about one in six use TNCs on a daily basis. Respondents under the age of 30 are about twice as likely as those aged 30 to 49 years old to use TNCs more than three days a week in the San Francisco Bay Area, and they are about 1.7 times as likely in the Los Angeles and San Diego metropolitan regions.

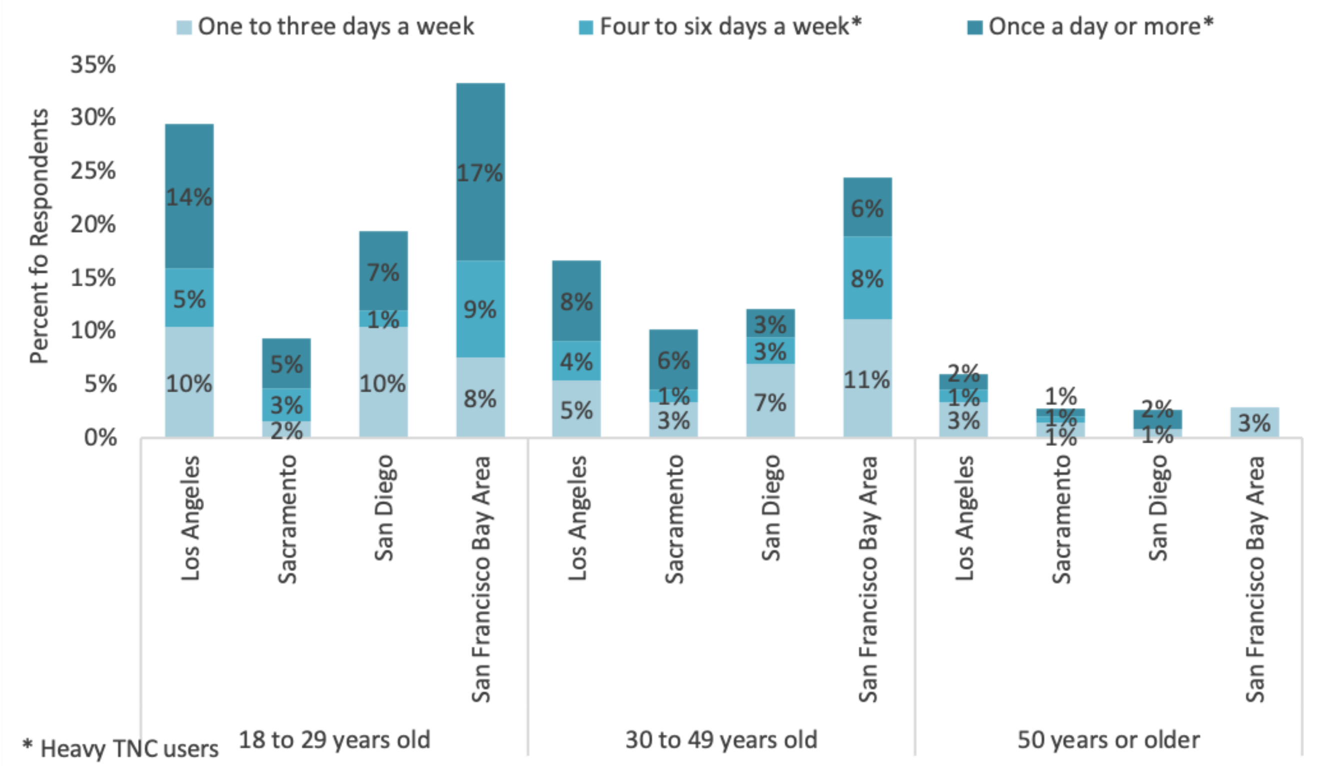

Figure 7. Distribution of TNC Trip Frequency by Age and Metropolitan Region

Respondents in the lowest income group — those earning less than $35,000 a year — are the most likely to use TNCs on a weekly and daily basis, across all metropolitan regions. Although respondents with $35,000 or less of annual income comprise about one third of TNC users in the Los Angeles and Sacramento samples and about one quarter of TNC users in the San Diego and San Francisco samples, about 70 percent of daily TNC users in San Diego and Sacramento and about 55 percent of daily TNC users in San Francisco and 40 percent in Los Angeles, have an annual income of less than $35,000. Across the Los Angeles, Sacramento, and San Francisco Bay Area metropolitan regions, respondents that do not own or lease a vehicle are more likely to use TNCs on a weekly basis than are vehicle owners. One in four non-vehicle owners from these three metropolitan regions uses TNCs once a week or more (see Figure 8). Interestingly, cross-tabulations of income and the frequency of TNC use suggest that frequent TNC use among the lowest income group in the Los Angeles and Sacramento regions may be similarly linked to a lack of vehicle ownership. In contrast, in the San Diego and San Francisco regions, low-income vehicle *owners* are more likely to use TNCs on a daily basis than low-income earners that do not own a vehicle.

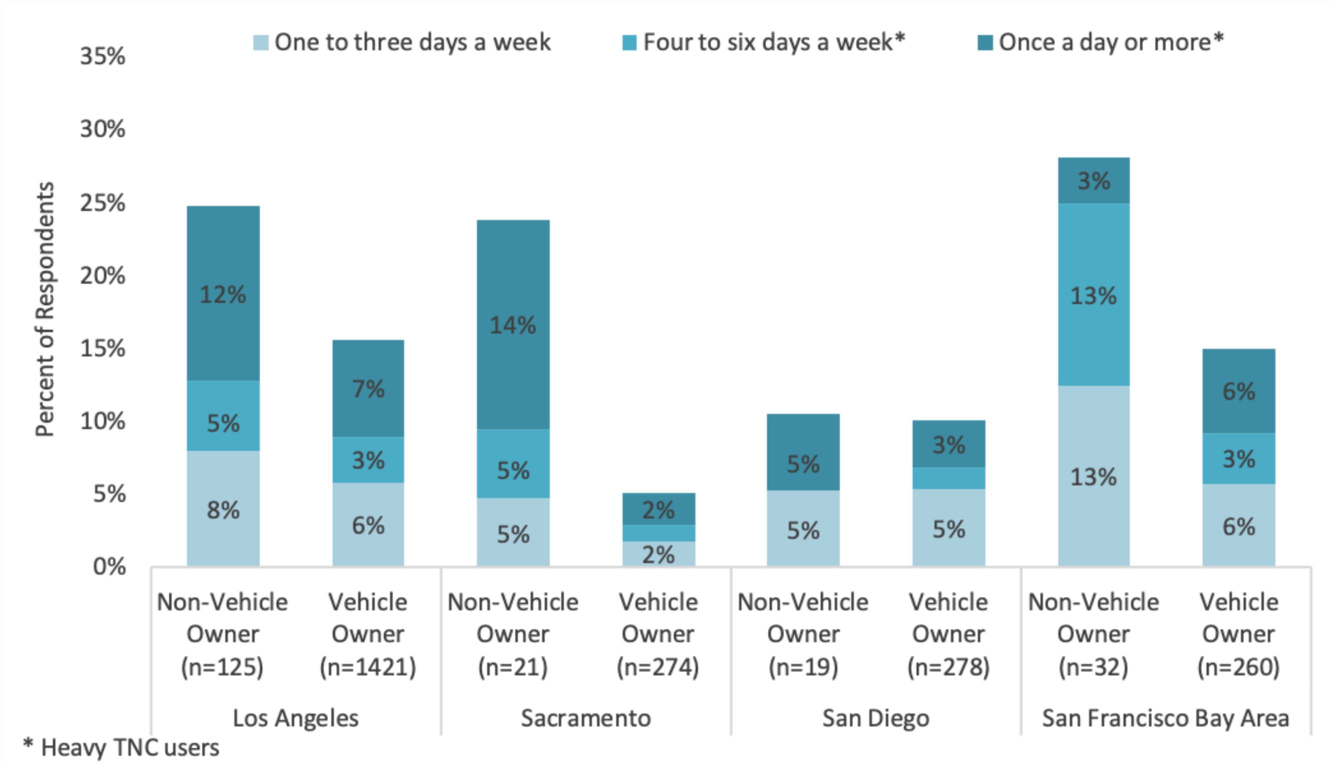

Figure 8. Distribution of TNC Trip Frequency by Vehicle Ownership and Metropolitan Region

There is a slight gender disparity in the frequency of TNC use, with males being more likely than females to use TNCs on a weekly basis across all metropolitan regions. When considering the confluence of gender and income, there is no significant difference by gender in the likelihood of weekly or heavy TNC use among those in the lowest income group. However, in the Los Angeles region males in the middle-income group are about twice as likely as females to be heavy TNC users and males in the highest income group are about three times as likely as females to be heavy TNC users.

