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Understanding Curb Management and Targeted Incentive Policies to Increase Pooling: Examining On-Demand Transportation Services with a Focus on Shared Rides

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16. Abstract

This study aimed to contribute to the growing body of literature on on-demand transportation services, with a particular emphasis on sharing or pooling a ride when using these services, such as transportation network companies (TNCs) and microtransit. In 2022, an online survey (shared mobility survey) was administered in both English and Spanish to persons 18 years old or older and in selected cities across Texas—ranging from large urban areas to small cities and rural areas. The survey was designed to collect a rich set of data from more than 2,500 participants and offered a reasonably representative sample of adults in Texas. The study conducted an extensive examination of the data collected to better understand on-demand mobility service use and user characteristics, including attitudes, perceptions, and concerns in general as well as while sharing trips. Barriers to using these services and potential improvements that would make sharing or pooling a trip more appealing were investigated for both current and future on-demand services. The study produced intriguing new findings that contributed to the literature, as well as findings that supported and occasionally deviated from the current literature.

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Executive Summary

Emerging technologies have the potential to cause major disruptions in transportation over the course of the next few years. The best example that highlights such potential disruptions is the rise in popularity of transportation network companies (TNCs), such as Uber and Lyft, in recent years. These TNCs, and other forms of on-demand transportation services, provide users with convenient ride-hailing options through their phones or the Internet. These services provide an opportunity for increased mobility for individuals who would otherwise not have access to a car; individuals can pay for rides as they are needed rather than make a sizeable investment in their own personal vehicle. The emergence of TNCs has already disrupted the taxi industry and changed the way people interact with transportation; people are no longer required to physically flag down a taxi if they need one, nor do they have to adjust their entire travel plan around the strict schedules set up by public transit services.

While these on-demand services have a myriad of potential benefits, there are also associated downsides due to more cars now being on the road, adding more vehicle miles traveled, more traffic congestion, and more pollution to the road, exacerbating existing social and environmental problems related to cars. The issues related to solo trips in cars will be compounded further if TNCs have a substitution effect on modes such as public transit and walking. These new services are also not as egalitarian as some may hope, with many of the same inequities currently present in traditional transportation modes also applicable to on-demand services. If the same minorities get left behind, on-demand transportation services will simply widen the gap between the haves and the have-nots instead of bridging them as originally intended.

While the literature on new mobility options is growing, more studies specifically focusing on on-demand transportation services are needed to help better understand and address the concerns noted above. Thus, this study examined user attitudes, perceptions, barriers, and solutions related to on-demand transportation in selected cities across Texas. As a potential solution to some of the aforementioned concerns, the adoption of pooled- or shared-ride services was given a special focus.

To answer some of the above questions, an electronic survey was developed and administered via Qualtrics to an online panel between February and May 2022 across select cities in Texas where the services of interest to the study are currently available. Quotas for various sociodemographic characteristics, such as age, gender, race, and income, were implemented using U.S. census data to ensure that the sample was representative of the general Texas population. A total of 2,527 participants were included in the sample; the sociodemographic traits of the sample and the larger Texas population were very similar.

The researchers began by assessing the users of on-demand transportation services, including who they were, what sociodemographic characteristics they possessed, how frequently they used these services and for what trip purposes, and what alternate modes of transportation they would have used if these services were not available. An attempt was made to determine which groups were more or less likely to use these services and why to understand if any differences in current usage were due to personal preferences or systemic issues. The primary benefits and concerns Texans have with these services were evaluated, and various operational/policy changes were examined to address their needs.

The study produced intriguing new findings that contributed to the literature, as well as findings that supported and occasionally deviated from the current literature. The two biggest concerns people had about all these new modes of transportation were safety and cost, but these concerns were not homogenous across different populations. Some of the most popular operational/policy proposals sought to improve safety while controlling

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for cost. The biggest issue preventing more people from choosing to share a ride through any of these new services was the added inconvenience of sharing a vehicle with strangers who likely have different destinations. Those who had shared a ride in the past but found the service unsatisfactory cited increased travel times as their main reason for disliking the service. Operational improvements that reduced the uncertainty surrounding shared rides and minimized inconvenience for passengers were among the most popular of the suggested changes.