Heavy TNC use also varies notably across race and ethnicity, reflecting differences in socio-economic disparities across racial and ethnic groups in each metropolitan region studied (see Figure 9). In aggregate, Caucasians/Non-Hispanics are significantly less likely to be heavy TNC users than all other racial/ethnic groups in both the San Diego and Sacramento regions, while Asians are the least likely to be heavy TNC users in the Los Angeles region. In the San Francisco Bay Area, African Americans are significantly more likely to be heavy TNC users compared to Asians and Caucasians/Non-Hispanics. This is due to a particularly high rate of heavy TNC use (44%) among African Americans earning less than $35,000 a year in the San Francisco Bay Area. Among this income group, African Americans are about twice as likely as Caucasians and Hispanics and four times as likely as Asians to be heavy TNC users. African Americans are also the most likely to be heavy TNC users among those earning less than $35,000 in the Los Angeles and Sacramento metropolitan regions, followed by Hispanics in Los Angeles and both Hispanics and Asians in Sacramento. In San Diego, Asians in this lowest income group are the most likely to be heavy TNC users with a rate of 20 percent followed by Hispanics with a rate of 10 percent, while no Caucasian/Non-Hispanics nor African Americans in this region were heavy TNC users. In the middle-income group (earning $35,000 to $50,000 annually), Hispanics were the most likely to be heavy TNC users in both the Sacramento and San Diego regions, while few to no individuals in the other racial/ethnic groups earning the same amount in those two regions were heavy TNC users. In Los Angeles, Caucasians/Non-Hispanics followed closely by African Americans are the most likely to be heavy TNC users among the middle-income group.

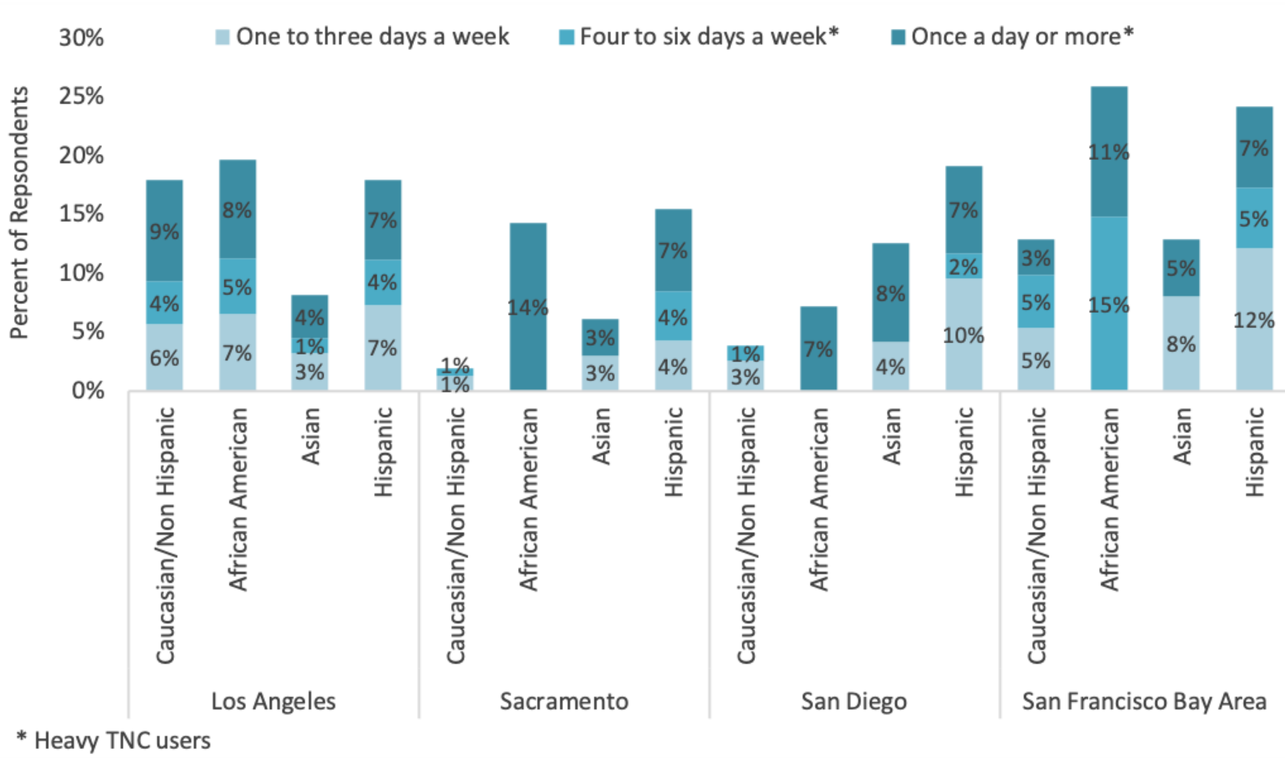

Figure 9. Distribution of TNC Trip Frequency by Race/Ethnicity and Metropolitan Region

The general TNC use trends with respect to age hold across each racial/ethnic group, although the confluence of age, income, and race/ethnicity become apparent when focusing on the distribution of heavy TNC users across race/ethnicity in each age group. In particular, heavy TNC use among young people reflects higher usage among: 1) higher income young Caucasian/Non-Hispanics and 2) lower income African Americans. About 30 percent of African Americans and 25 percent of Caucasian/Non-Hispanics aged 18 to 29 years old use TNCs more than three days a week, compared to about 15 percent of Hispanics and about 10 percent of Asians in this same age group.

TNC users with a medical condition/handicap, which makes it challenging to travel outside of home, are significantly more likely than others to be heavy TNC users. As displayed in Figure 10. these respondents are more than twice as likely to use TNCs on a daily basis than those who do not have a condition in all metropolitan regions except Sacramento. In the San Francisco Bay Area, respondents that have a medical condition/handicap are about three times more likely to use TNCs more than three days a week than those that do not have such a condition.

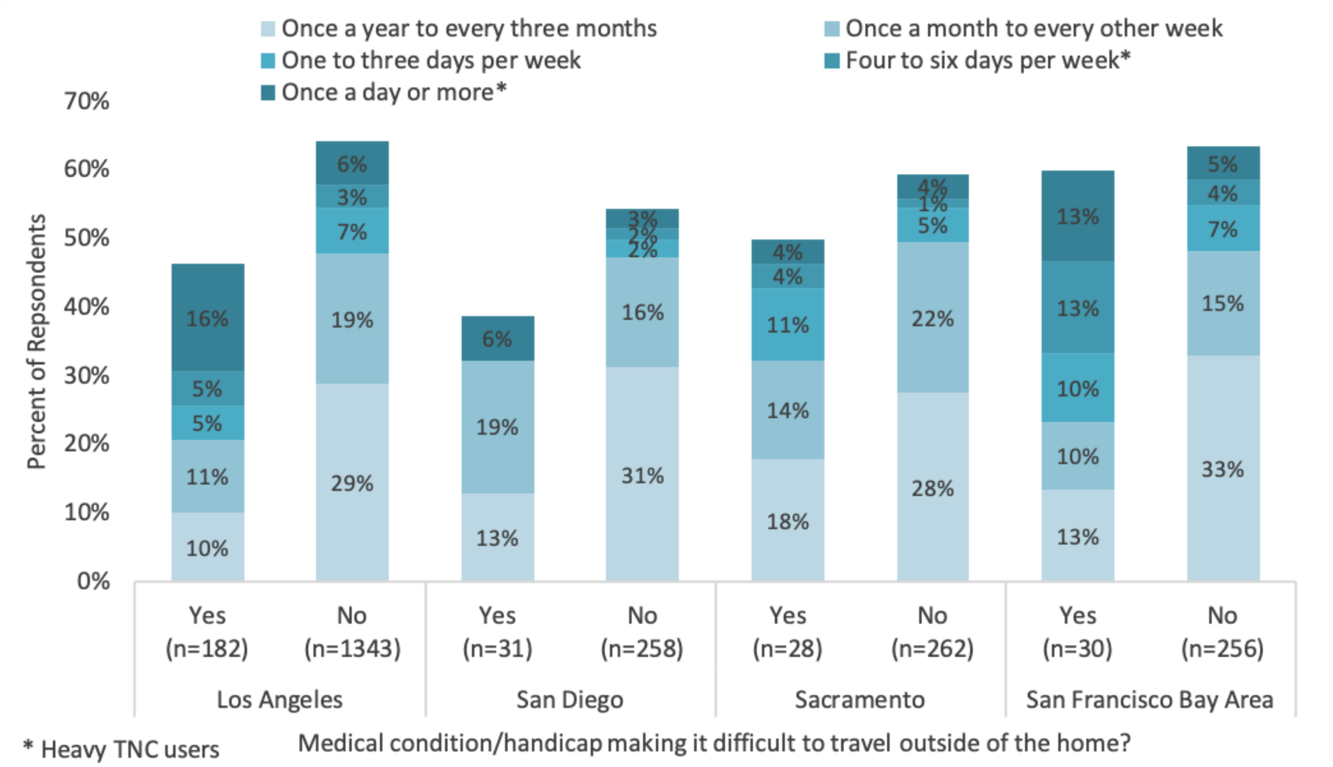

Figure 10. Distribution of TNC Trip Frequency by Medical Condition/Handicap and Metropolitan Region

TNC Trip Purposes

In order to further our understanding of the use of TNC services to different population segments, we turn our attention to an analysis of the trip purposes served by TNCs. Respondents that used TNCs in their metropolitan region in the past year were asked to identify what trip purposes they use TNCs for in their metropolitan region, shown in Figure 11. Consistent with previous TNC studies of user behavior, the most popular trip purposes among active TNC users across all metropolitan regions include: 1) traveling to or from restaurants or bars, 2) other social or recreational activities, and 3) airport travel. Weekly TNC users are significantly more likely to use TNCs to: 1) commute to or from work or school, 2) attend work-related meetings, 3) go grocery shopping, and 4) visit friends or relatives than are less frequent users. In addition, weekly TNC users in the Los Angeles and San Francisco Bay Area regions are significantly more likely to: 1) pick up or drop off children and 2) go to or from healthcare services.