If the issues surrounding shared trips can be addressed, both at the overall population level and specific group sublevels, more individuals can be incentivized to pool their rides instead of taking solo trips. Fewer cars on the road will lead to less traffic, noise, and pollution, all of which will have positive social, health, and environmental impacts. When coupled with easier access to transportation for marginalized groups, some of the inequity that currently exists in transportation can be reduced. The emergence of TNCs and on-demand transit services provides a unique opportunity to increase mobility while providing travelers with more freedom and flexibility than ever before. However, if the issues associated with these on-demand services are not actively addressed before widespread implementation, the mistakes of the past may be repeated, compounding existing problems.

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Chapter 1. Introduction

Advances in technology and data analytics have allowed new mobility options that include unique travel characteristics such as on-demand and app-based services to emerge. These new mobility options could significantly influence travel behavior, as well as the level and distribution of travel demand. The likely long-term impacts of these new mobility options will depend on when, how, why, and by whom they are adopted and used.

Acquiring reliable information can be challenging given that preferences change as policies, society, and technology mature. In addition, existing research is limited, even for more developed services, particularly because business models are still evolving, data on usage and users are often considered proprietary information, and research is usually conducted on hypothetical scenarios and stated responses. It is essential for researchers, practitioners, and policymakers to track and monitor the usage and adoption patterns and develop insights into how emerging and future mobility options evolve and how they contribute to sustainable mobility.

These new mobility options have the potential to address various transportation issues such as traffic congestion and air pollution by reducing private vehicle ownership and single-occupancy vehicle (SOV) use, while improving personal mobility. However, well-designed policy and planning strategies—supported by a robust understanding of these services and their role in the overall transportation ecosystem—are needed. The concept of sharing, supported by the evolution of emerging technologies, is particularly important in transforming mobility and providing opportunities to increase shared-ride trips in vehicles.

Opportunities to increase pooling rates among transportation network company (TNC) users are available through incentives and promotions for splitting a ridesourced trip, particularly for trips to public transit stations, employment centers, and designated pickup/drop-off locations. Many microtransit services operated by or in partnership with public transit agencies are designed to fill gaps in service between the fixed-route network and group travel in places where fixed-route transit has not performed well.

This study aimed to contribute to the growing literature on these new mobility options, specifically focusing on on-demand transportation services. Through an online survey conducted in Texas in 2022, the researchers examined pooling options available from on-demand transportation companies, including TNCs and microtransit services. The findings provided an overall picture of the use and user characteristics of on-demand mobility services, including user attitudes, perceptions, and concerns toward pooling. In addition to examining the factors influencing service usage and trends, researchers explored barriers to using these services and potential improvements that would make sharing or pooling a trip more attractive for both current and future modes of transportation.

The remainder of this report includes the following four chapters:

- Chapter 2 reflects on the prior research findings regarding the potential benefits of pooling and potential disruptions.
- Chapter 3 describes the shared mobility survey, with details of the data collection and data characteristics.
- Chapter 4 presents the survey data analysis through an extensive discussion of the findings related to pooling through TNCs, microtransit services, and shared automated vehicles (SAVs).
- Chapter 5 concludes the study with a summary and final remarks on potential recommendations to encourage pooling when using on-demand transportation services.

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Chapter 2. Benefits of Pooling and Potential Disruptions

This chapter provides a review of research on the measured benefits of pooling and potential disruptions. The outright benefits of ridepooling services are not conclusive based merely on the service being offered. Schaller (2021) studied the effectiveness of TNCs in reducing vehicle miles traveled (VMT) in five areas of the United States and determined that pooling trips on these services led to the doubling of VMT over the patrons' previous mode. This phenomenon was due to additional deadhead miles and patrons switching to ridepooling services from a different non-SOV mode. Any trips on ridepooling services that do not meet certain delay tolerances or time windows for travel may not actually reduce VMT or vehicle emissions (Yan et al., 2020).

Researchers also conducted an extended review of existing pooled travel choice studies—including factors affecting pooling, as well as existing or suggested strategies for encouraging pooled rides—over the course of this project.

- ❖ Results from this additional review are detailed in the research paper titled 'Strangers On This Road We Are On: A Literature Review of Pooling in On-Demand Mobility Services' by Hansen and Sener (2022).

Congestion

The largest potential benefit of dynamic ridesourcing through shared fleets (and in the future, SAVs) is the reduction of overall VMT if travelers massively adopt shared rides (Lavieri & Bhat, 2018). Existing shared mobility trips in urbanized areas that are taken as exclusive rides could likely be pooled in the same vehicles instead. A study of cellphone data in Orlando, Florida, found that nearly 60 percent of single-person trips could be shared (using an SAV fleet) with less than 5 minutes of additional travel time for travelers, while additional trips could be shared with 15 or 30 minutes of added time (Gurumurthy & Kockelman, 2018).

Ridepooling programs from on-demand automated vehicle (AV) services could help reduce required fleet sizes and alleviate traffic congestion, thus saving travel time for all road users (Farhan & Chen, 2018). By comparing data from ridesourcing markets with and without ridepooling services, Ke, Yang, Li, et al. (2020) found that time costs (travel time plus wait time) for all road users could be reduced through optimal matching windows for passengers and ridepooling services. The factors for successful ridepooling programs in this analysis were passenger demand and pool-matching strategy (Ke, Yang, & Zheng, 2020).

Two recent studies that examined ridesourcing survey data in Chicago and Boston revealed important information about travel choices with respect to sharing vehicles with other passengers, providing implications for vehicle congestion in cities. In Chicago, about 26 percent of ridesource users were willing to pool, about 72 percent of those users' trips involved an additional rider, and about 19 percent of shared rides were actually pooled (Hou et al., 2020). In Boston, about 20 percent of ridesourced trips were pooled with other riders; 59 percent of trips used a ridesourcing service instead of fixed-route public transit because of time savings, accounting for an additional vehicle onto the roadway system (Gehrke & Reardon, 2021).

Other studies that highlight the effects of ridepooling on congestion (along with other related results) include the following:

- In a simulation of SAVs set in the Minneapolis–St. Paul region of Minnesota, dynamic ridepooling of vehicles decreased total VMT and empty-vehicle miles traveled by 17 percent and 26 percent on average, respectively. The SAV simulation considered 2–5 percent of the region's total trips, including 20 percent of trips in the central downtown region (Yan et al., 2020).

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- An analysis of vehicle trajectory data from taxis in Berlin, Germany, found that ridepooling could reduce VMT by 33 percent when implemented on a large scale across the entire fleet. Widespread shared rides in taxis could likewise save 28.3 million gallons of gasoline and reduce carbon dioxide (CO_2) emissions by 2,392 tons annually (Cai et al., 2019).
- Analyses of rider questionnaires, online survey data, and ridesplitting data from DiDi Chuxing in Hangzhou, China, estimated that ridesplitting could decrease vehicle kilometers traveled by 52,751–58,124 or 5,051 vehicles per day on roads, and could reduce some persons' willingness to purchase a personal vehicle (Chen et al., 2018; Zheng et al., 2019).

Energy Use

Any subsequent reductions in traffic congestion from ridepooling will subsequently reduce energy consumption in power-shared vehicles as well. The extent of this reduction depends upon the type of vehicle used in the shared fleet transportation system. Yan et al. (2020) simulated SAV trips and found that the use of hybrid electric vehicles lowered estimated energy consumption by 21 percent, while the use of battery-electric vehicles lowered energy consumption by 64 percent (assuming no new or longer trips).