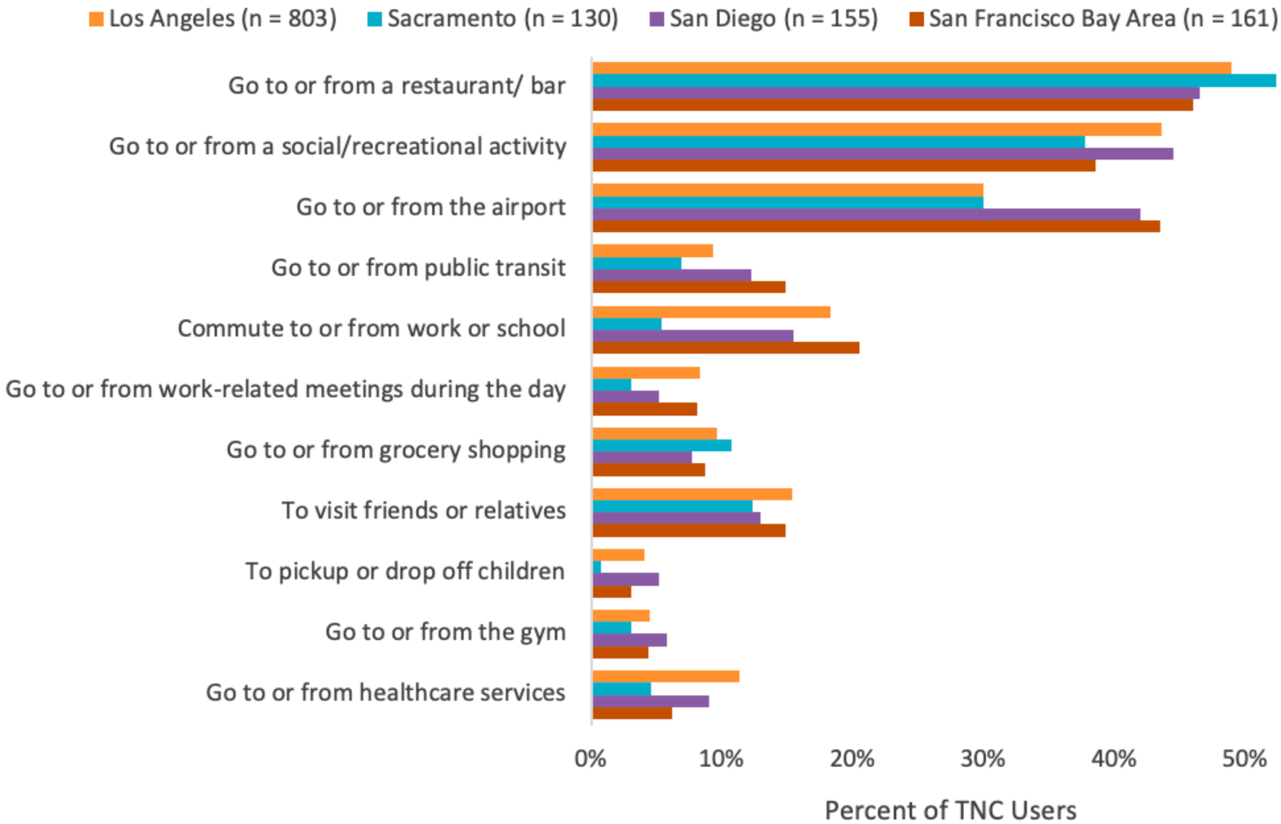

Figure 11. Distribution of TNC User Trip Purposes by Metropolitan Region

About 40 percent of weekly TNC users in the San Diego metropolitan region, about 30 percent in the Los Angeles and San Francisco Bay Area regions, and about 20 percent in the Sacramento region use TNCs to commute to or from work or school, and about 15 percent to 20 percent of weekly users use TNCs for work-related travel during the day, across all metropolitan regions. While there is little variation across income groups in the rate of weekly TNC users that use TNCs to commute to/from work in the Los Angeles metropolitan region, those in the lowest income group are significantly more likely than other weekly TNC users to use TNCs to commute to/from school. In the Sacramento and San Diego regions, weekly TNC users in the lowest income group are more likely to use TNCs to commute to/from work/school, while the San Francisco Bay Area is the only region in which the use of TNCs for commuting increases with income.

The portion of monthly and weekly TNC users that use TNCs to connect to/from public transit stations is notably lower than the portion of those that use public transit on a weekly basis, across the four metropolitan regions studied. Only about one quarter of all weekly public transit users report using TNCs to go to/from public transit stations, with little variation across weekly users of public bus and rail services. One exception is commuter rail riders in the Los Angeles metropolitan region, who are more likely to report using TNCs to connect to public transit than other public transit users in their region. In the Sacramento and San Francisco Bay Area regions, there is no significant difference between the portion of monthly and weekly TNC users that use TNCs to go to/from public transit stations, with only about 10 percent and 20 percent of these users doing so in each region, respectively. In contrast, about 10 percent of monthly TNC users in the Los Angeles and San Diego regions use TNCs to connect to public transit stations, while about 20 percent and 30 percent of weekly TNC users do so in each region, respectively. In future research, the authors plan to investigate the contextual and operational factors in traveler choice between TNCs and public transit.

In the San Francisco Bay Area, weekly TNC users earning less than $35,000 are significantly more likely to use TNCs to connect to public transit than those with higher incomes. Moreover, among weekly TNC users in the San Francisco Bay Area, African Americans are significantly more likely than other groups to be using TNCs to connect to public transit stations, followed by Caucasians/Non-Hispanics and Hispanics. African American weekly TNC users in the San Francisco Bay Area are also significantly more likely than other weekly TNC users in the region to use TNCs to visit friends/relatives, pick up or drop off children, and go to the gym. In the Los Angeles metropolitan region, African Americans are significantly more likely than other groups using TNCs on a weekly basis to use them to go shopping for groceries or other items and run errands.

Vehicle ownership is a significant factor in some, though not all, of the trends in the TNC trip purposes of weekly TNC users. In particular, weekly TNC users that own a vehicle in the San Francisco Bay Area and Los Angeles regions are significantly less likely to use TNCs to access healthcare services and go grocery shopping compared to those that do not. In the San Francisco Bay Area, weekly TNC users that own a vehicle are also significantly less likely to use TNCs to access public transit. Interestingly, vehicle owners in the San Francisco Bay Area are more likely than those that do not own a vehicle to use TNCs to commute to/from work, which may reflect the inconveniences and costs of parking in the region.

Finally, there are slight differences across genders in the trip purposes of frequent TNC users. Male weekly TNC users are more likely than their female counterparts to commute to work using TNCs in the two Southern Californian metropolitan regions, while the opposite is true in the two Northern regions. In the San Francisco Bay Area, female weekly TNC users are significantly more likely to access public transit, go grocery shopping, and go to the gym using TNCs than are male weekly users. In future research, the authors plan to further investigate the socio-demographic trends discussed here to determine to what degree they reflect the general differences in travel patterns in each region as opposed to differences in behavior that are unique to on-demand mobility services.

Propensity to Consider Pooling

Next, TNC pooling is examined. TNC users were asked how often they consider using the pooled ride options (e.g., Uber Pool, Uber Express POOL, or Lyft Shared rides (formerly Lyft Line)) when using TNCs. Across all metropolitan regions in which pooled ride options were available at the time of the survey, about 30 percent of TNC users consider using shared-ride options more than half of the time that they use TNCs, while about 60 percent say they consider pooling less than half of the time. Across all metropolitan regions with pooled TNC ride services,[11] infrequent TNC users are the least likely to consider pooled ride options when using TNCs. The majority of respondents that use TNCs less than once a month consider sharing their rides less than half the time. As displayed in Figure 12 below, heavy TNC users are significantly more likely to consider sharing TNC rides than less frequent users. Across all metropolitan regions, the portion of users that never consider pooling when using TNCs decreases with trip frequency.

[11] Note, pooled TNC services were not available in the Sacramento metropolitan region at the time of the survey.

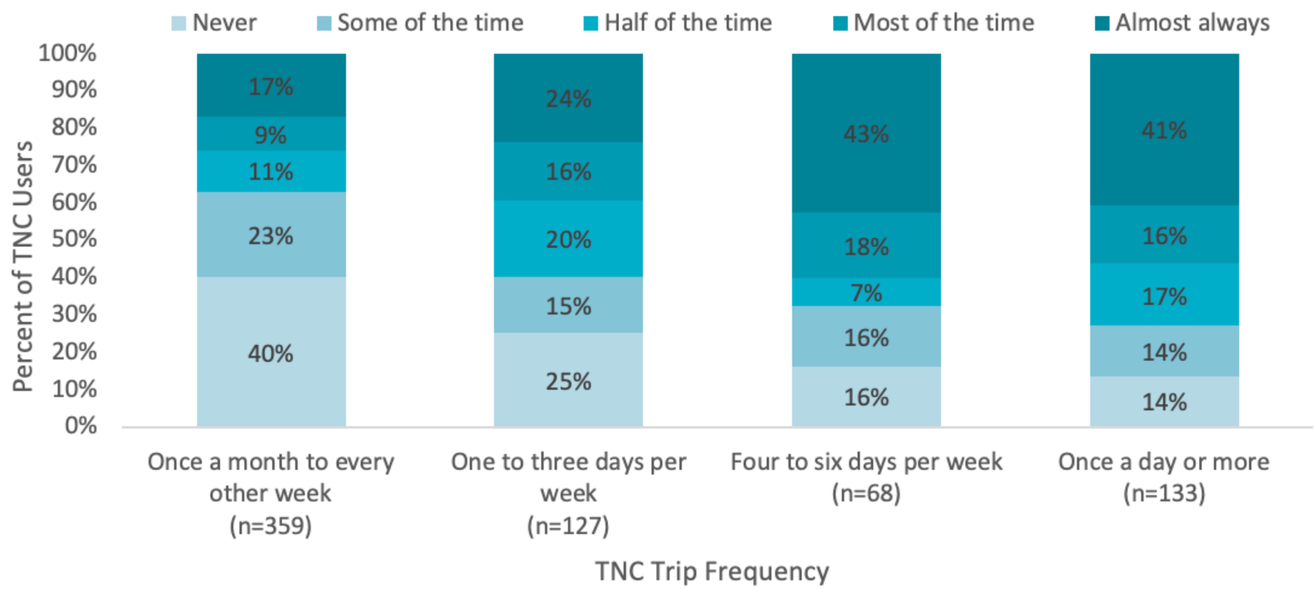

Figure 12. Distribution of How Often TNC Users Consider Using Shared TNC Options by Frequency of TNC Use

Attitudes and Perceptions of TNCs and Pooled Rides

In this section, we investigate the attitudes and perceptions of TNC users and nonusers with respect to driver and pooled passenger interactions, the efficiency of shared-ride services, and the environmental impacts of TNC services. Respondents were asked to consider a series of statements describing their attitudes and perceptions about aspects of TNC use, both generally and when pooling rides. When the statements described aspects of TNC use, TNC users were asked to consider how often the statement applied to their TNC use, while nonusers were asked to consider how often the statement would apply to them if they were to use TNCs. The distribution of users and nonusers that responded “never” or “rarely” versus “most of the time” or “almost always” are shown in Figure 13 below in blue and orange, respectively. TNC users are less likely than nonusers to be uncomfortable interacting with drivers. We observe that about 44 percent of TNC users are never or rarely uncomfortable being driven by a stranger, while about 42 percent of nonusers expect to be uncomfortable with this most of the time or almost always. TNC users are more likely than nonusers to be comfortable sharing a ride with a stranger, although they are only slightly more likely than nonusers to enjoy chatting with other passengers. TNC users are more likely to never or rarely enjoy chatting with other passengers than they are to enjoy it. Both TNC users and nonusers have favorable perceptions of TNC environmental impacts, with TNC users being slightly more likely to believe that TNCs have a positive overall impact on the environment and pooled ride TNCs are better for the environment than riding alone. The following subsections further discuss these trends and their variation across geographic regions.

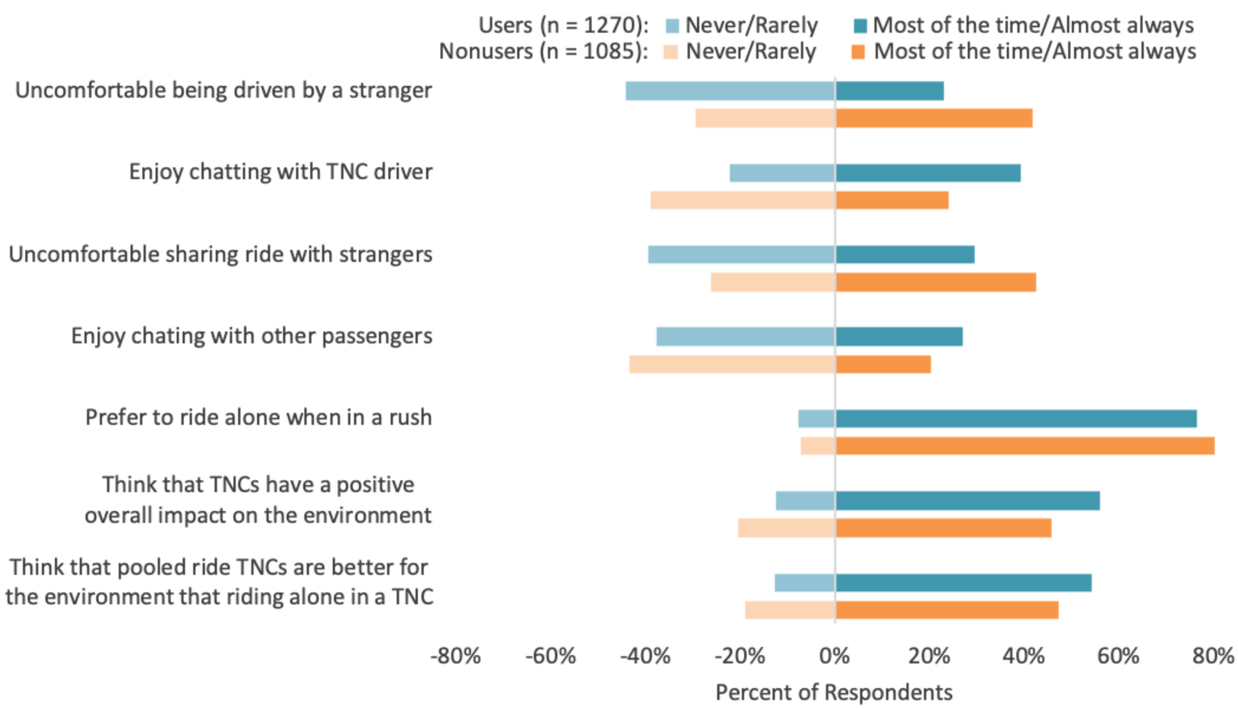

Figure 13. Attitudes and Perceptions of TNCs and Pooled Rides

Driver Interaction

TNC services today provide users with on-demand rides in vehicles owned and driven by contracted drivers. The driver-passenger relationship is typically informal, with the level of interaction between drivers and passengers varying from no more than a simple greeting at the start and end of a ride to lively conversation among two strangers. Riders' personal preferences regarding being driven by a stranger and the possibility of engaging in conversation with their driver (as conversation may be initiated by either the rider or the driver) may impact the TNC demand. In a future scenario in which TNC services are provided via a shared automated fleet, negative attitudes and perceptions of driver interactions will no longer apply. Thus, it is important to understand how, if at all, the human driver aspect of TNC services affects the demand for on-demand ride services.

TNC users are significantly more comfortable with being driven by a stranger than nonusers. About 40 to 50 percent of TNC users across all metropolitan regions say they are never or rarely uncomfortable being driven by a stranger, while about 20 to 25 percent are uncomfortable most of the time or almost always. In contrast, about 35 to 45 percent of nonusers across all metropolitan regions said that, if they were to use TNCs, they would be uncomfortable being driven by a stranger most of the time or almost always.

There is little variation across metropolitan regions in how comfortable TNC users feel being driven by a stranger. However, when it comes to conversing, TNC users in the San Francisco Bay Area are the least likely to enjoy chatting with their drivers across all metropolitan regions. While TNC users in all three other regions are more likely to enjoy talking with their drivers, TNC users in the San Francisco Bay Area are almost equally likely to enjoy conversing most of the time or almost always as never or rarely. Nonusers in the San Francisco Bay Area mirror this sentiment, as they are the least likely to enjoy speaking with Uber/Lyft drivers compared to nonusers in other regions.

Males are generally more comfortable than females with driver interaction across both TNC users and nonusers. Males were significantly more likely than females to say that they never or rarely feel uncomfortable being driven by a stranger and they enjoy chatting with their driver most of the time or almost always. While female TNC users were less likely than their male counterparts to provide the extreme answer (i.e., they are almost always uncomfortable being driven by a stranger), they were significantly more likely to provide this response across all metropolitan regions. However, when it comes to chatting with drivers, female TNC users across all regions except for San Francisco were significantly more likely than male TNC users to say they never/rarely enjoy this level of interaction. This sentiment is mirrored by female nonusers.

Nonuser perceptions of whether they would enjoy talking with their TNC drivers may be an adoption barrier. While about 30 to 40 percent of TNC users say they enjoy chatting with their driver "most of the time" or "almost always," only about 20 to 25 percent of nonusers across all regions say they would enjoy speaking with their Lyft/Uber driver to the same degree. Finally, about 40 percent of nonusers across all metropolitan regions say they would "never" or "rarely" enjoy talking with their TNC drivers.

Passenger Interaction in Pooled Rides

Interaction between passengers that are otherwise strangers to one another is inherent in the experience of using pooled TNC services. Although booking a pooled TNC ride does not always result in an additional rider being matched, the choice to pool implies the passenger understands that their ride may deviate from their own shortest path to pick up and/or drop off additional passengers who may also be interested in conversing with the driver and other passengers. Thus, rider attitudes toward sharing their rides with strangers and the degree to which they enjoy talking with other passengers contributes to an understanding of the degree to which passenger-to-passenger interactions pose a barrier in the choice to pool or not.

Although TNC users are more likely to be comfortable sharing their rides with strangers, they are generally more comfortable being driven by a stranger than pooling rides with strangers. Approximately 40 to 45 percent of TNC users are never or rarely uncomfortable pooling rides with strangers, and about 20 to 30 percent of TNC users enjoy chatting with other passengers “most of the time” or “always,” across all metropolitan regions.