Compared to privately owned electric vehicles, ridepooling of electric SAVs could also substantially reduce the number of charging stations needed to keep shared fleets operational (Farhan & Chen, 2018). A case study analyzing traffic emissions from ridepooling in Shanghai, China, found that pooled rides (compared to exclusive ridesourcing or SOV trips) could reduce fuel consumption by 15–23 percent. Ridepooling may decrease emissions in denser areas but may slightly increase emissions on branch roads where pickups are made (Yan et al., 2020). With pooled services as a subset of ridesourcing services, a reduction in VMT may not occur if in lieu of the service availability, the traveler takes fixed-route transit, walks, bikes, or does not make the trip (Morris et al., 2020).

Emissions

In addition to reduced congestion and energy consumption, pooling trips has the potential to reduce the release of CO_2 and other harmful emissions from automobiles into the atmosphere. Ridesplitting products on TNC services in China (DiDi Chuxing) have reportedly increased vehicle occupancy rates by up to 1.52 passengers per ridesourcing trip (Xue et al., 2018). Using 2015 ridesourcing data from Beijing, China, Xue et al. (2018) found that this increased vehicle occupancy rate along with other strategies for shortened pickup times and managed operations would—best-case scenario—reduce CO_2 and NO_x emissions by 44 percent. Lokhandwala and Cai (2020) used New York City taxi data to simulate optimal ridepooling preferences for AV system riders. In different scenarios of rider preferences (based on time and cost factors), the model estimated a difference of approximately 34 tons in CO_2-equivalent emissions. Yan et al. (2020) found that using hybrid electric vehicles in an SAV system would lower tailpipe emissions by 30 percent (assuming no new or longer trips occurred).

The rates of shared rides in certain use cases for travel (types of trips) in TNC services are critical for actual emissions reductions. Increased use of TNCs by travelers without proper interventions and incentives to encourage pooling will likely result in higher vehicle emissions from increased vehicles on the road, particularly from the deadheading behavior of drivers cruising around on roads while waiting for their next trip request match (most drivers do not park their car in between rides) (Wenzel et al., 2019). Even in the case of SAVs—unless they are electrified—automated fleets are expected to increase vehicle emissions and air pollution levels in places of operation, particularly in disadvantaged neighborhoods (Ezike et al., 2019).

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Other Potential Benefits

Two other potential benefits of ridepooling are decreased infrastructure needs and increased safety for road users, although these benefits are largely theoretical and unproven. In the long term, increased ridepooling and sharing of AVs could contribute to reduced road infrastructure costs (including land devoted to parking spaces) and reduced car dependency through more zero/low-vehicle households, although further study is needed to understand the magnitude of these possible benefits (Alemi et al., 2019; Okeke, 2020).

Reduced vehicle crashes and traffic fatalities can also be a benefit of increased ridepooling, particularly in the case of SAVs (Fagnant & Kockelman, 2014). However, one study of possible correlations between ridesourcing services and traffic fatalities in 2016 found that the introduction of pooled service options (based on product launch dates of large TNCs) did not reverse a documented increase in fatal accidents from TNCs' initial arrival, most likely due to an insufficient proportion of pooled rides (at the time) for such an effect (Barrios et al., 2018).

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Chapter 3. Shared Mobility Survey: Methods and Data

Survey Design and Execution

In this study, researchers conducted an online survey (shared mobility survey) to examine on-demand transportation services with a focus on pooling decisions among Texas residents. The researchers received approval from the Institutional Review Board (IRB) of the Texas A&M University Human Subjects Protection Program prior to collecting data.

The survey was designed to collect a rich set of data from participants, including the following:[1]

- Individual demographics, socioeconomic characteristics, work-related characteristics, and household characteristics.
- Use of various transportation modes for travel in participants' local area.
- Use of on-demand transportation services and pooling, including trends, attitudes, perceptions, and concerns.
- Potential improvements that would make sharing/pooling more attractive for participants.
- Intended use of AV and shared automation, including attitudes, perceptions, barriers, and potential solutions.