Although little to no difference is observed across genders in propensity to consider pooling, there are significant gender disparities in attitudes toward sharing. In all regions except San Francisco, male TNC users are significantly more likely than their female counterparts to say they are never uncomfortable sharing a ride with a stranger. In Los Angeles, female TNC users are significantly more likely than males to sometimes be uncomfortable, and in Sacramento and San Diego, female TNC users are significantly more likely to be uncomfortable sharing most of the time or almost always. While there is no significant gender disparity in feelings about sharing a ride among TNC users in San Francisco, female TNC users in that region are significantly more likely to be averse to chatting with strangers during a ride. This gender difference is mirrored among TNC users across all metropolitan regions. In slight contrast to TNC users, female nonusers in all regions except for San Francisco are significantly less likely to expect to enjoy chatting with other riders and significantly more uncomfortable sharing a ride with strangers across all regions except for Los Angeles.

Similar to the trends in driver interactions, nonusers are significantly more uncomfortable than TNC users with pooling and interacting with other passengers who they do not know. Across TNC users and nonusers, respondents from the larger Los Angeles and San Francisco Bay Area regions are the least comfortable pooling TNC rides with strangers. Both TNC users and nonusers in the San Francisco Bay Area are the least likely of all metropolitan regions to enjoy talking with other passengers when pooling TNC rides, with TNC users being almost twice as likely to “never” or “rarely” enjoy chatting with other passengers than enjoying it “most of the time” or” almost always.” In the San Diego metropolitan region, nonusers are slightly more optimistic about how much they would enjoy chatting with other passengers than the TNC users in the same region. Although the Sacramento metropolitan region did not have pooled TNC rides available at the time of the study, nonusers from the Sacramento region are about as comfortable with the idea of sharing rides with strangers as are nonusers from San Diego, and they are slightly less optimistic about how often they would enjoy talking with other passengers.

Environmental Impacts of TNCs and Pooled Rides

Public perceptions of the environmental impacts of TNCs have the potential to impact ridership and choices between ride options, particularly among environmentally conscientious travelers. We find that the majority of TNC users and nonusers are optimistic about the overall impacts of TNCs on the environment, as well as the relative impact of pooled rides compared to riding alone in a TNC. TNC users are more optimistic than nonusers in these perceptions, particularly in the San Francisco Bay Area where about half of TNC users think that TNCs have a positive overall impact on the environment (with and without pooling) most of the time or almost always compared with only about 35 percent of nonusers that think so. Across all regions, TNC users have a slightly stronger positive perception of the relative impact of pooled rides compared to riding alone in a TNC. In the Sacramento region, where TNC users did not yet have access to pooled TNC rides, 60 percent of TNC users think pooled rides are better for the environment than riding alone compared to just under half of nonusers.

Discrete Choice Analysis

This section explores the mode choice model estimation. The final model specification is presented in Table 4 below.[12] The estimated time and cost parameters are all generic across alternatives. Thus, the coefficient estimates of those variables are the same across all three TNC alternatives. The remaining parameters are specified with the ride-alone TNC alternative as the base (the ride-alone coefficients for these parameters are set equal to zero) and they are either generic across the pooled ride options (e.g., the promotional offer parameters) or alternative-specific, with a separate coefficient estimated for door-to-door and indirect pooled rides. Where applicable, region-specific parameter coefficients are shown side-by-side in the table, spanning the columns that correspond to the metropolitan region for which the parameter is specified. For example, the trip destination parameter for public transit station-bound trips is specified for each metropolitan region separately, while the 30 to 50 years of age group parameter is specified using three coefficients for each shared-ride alternative according to three regional groupings: 1) Los Angeles metropolitan region, 2) Sacramento and San Diego regions, and 3) San Francisco metropolitan region. The latter parameter specification indicates that there is a significant difference in the demand sensitivity for shared TNC rides across the three metropolitan region groupings, but no significant difference across the Sacramento and San Diego metropolitan regions.

Table 4. TNC Mode Choice Model Results

	DOOR-TO-DOOR POOLED RIDE				INDIRECT POOLED RIDE			
	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA
Constants								
Alternative-Specific Constant (ASC)	-1.493***				-1.409***			
Estimated Travel Time								
Wait time (minutes)	-0.033***	-0.025*	-0.033***	-0.052***	-0.033***	-0.025*	-0.033***	-0.052***
Walk time (minutes)	n/a				-0.016	-0.072***	-0.042**	
In-vehicle time (minutes) – Income less than $100,000	-0.008**	-0.012**	-0.012*	-0.012**	-0.008**	-0.012**	-0.012*	-0.012**
In-vehicle time (minutes) – Income $100,000 or more	-0.021***	-0.031***	-0.012*	-0.031***	-0.017***	-0.031***	-0.012*	-0.031***

[12] The model has a null log likelihood value of -10,897.14. The log likelihood of the final model is – 9,237.41, with pseudo r-squared and r-bar-squared values of 0.152 and 0.145, respectively.

	DOOR-TO-DOOR POOLED RIDE				INDIRECT POOLED RIDE			
	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA
Estimated Cost								
Cost ($)	-0.022***	-0.035***	-0.029***	-0.032***	-0.022***	-0.035***	-0.029***	-0.032***
Promotional Offer								
Type 1 (% off of next ride)	0.013***				0.013***			
Type 2 (1/# of rides to get one free)	0.47**				0.47**			
Type 3 ($ off of transit fare)	0.060*				0.60*			
Trip Origin [Home]								
Somewhere other than home	0.072				0.203**			
Trip Destination [Home]								
Restaurant/Bar	0.329***				0.173*			
Airport	0.245*				0.153			
Public transit station	0.228*	0.211	-0.002	0.513**	0.228*	-0.449	-0.002	0.513**
Work	0.485***				0.485***			
Social/Recreational activity	0.190*				0.190*			
Time Sensitivity [Some/plenty of time to spare]								
No time to spare	-0.360***				-0.595***			
Gender [Male]								
Female	0.084				0.253***			
Age [18 to 29 years old]								
30 to 50 years old	-0.119*	0.124		-0.444**	-0.119*	0.124		-0.444**
50 to 70 years old	0.082			-0.325*	0.082			-0.325*
70 years or older	-0.037		0.377	-0.240	-0157		0.704**	-0.359

	DOOR-TO-DOOR POOLED RIDE				INDIRECT POOLED RIDE			
	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA
Employment Status [Unemployed/Retired]								
Employed/Student	-0.218**				-0.218**			
Income [$35,000 to $99,999]								
Less than $35,000	0.041				0.073			
$100,000 or more	-0.153*				-0.346***			
Medical Condition/Handicap [None]								
Medical Condition/Handicap	0.395***				-0.232*			
Car Ownership [Non-owner]								
Vehicle owner	0.603***	-0.114***	0.603***		0.346**	-0.371**	0.346**	
Mobility Profile [Use mode less than once a week]								
Drive alone	-0.299***	0.638**	-0.299***		-0.299***	0.638**	-0.299***	
Public bus	0.125*				0.125*			
Rail	0.099				-0.482***	0.695***		
Carpool/Vanpool	0.463***				0.463***			
Shared micromobility	0.497**				0.497**			
TNC Use [Use TNCs less than once a year]								
Use TNCs once a year to once every other month	0.121				0.121			
Use TNCs once a month to once every other week	-0.017*				-0.017*			

	DOOR-TO-DOOR POOLED RIDE				INDIRECT POOLED RIDE			
	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA	LOS ANGELES	SACRA-MENTO	SAN DIEGO	SAN FRANCISCO BAY AREA
Use TNCs one to three times per week	0.357***				0.357***			-0.967***
Use TNCs more than three times per week	0.170				-0.157***			-1.482***
TNC tenure (years since started using TNCs)	0.030*				0.030*			
Attitudes/Perceptions [Never]								
Enjoy chatting with driver: Nonusers	-0.156***				-0.157***			
Uncomfortable sharing rides with strangers: Users and Nonusers	-0.233***				-0.233***			
Enjoy chatting with other passengers: Users	0.126***				0.136***			
Enjoy chatting with other passengers: Nonusers	0.250***				0.250***			
Believe pooled rides are more environmentally friendly than ride-alone TNCs: Users	0.084**			0.220**	0.154***			0.290***

* : p-value < 0.1; ** : p-value < 0.01; *** : p-value < 0.001

The coefficient estimates for the ASC parameters indicate that, all else equal, individuals have a large, highly significant preference for the ride-alone TNC option over either pooled ride option. There is also a slight preference for the door-to-door over the indirect pooled ride option.

The Sensitivity of Pooling Demand to Travel Time, Cost, and Promotional Offers

The TNC demand sensitivities with respect to travel time and cost provide invaluable insight into the tradeoffs of travelers when choosing between TNC ride options for a particular ride. In the Los Angeles and San Francisco Bay Area metropolitan regions, TNC mode choices are most sensitive to estimated wait time, whereas travelers in the Sacramento and San Diego metropolitan regions are most sensitive to walking time. The model reflects a significant difference in the sensitivity of demand to in-vehicle time across income groups in all metropolitan regions surveyed, except for San Diego. In the other three regions, travelers earning $100,000 or more annually were about twice as sensitive to in-vehicle time as those earning less than $100,000. The alternative-specific specifications for the in-vehicle time parameters were also tested to investigate the potential that individuals value their time in a shared vehicle differently than when riding alone. These tests failed, indicating that other explanatory variables in the model capture the sensitivity of preferences across ride options (i.e., time sensitivity, age, income, mobility profiles, and attitudes toward sharing and chatting with other passengers).