An electronic survey was developed using Qualtrics survey software and administered to an online panel through Qualtrics to complete the fielding process. Qualtrics builds samples from multiple sources (through certified sample partners) instead of relying on a single panel, checks every IP address, and uses digital fingerprinting technology to exclude duplication and ensure validity. Prior to survey deployment, each sample from the panel base is proportioned to the general population and then randomized. Qualtrics uses niche panels created through specialized recruitment campaigns to access hard-to-reach groups. Panel respondents are compensated based on the length of the survey, their specific panelist profile, and the difficulty of acquiring a target (Qualtrics, 2014).

The soft launch of the survey was initiated in February 2022. Following the review of the survey data from the soft launch, the full launch was initiated in late February 2022, and the survey ended in early May 2022. The survey was administered in both English and Spanish to persons 18 years old or older who lived in selected cities in Texas. Nearly all surveys were completed in English (98 percent in English versus 2 percent in Spanish). The average time to complete the survey was 24 minutes, while the median time to complete the survey was 17 minutes.

Quotas were established to ensure that the sample was well-balanced and representative across a variety of demographic characteristics, including age, gender, race, and income. Quotas were also used for the study area that included 10 Texas cities—ranging from large urban areas to small cities and rural areas—where microtransit services were in operation at the time of the survey. These cities included San Antonio, Houston, Dallas, Austin, Lubbock, Denton, Edinburg, Arlington, Bastrop, and Terrell. Figure 1 shows the spatial distribution of these cities in the study area, together with the final sample size for each city.

The research team reviewed the data throughout the fielding process to meet the sample targets. Toward the end of the fielding—when it was not feasible to gather more data from a particular group—some of the quotas

[1] The survey instrument is available upon request from the first author of this report.

were relaxed to allow for larger sample sizes. Qualtrics was able to determine nonmeaningful responses (i.e., responses from *speed fillers* who randomly select options to maximize their financial returns) and filter them out. Additional checks were performed during data collection and review prior to data analysis.