Figure 14 below displays the estimated values of different components of TNC travel time. Estimating the same model specification presented in Table 4 without the interaction terms for income and in-vehicle time produced the following estimates of the average values of in-vehicle time for each metropolitan region: $29.20, $27.30, $26.00, and $34.50 for the Los Angeles, Sacramento, San Diego, and San Francisco Bay Area metropolitan regions, respectively. These values are fairly close to the 2018 mean hourly wages in the Los Angeles, Sacramento, San Diego, and San Francisco Bay Area metropolitan regions of $27.83, $27.13, $27.93, and $34.81, respectively (U.S. Bureau of Labor Statistics, 2019). When the in-vehicle time parameter is interacted with income, we observe significantly different values of in-vehicle time for travelers earning above $100,000 per year compared to those earning less, across the Los Angeles, Sacramento, and San Francisco Bay Area metropolitan regions.

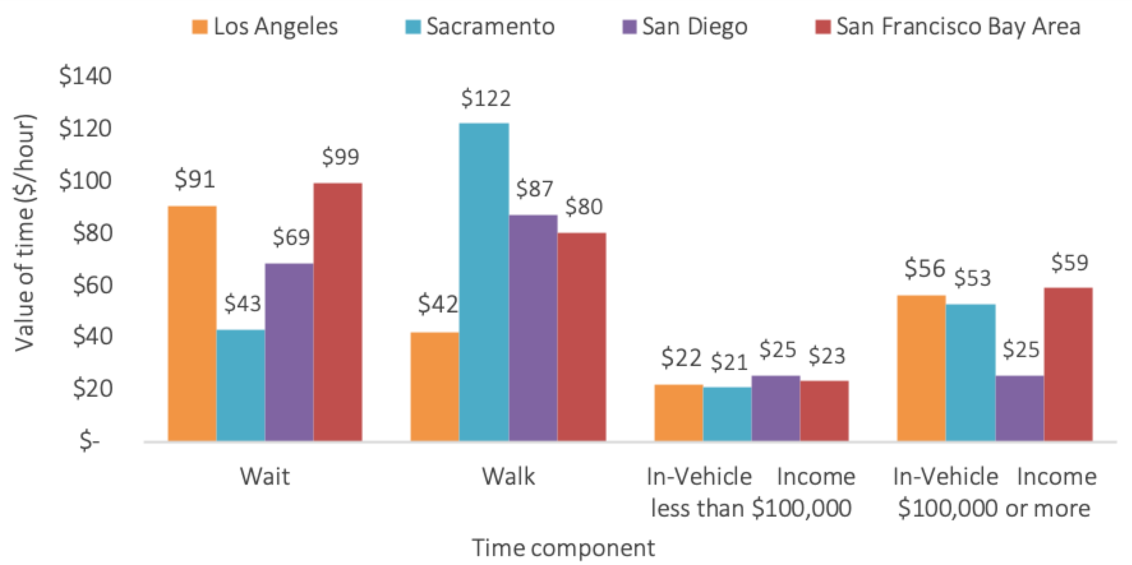

Figure 14. TNC Mode Choice Model Value of Time Estimates

In the Los Angeles metropolitan region, the estimated value of walking time is about half the value of wait time. This means that, when choosing between TNC ride options, a traveler in Los Angeles would be indifferent between two additional minutes of walking time and one extra minute of estimated wait time. In other words, if everything else about two ride options is equal, a traveler in Los Angeles would rather spend their time walking to a pickup or drop-off location than waiting to be picked up. This suggests that the efficient operation of indirect on-demand pooled ride services could play a role in increasing average TNC vehicle occupancy and decreasing total VMT from TNC use, while fostering greater pooling demand. However, this strategy alone may not be successful across all markets, as demonstrated by the very high estimated value of walking time for the Sacramento metropolitan region.

Promotions that offer travelers discounts for future TNC or public transit trips can significantly increase the likelihood that an individual chooses to use a pooled on-demand ride service. Among the three promotional types tested, the offer of a percent discount on a future ride in return for choosing a pooled ride resulted in the most significant impact on TNC mode choices. The second promotion type was specified as the number of rides that had to be taken to get one free ride, so the estimated coefficient represents the added utility from an offer of 'take one pooled ride get one free.' As one might expect, the positive influence of the promotion on the choice to pool diminishes as more rides are needed to get one free. The third promotion type, which offered a discount off of a public transit fare for choosing to pool to a public transit station, represents an attractive TDM strategy for promoting public transit ridership through improved first mile/last mile connectivity using pooled on-demand rides. Moreover, offering a dollar off of a public transit fare is about twice as effective at increasing likelihood to pool as taking a dollar off of the estimated cost of a trip.

Sensitivity of Pooling Demand to Trip Context

The origin and destination of a trip can influence a traveler's preference when choosing between TNC ride options. Travelers are the least likely to choose to pool when starting or ending a trip from their home. When considering TNC options for a trip that starts somewhere other than home, travelers are significantly more likely to choose indirect pooled rides, indicating that people may be more willing to walk to a pickup location when they are already away from home. When requesting a ride from home, TNC users are more likely to be better able to use their wait time in a productive manner and thus may be less willing to choose a ride option that requires them to leave their home earlier to walk to a pooled ride.

Compared to all other trip destinations, travelers are generally most likely to prefer to ride alone when making a trip destined for home, and they are most likely to pool when considering TNC options for a commute trip. Travelers in the San Francisco Bay Area are the most likely to choose shared-ride options when linking to a public transit station, whereas linking to transit has no significant influence on preferences for pooled rides for those in the San Diego region. While travelers in the Los Angeles and Sacramento metropolitan regions are about as likely to choose a door-to-door pooled ride to get to a public transit station as they are for an airport trip, travelers in the Sacramento region have a significant aversion to the indirect shared TNC ride option for transit-linking trips. This result may be dually affected by the lack of exposure to indirect pooled rides in the Sacramento region at the time of the survey, as well as important exogenous factors related to the distribution of public transit stations and the surrounding land use in the Sacramento region.

In comparison to home-bound trips, travelers are significantly more likely to share their rides when traveling to a restaurant or bar, although they prefer to use the door-to-door over the indirect pooled ride option for such trips. Similarly, there is a significant preference for door-to-door over indirect pooled rides for airport trips in which the prospect of carrying luggage while walking to or from a pickup or drop-off location is predictably less attractive than a door-to-door service. Although the coefficient for indirect pooled rides to the airport is not significant at a 90 percent confidence level, the coefficient estimate is relatively large and positive. This might reflect that airport-bound trips tend to be longer in distance than trips to other destinations. Thus, estimated airport trip times and travel costs were greater, on average, than those of other trip purposes, resulting in a greater absolute cost difference between the three TNC ride options. When considering an airport trip, travelers may be particularly sensitive to travel costs as an added expense to airfare and thus be attracted to the large cost savings provided by shared TNC ride options in comparison to the ride-alone TNC option.

The inclusion of the time sensitivity variable in the trip context for each choice experiment allows for the interpretation of the trip purpose coefficient estimates in the model to be independent from assumptions regarding a traveler's relative time sensitivity across trip destinations. The corresponding coefficient estimates reflect the significance of time sensitivity in TNC mode choices by exhibiting a strong preference to ride alone for trips in which there is no time to spare in contrast to those in which there is some or plenty of time to spare. Not surprisingly, travelers are significantly less likely to choose an indirect pooled ride over a door-to-door pooled ride when they have no time to spare. These results likely reflect exogenous factors corresponding to a traveler's beliefs about the reliability of estimated travel times across shared-ride services.

Socio-Demographic Factors in Pooling Demand Sensitivity

The TNC mode choice model enables examination of the differences between individuals presented with identical TNC options under the same trip context. Across all metropolitan regions, females, unemployed or retired individuals, and people with an annual income of less than $35,000 are the most likely to choose a pooled ride. In addition, female and low-income travelers are more likely to choose an indirect pooled ride, while individuals with an annual income of $100,000 or more are even less likely to choose an indirect pooled ride than they are to choose a door-to-door pooled ride. In the San Francisco Bay Area, the youngest age group (18 to 29 years old) is the most likely to share an on-demand ride, while the oldest age group (70 years or older) is the most likely to do so in the San Diego metropolitan region. In all metropolitan regions surveyed, except for San Diego, travelers 70 years or older are significantly less likely to choose an indirect pooled ride. In San Diego, however, travelers in the oldest age group are even more likely to choose an indirect pooled ride than they are to choose a door-to-door pooled ride or to ride alone. Investigation of the interaction of income with the age group parameters revealed that the affinity for pooled rides among the eldest age group in San Diego is primarily driven by respondents in this age category earning less than $35,000.

People with a medical condition or handicap are significantly more likely than others to choose a door-to-door pooled ride over riding alone. However, they would rather ride alone than take an indirect pooled ride, as the need to walk to or from a pickup or drop-off location is particularly burdensome for this population segment. In all metropolitan regions surveyed, except for Sacramento, vehicle owners have a greater preference for pooling than non-vehicle owners, although vehicle owners prefer door-to-door pooled rides over indirect pooled rides across all metropolitan regions.

The majority of parameters representing race/ethnicity in the mode choice model were found to be insignificant as measured by the asymptomatic t-test. Only the variable for Asians was significant for the Los Angeles and Sacramento regions. These variables indicated that Asians in these regions prefer ride alone over shared TNC services. However, when jointly testing the significance of race/ethnicity variables, the likelihood ratio test is rejected in favor of an unrestricted model without these variables. Thus, the parameters were removed from the model for simplicity and ease of interpretation of the final results.