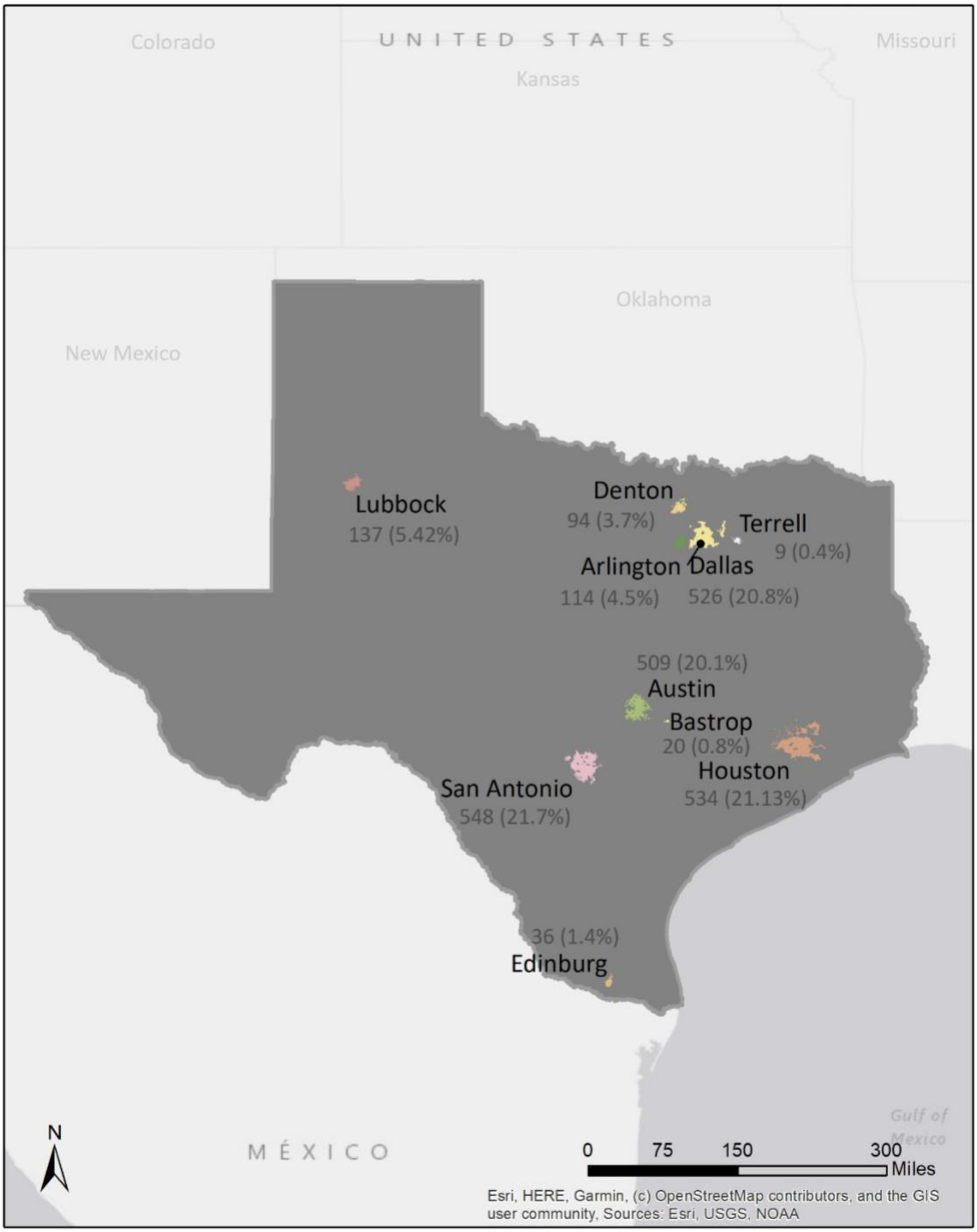

Figure 1. Study area cities in Texas and their final survey sample sizes.

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A total of 2,527 usable surveys were collected. Compared to Texas population data from the United States Census Bureau's (2022) American Community Survey 2020, the survey data provided a fairly representative sample of adults in Texas. Table 1 displays the characteristics of participants in the analytical sample, as well as the Texas population (based on the selected demographic quotas). Compared to the Texas population, survey respondents skewed slightly toward younger age groups and females. Hispanics and people in the highest income bracket (>$100,000) were slightly undersampled compared to the Texas population at large.

Online surveys are inherently biased against those with limited or no internet access, producing possible issues for any analysis conducted. Uniformly distributed internet access among different groups could lessen this bias, but prior research has shown that such uniformity does not exist. The Pew Research Center (2022) found that, as of 2021, 99 percent of those aged 18–29 used the internet, while only 75 percent of those aged over 65 did. They also found that 99 percent of those who made over $75,000 annually and 98 percent of college graduates used the internet, compared to 86 percent of those who made under $30,000 annually and 86 percent of those who had a high school education or less, respectively. They did not, however, find significant differences in internet use across race, gender, or community type, with 95 percent, 94 percent, and 90 percent of urban, suburban, and rural respondents using the internet, respectively.

Prior research has produced mixed results regarding the effects of unequal internet access on online survey bias. A survey of water supply managers in Oklahoma found that roughly equal proportions of rural and urban managers preferred an online version of the survey (instead of a paper version) and that response rates were higher for rural managers than urban managers, although this difference was not statistically significant (Boyer et al., 2019). This finding should assuage any fears that online survey methods are underrepresenting rural Texans. Contrary to findings that internet usage did not differ between racial groups (Pew Research Center, 2022), a previous survey of parents of preschool students found that among those who passed initial screening questions and met eligibility criteria, non-Hispanic White and Asian parents were 1.7 and 2.1 times more likely, respectively, than Black parents to provide consent to participate in the study (Jang & Vorderstrasse, 2019). Both sets of parents were also more than 3 times as likely to complete the entire survey than Black parents. The same study found that participants with a high school diploma or less were less likely to complete the entire survey, while no significant relationship existed between annual family income and survey completion rate. These results suggest that despite the similar internet use rates among non-Hispanic White, Asian, and Black internet users, Black users would be less likely to participate in and complete online surveys. This phenomenon was not observed in this study's sample; Blacks were slightly overrepresented and non-Hispanic Whites were slightly underrepresented in this study's sample.

Those in the highest income bracket (more than $100,000 annually) were also undersampled by nearly 7 percent. Qualtrics offers financial compensation to survey participants, raising concerns of bias toward lower-income participants (financial rewards may be more impactful for lower-income participants than higher-income participants). However, prior research suggests that these concerns are unwarranted. An online survey of undergraduate students at a Midwestern American university found that financial incentives not only improved the response rate of participants, but they also improved the representativeness of the sample in relation to the target population (DeCamp & Manierre, 2016). Another study found that those in the highest income bracket (more than $150,000 annually) did not have statistically significant decreased odds of returning to a survey compared to the baseline group (less than $25,000 annually) when financial incentives were offered (Yu et al., 2017).

As discussed above, valid concerns have been raised regarding potential bias attributable to online survey methods and financial incentives for participants. However, existing research has shown that the positive

aspects of these methods and strategies outweigh the negative aspects. Although some differences between the sample and the true population proportions were observed in this study, the researchers felt these differences were sufficiently small and would not be significantly detrimental to the analysis, especially considering the focus on behavioral patterns. Previous studies have used similar methods and helped guide the methodology of this report.

Table 1. Comparison of the Survey Sample and the Texas Population

Demographic Variables Used for Survey Quotas		Analytical Sample (N=2,527)	Texas Population*
Age	18–34	36.4%	33.0%
	35–54	31.0%	35.0%
	55–74	24.5%	25.3%
	75 or over	2.4%	6.7%
Gender	Male	42.1%	49.7%
	Female	57.0%	50.3%
	Nonbinary/third gender**	0.7%	N/A
	Prefer not to say***	0.2%	N/A
Race/Ethnicity	Not Hispanic White or Caucasian	38.8%	41.4%
	Not Hispanic Black or African American	15.4%	11.8%
	Hispanic	33.9%	39.4%
	Other	9.8%	7.4%
	Prefer not to answer***	2.1%	N/A
Household income	Less than $25,000	19.1%	18.3%
	$25,000 to $49,999	23.8%	21.2%
	$50,000 to $99,999	31.7%	30.1%
	$100,000 or more	23.6%	30.4%
	Prefer not to answer***	1.7%	N/A

Note: N/A = not applicable.
**Data provided as five-year estimates by the United States Census Bureau's American Community Survey 2020 are available online at https://www.census.gov/programs-surveys/acs/ (accessed October 29, 2022).*
***Quotas were set to obtain equal distribution across participants who identified their gender as male or female. Participants who identified themselves as nonbinary/third gender were not restricted by quotas and instead specified as natural fallouts in the sample.*
****The survey included the option of prefer not to say/answer; quotas were set without considering this option.*

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Survey Sample Characteristics

As previously stated, the survey gathered a variety of information from participants. Table 2 and Table 3 summarize individual characteristics and household/housing characteristics, respectively.