It is important to note that the discrete choice model represents a linear utility function of the corresponding coefficients for a particular individual in a particular trip context with certain ride options. Thus, an employed 30- to 50-year-old who owns one or more cars and has an annual income of $100,000 or more in Los Angeles or San Diego is still more likely to prefer a ride-alone option than would their counterpart (e.g., *unemployed* 30- to 50-year-old vehicle owner *earning less than* $100,000/year).

Pooling Demand Sensitivity Across Mobility Profiles and TNC Use

While vehicle owners are generally more likely to choose a pooled ride over riding alone in a TNC, those that drive alone in their vehicle on a weekly basis are significantly less likely to share compared to other people, across all metropolitan regions except for Sacramento. When considering the coefficient estimates for vehicle ownership and weekly drive alone behavior together, it appears across all metropolitan regions that weekly auto drivers have a significant preference for door-to-door pooled rides over riding alone in a TNC.

Weekly users of other shared modes are generally more likely to share a ride in a TNC than other travelers. Across all of the metropolitan regions, weekly public bus users are slightly more likely to choose pooled rides over riding alone. Weekly rail users, on the other hand, have a significantly large preference for indirect pooled rides over either riding alone or using a door-to-door pooled ride, across all of the metropolitan regions except for Los Angeles, where weekly rail users have a significant and comparatively large aversion to indirect pooled rides. Weekly carpool and/or vanpool use, as well as the use of shared micromobility services on a weekly basis are both strong positive factors in an individual's likelihood to pool. Weekly taxi use did not result in a significant difference in preferences for pooling in TNCs, though we note that the estimated coefficient was slightly negative, as expected.

Likelihood to choose pooled rides increases with a traveler's tenure as a TNC user, although it varies with respect to TNC trip frequency. The trend in pooling demand sensitivity with respect to TNC trip frequency suggests that, while TNC weekly users are the most likely to choose a door-to-door pooled ride over riding alone, travelers that use TNCs more than three times per week are less likely to do so and actually prefer to ride alone over using indirect pooled rides, across all of the metropolitan regions. In the San Francisco Bay Area, where TNC users are likely to have had the most experience with indirect pooled rides, weekly TNC users are significantly less likely to choose indirect pooled rides compared to riding alone or choosing a door-to-door pooled ride. Finally, monthly TNC users do not exhibit a large preference across TNC ride options, although less frequent TNC users have a slight preference for pooled rides compared to inactive TNC users and nonusers.

Pooling Demand Sensitivity and Traveler Attitudes and Perceptions

The underlying attitudes and perceptions that both TNC users and nonusers have about interactions with drivers and other passengers and the environmental impact of shared-ride TNC services are a significant factor in the sensitivity of demand for pooling. The attitude and perception variables were included in the mode choice model using a Likert scale from zero to four corresponding to responses ranging from 'never' to 'almost always.' There were no significant differences in demand sensitivities to attitudes and perceptions regarding TNC driver and passenger interaction across the door-to-door and indirect pooled ride options. Although TNC users are significantly more likely than nonusers to have positive attitudes about chatting with TNC drivers, driver interaction is not a significant factor in their TNC mode choices. On the other hand, nonusers, 40 percent of whom say they would never or rarely enjoy chatting with TNC drivers, are significantly less likely to pool the more they expect to enjoy chatting with drivers. When it comes to interacting with other passengers, positive attitudes toward sharing a ride and chatting with other passengers have significant positive effects on pooling preference across TNC users and nonusers. Although there was not a significant difference in pooling demand sensitivity with respect to how comfortable users and nonusers feel about sharing rides with strangers, experience with on-demand rides dampens the increased likelihood for sharing with respect to how much someone enjoys chatting.

TNC user perceptions of the positive environmental impact of shared-ride options significantly increases their likelihood to pool. The impact of these perceptions is stronger for indirect pooled rides across all of the metropolitan regions. In the San Francisco Bay Area, the demand sensitivity for pooling is significantly more sensitive to perceptions about the environmental impact of pooled rides than in any of the other regions.

Conclusions and Policy Recommendations

Opportunities to expand pooling are diverse and vary across the four metropolitan regions explored in this report. TDM strategies that employ an understanding of the time and price tradeoffs of travelers under various trip contexts have the potential to increase systemwide vehicle occupancy by incentivizing multiple forms of pooling including: on-demand pooling, app-based ridesharing, microtransit, and traditional public transit. However, careful consideration must be made of regional variations in demand sensitivity to on-demand rides as well as the disparate impacts that such policies may have on marginalized population groups, who are among the heaviest TNC users.

Heavy TNC users (those that use TNCs more than three times per week) are disproportionately young, low-income, and non-vehicle owners compared to less frequent TNC users and nonusers. Heavy TNC use also varies notably across race and ethnicity, reflecting differences in socio-economic disparities across racial and ethnic groups in each metropolitan region studied. In particular, heavy TNC use among young people reflects higher usage among: 1) higher income young Caucasian/Non-Hispanics and 2) lower income African Americans. Although heavy TNC users constitute a relatively small portion of the overall population across the four metropolitan regions surveyed, they represent a cohort of TNC users that will be among the most impacted by TDM policies, as they have incorporated on-demand ride services into their weekly routine beyond just weekend travel and are likely to consider on-demand rides in their mode choice decisions on a daily basis. Across all metropolitan regions, the majority of daily TNC users are making multiple TNC trips per day. While heavy TNC users are the most likely to consider a pooled ride option when using TNC services, they are less likely than weekly users to choose a pooled ride when trading off comparable ride-alone, door-to-door pooled ride, and indirect pooled ride options. Based on their greater propensity to use TNCs for essential trip purposes, there is a sizable opportunity to increase pooling rates among heavy TNC users through promotional offers for pooling to public transit stations, employment centers, and healthcare services. In particular, subsidized pooled rides for travelers that are low-income, unemployed, or have a medical condition/handicap could greatly increase mobility and accessibility for these groups.

However, it is vital to consider the travel time reliability of shared-ride services when targeting pooling incentives at marginalized populations and highly time sensitive trip purposes. As demonstrated by the history of ridesharing, a critical mass of riders willing to pool is needed to foster convenience and reliability to retain ridership. While the necessary density of pooling ridership may be achieved over time with increased adoption of on-demand mobility and successful TDM strategies, special consideration is necessary for supporting the earliest group of targeted adopters, particularly those who rely the most on shared services and cannot afford the consequences of an unreliable service. Several shared micromobility permit programs have demonstrated a framework for regulating the level of service provided on a geographic basis, typically with the aim of ensuring spatial equity by mandating minimum vehicle availability standards in historically underserved or public transit-poor neighborhoods. Analogous strategies may be developed for on-demand ride services by regulating wait times for particular geographic regions or user groups. The California Public Utilities Commission recently implemented such a regulation for the level of service provided by TNC wheelchair accessible vehicles by establishing response time standards specific to each geographic area of the state (CA Pub Util Code § 5440.5).

Indirect pooled rides offered by TNCs and microtransit providers alike pose a substantial opportunity to reduce congestion from single-occupant vehicle use and deadheading. Since indirect pooled rides are designed to minimize deviations from the common path between multiple passengers by requiring that riders walk to and/or from a pickup and/or drop-off location, they can decrease the total travel time of on-demand trips. Moreover, able travelers in some metropolitan regions would rather walk a minute than wait a minute. Thus, by converting waiting time to walking time and reducing in-vehicle time, indirect pooled rides can be a significantly more attractive pooled ride option with co-benefits for society and the environment.

Both curb access management and mileage-based road pricing can serve as effective TDM strategies to increase indirect pooling.[13] In residential and commercial zones, dedicated pickup and drop-off locations for on-demand rides can aid in aggregating demand for indirect ride services, while providing a mechanism for pricing and/or enforcement of desirable curb access restrictions. While mileage-based road pricing can incentivize pooling in general, it can create a particularly large incentive for indirect pooled rides, which not only distribute the cost per mile across a larger number of riders but also reduce VMT for any particular trip. In particularly congested conditions that arise frequently in central business districts during peak commute hours, the combination of mileage-based congestion charging with time-sensitive curb access restrictions offers a promising strategy to manage congestion from on-demand rides while incentivizing pooling. Travelers departing from a congested area may be able to save considerable amounts of both in-vehicle and wait times by walking to/from a strategically placed pickup/drop-off location that minimizes VMT through congested streets as well as the resulting congestion charges accrued from such a trip. Moreover, on demand service providers may achieve higher pooling rates by allowing riders to request a hybrid indirect and door-to-door ride. Travelers are more willing to choose an indirect ride when starting a trip from outside their home, but least willing to share when taking a trip from home. Thus, offering the option to request an indirect ride with a direct drop-off can attract additional pooling demand.

Simple promotions can also provide effective incentives for pooling. Offering a discount off of a future ride in return for choosing a pooled ride can be a particularly useful strategy for reducing VMT during periods of peak or abnormal congestion, such as during rush hour or during a major event. Travelers can also be given incentives to pool across multiple trips by offering a free ride in return for a number of pooled rides. This strategy could be particularly effective for encouraging heavy TNC users to try pooling, as there is less risk of inducing additional on-demand rides, while ample opportunities exist for these already captive users to make a shift in their on-demand ride choices. Finally, offering a discount on a public transit fare in return for pooling to a public transit station poses an attractive strategy for increasing public transit ridership through pooled first/last mile connections. Similar incentive policies may be effective for other forms of on-demand shared mobility such as bikesharing and scootersharing.

However, we observed that the majority of weekly TNC users are not using TNCs in conjunction with public transit. Although public transit use is greatest among high frequency TNC users, the share that access public transit using TNCs is comparatively small. In the Los Angeles and San Francisco Bay Area regions, where about half of weekly TNC users are also weekly rail riders (mostly rapid transit riders) and about 55 percent and 70 percent are bus riders, respectively, only about 20 percent of weekly TNC users in these regions use TNCs to get to/from public transit stations. Previous research has found that faster travel times and less wait times are among the top reasons that travelers choose TNCs over public transit (Feigon and Murphy, 2018). More research is needed to discern the trip purposes and contexts in which travelers choose to

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[13] Mileage-based road pricing encompasses both mileage-based road user fees (MBUF) and area-wide congestion charging in which vehicles are charged a specified fee per mile driven. MBUFs are currently being piloted in select states across the United States including California, primarily as a transportation funding mechanism to replace gas excise taxes. Congestion pricing policies are increasingly under consideration in many metropolitan regions including San Francisco and Los Angeles to improve transportation system performance by charging vehicles for access to roads in designated areas during congested periods. As opposed to cordon tolls which charge for entry and/or exit to a charging zone, area-wide congestion pricing schemes charge vehicles per mile driven within the zone.

use a TNC rather than a public transit service. Nevertheless, it is clear that there are travelers who regularly access public transit for certain trips and choose to use TNCs for others. Thus, strategies for encouraging pooled on-demand rides must strike a delicate balance that effectively shifts demand from ride alone to pooled on-demand options, while minimizing further substitution of on-demand rides for public transit. This will be particularly important following the 2020 COVID-19 pandemic when travelers may still have concerns about hygiene and social distancing associated with shared mobility vehicles, pooling, and public transit use.

Although concerns for the potential health risks of using on-demand rides and pooling were not explored in this study, as the survey predates the COVID-19 pandemic, we find that attitudes and perceptions about interactions with TNC drivers and other passengers, as well as the environmental impacts of TNCs are significant factors in on-demand mode choices. TNC users have more positive attitudes toward interacting with a driver and other passengers than do nonusers, suggesting that these factors may pose a barrier to TNC adoption generally and pooled rides, in particular. The privacy of a ride alone in an automated vehicle is likely to attract additional users to the on-demand ride market who are likely to have negative attitudes toward interacting with other passengers. The regional variation in these attitudes as well as the perception of the environmental impacts of TNCs and pooled rides suggest the potential for region-specific influences on TNC modal choices.

Finally, there is tremendous untapped potential to increase the market share of pooling among commuters. We found that the likelihood to pool is greatest for work trips in all metropolitan regions studied except for the San Francisco Bay Area, where trips to public transit have a slightly higher likelihood for pooling. The commuting choice experiments were posed as plan ahead scenarios, in which respondents were asked to consider they were planning a trip to work for the following morning. Thus, the increased likelihood to pool for commute trips may also reflect the increased willingness of travelers to pool for trips in which they can reserve a reliable pooled ride in advance. This option is currently provided by app-based carpooling services, microtransit services, and TNCs in some pilot areas.

This research suggests that there are key differences in the demand for pooling reflected by the four geographic regions examined in this report, the range of sociodemographic factors, and TNC-service options. Policies should be crafted to reflect the geospatial and sociodemographic differences across regions to encourage pooling and more efficient TNC routing to reduce deadheading and excess VMT. Careful experimentation with pricing strategies and incentives would provide key insights in how to best maximize the societal and environmental benefits of these services and to better prepare for SAV services in the future.

Appendix

Table A1. Distribution of Alternative-Specific Attribute Levels in the SP Choice Experiments

	Minimum	Maximum	Mean	Standard Deviation
Estimated wait time (min)				
Ride Alone	2	9	5.7	2.8
Door-to-door pooled ride	2	9	5.7	2.9
Indirect pooled ride	2	9	5.7	2.9
Estimated in-vehicle time (min)				
Ride Alone	7	74	34	22.1
Door-to-door pooled ride	7	126	47	32.2
Indirect pooled ride	7	126	47	32.2
Estimated walking time (min)				
Indirect pooled ride	2	10	6	2.9
Estimated Cost ($)				
Ride Alone	2.0	173.0	43.5	39.8
Door-to-door pooled ride	1.5	157.4	34.1	31.4
Indirect pooled ride	1.1	143.2	26.7	24.7

Table A2. Correlations Between Respondents' Socio-Demographic Characteristics

		Female	Age	Income	Educa-tion	African American	Asian	Cauc-asian	Hisp-anic	Employed	Student	Retired	Vehicles
Los Angeles	Age	-0.12											
	Income	-0.21	0.29										
	Education	-0.20	0.25	0.48									
	African American	0.08	0.09	-0.09	-0.09								
	Asian	-0.05	0.11	0.17	0.27	n/a							
	Caucasian	-0.24	0.29	0.29	0.32	n/a	n/a						
	Hispanic	0.21	-0.39	-0.35	-0.47	n/a	n/a	n/a					
	Employed	-0.03	-0.40	0.02	-0.02	-0.06	0.01	-0.10	0.12				
	Student	0.13	-0.31	-0.19	-0.13	-0.01	-0.07	-0.11	0.15	-0.41			
	Retired	-0.03	0.63	0.09	0.10	0.08	0.03	0.18	-0.23	-0.82	-0.12		
	Vehicles	-0.10	0.16	0.40	0.17	-0.06	0.04	0.07	-0.08	0.03	-0.12	0.05	
	Handicap/Medical Condition	-0.05	-0.03	-0.02	0.04	-0.01	-0.05	0.16	-0.10	-0.03	-0.03	0.04	0.04

		Female	Age	Income	Educa-tion	African American	Asian	Cauc-asian	Hisp-anic	Employed	Student	Retired	Vehicles
San Deigo	Age	0.19											
	Income	0.06	0.27										
	Education	0.21	0.42	0.50									
	African American	-0.05	-0.06	-0.06	-0.09								
	Asian	0.01	-0.08	0.04	0.09	n/a							
	Caucasian	0.30	0.46	0.21	0.34	n/a	n/a						
	Hispanic	-0.33	-0.42	-0.29	-0.44	n/a	n/a	n/a					
	Employed	-0.03	-0.51	-0.07	-0.22	0.02	0.08	-0.25	0.25				
	Student	-0.05	-0.31	-0.11	-0.10	-0.06	0.04	-0.16	0.12	-0.22			
	Retired	0.06	0.65	0.10	0.26	0.00	-0.10	0.32	-0.29	-0.90	-0.16		
	Vehicles	0.01	0.14	0.40	0.21	-0.08	-0.08	0.19	-0.14	-0.05	-0.03	0.07	
	Handicap/Medical Condition	-0.02	0.02	-0.07	-0.13	0.13	-0.02	-0.16	0.08	-0.09	0.05	0.08	-0.19

		Female	Age	Income	Educa-tion	African American	Asian	Cauc-asian	Hisp-anic	Employed	Student	Retired	Vehicles
Sacramento	Age	0.10											
	Income	-0.07	0.31										
	Education	0.12	0.44	0.44									
	African American	0.09	0.03	-0.10	-0.10								
	Asian	0.10	-0.05	0.01	0.04	n/a							
	Caucasian	0.05	0.50	0.32	0.48	n/a	n/a						
	Hispanic	-0.12	-0.46	-0.29	-0.49	n/a	n/a	n/a					
	Employed	-0.02	-0.58	-0.16	-0.22	0.04	0.00	-0.26	0.24				
	Student	0.01	-0.27	-0.10	-0.22	0.01	0.13	-0.21	0.10	-0.30			
	Retired	0.02	0.73	0.22	0.33	-0.05	-0.08	0.36	-0.27	-0.88	-0.15		
	Vehicles	-0.08	0.10	0.36	0.24	-0.07	-0.01	0.09	-0.07	-0.07	-0.11	0.11	
	Handicap/Medical Condition	-0.03	0.05	-0.03	-0.02	0.11	0.03	0.05	-0.12	-0.01	-0.03	0.02	0.05

		Female	Age	Income	Educa-tion	African American	Asian	Cauc-asian	Hisp-anic	Employed	Student	Retired	Vehicles
San Francisco Bay Area	Age	-0.10											
	Income	0.01	0.19										
	Education	0.07	0.33	0.51									
	African American	0.06	-0.15	-0.22	-0.16								
	Asian	0.06	-0.05	0.07	0.11	n/a							
	Caucasian	-0.01	0.39	0.14	0.34	n/a	n/a						
	Hispanic	-0.06	-0.32	-0.16	-0.42	n/a	n/a	n/a					
	Employed	0.21	-0.48	0.03	-0.02	-0.02	-0.01	-0.13	0.16				
	Student	-0.06	-0.27	-0.02	-0.10	0.06	0.07	-0.14	0.08	-0.25			
	Retired	-0.19	0.59	-0.04	0.05	-0.01	-0.03	0.20	-0.19	-0.92	-0.11		
	Vehicles	-0.08	0.12	0.38	0.13	-0.17	0.06	0.04	-0.03	0.04	0.03	-0.05	
	Handicap/Medical Condition	-0.05	-0.09	-0.07	-0.05	0.05	-0.01	-0.06	0.03	0.10	-0.07	-0.08	-0.16

Pearson's correlation coefficients are shown. The age and vehicles variables are continuous; the income variable is also continuous, using the median income for each income group; the education variable is ordinal; all other variables are binary. The race/ethnicity variables are mutually exclusive.

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