Table 2. Description of Individual Characteristics in the Sample

Variable	Category	Number	Percent
Age	18–24	373	14.8%
	25–34	547	21.6%
	35–44	607	24.0%
	45–54	320	12.7%
	55–64	339	13.4%
	65 or over	341	13.5%
Gender	Male	1064	42.1%
	Female	1440	57.0%
	Nonbinary/third gender	17	0.7%
	Prefer not to say	6	0.3%
Race	Native American Indian or Alaska Native	104	4.1%
	Asian	232	9.2%
	Black or African American	478	18.9%
	Native Hawaiian or Other Pacific Islander	30	1.2%
	White or Caucasian	1443	57.1%
	Other	186	7.4%
	Prefer not to answer	54	2.1%
Hispanic, Latin, or Spanish Origin	Yes	899	35.6%
	No	1628	64.4%
Disability	No disability	1983	78.5%
	Have one or more disability	544	21.5%
Disability type (percentage of individuals with a disability)	Deaf or serious difficulty hearing	183	33.6%
	Blind or serious difficulty seeing	197	36.2%
	Need to travel with a service animal	107	19.7%
	Serious difficulty walking or climbing stairs	281	51.7%
	Disability that affects the ability to get a driver's license	142	26.1%
	Disability that affects the ability to travel alone for transportation, such as going to school or shopping	139	25.6%

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Variable	Category	Number	Percent
Education	Less than high school, high school graduate, or GED	548	21.7%
	Technical or trade certificate	95	3.8%
	Some college	541	21.4%
	Associate degree	285	11.3%
	Bachelor's degree	660	26.1%
	Master's degree or more	398	15.7%
Employment	Employed full time	1297	51.3%
	Employed part time	329	13.0%
	Retired	354	14.0%
	Student	143	5.7%
	Unemployed—looking for work	248	9.8%
	Unemployed—not looking for work	187	7.4%
Work location (percentage of employed)	Working from home	521	32.1%
	Working outside the home	794	48.9%
	Both (home and outside the home)	308	19.0%
Own or have access to a personal vehicle	Yes—vehicle is in working condition	2091	82.7%
	Yes—vehicle is not in working condition	63	2.5%
	No	373	14.8%
Have a valid driver's license	Yes	2143	84.8%
	No	384	15.2%
Own or have access to a smartphone used regularly	Yes—with reliable high-speed access to internet	2409	95.3%
	Yes—with no reliable high-speed access to internet	78	3.1%
	No	40	1.6%
Technology adoption	I am among the first of my friends and family to adopt new technology	1077	42.6%
	I wait awhile and eventually adopt new technology	1116	44.2%
	I am among the last of my friends and family to adopt new technology, if I adopt at all	334	13.2%

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Table 3. Description of Household and Housing Characteristics in the Sample

Variable	Category	Number	Percent
Household income	Less than $25,000	483	19.1%
	$25,000 to $49,999	601	23.8%
	$50,000 to $74,999	471	18.6%
	$75,000 to $99,999	332	13.1%
	$100,000 to $149,999	351	13.9%
	$150,000 or more	245	9.7%
	Prefer not to answer	44	1.7%
Household type	Single, no children or dependents	850	33.6%
	Single, with children or dependents	293	11.6%
	Married or domestic partner, no children or dependents	615	24.3%
	Married or domestic partner, with children or dependents	690	27.3%
	Other	79	3.1%
Age of children in household (percentage of households with children)	0–6 years	421	42.8%
	7–12 years	391	39.8%
	13–15 years	245	24.9%
	16–17 years	236	24.0%
Household living situation	Renting a house or apartment	970	38.4%
	Living with parents—rented house or apartment	153	6.1%
	Living with parents—owned house or apartment	241	9.5%
	Own a house or apartment	1086	43.0%
	Other	77	3.0%
Household residential area type	Urban	1306	51.7%
	Suburban	997	39.5%
	Rural	141	5.6%
	Not sure	83	3.3%
Language spoken at home	English only	1646	65.1%
	English mostly	386	15.3%
	English and another language equally	414	16.4%
	Another language mostly	62	2.5%
	Another language only	19	0.8%

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About 60 percent of the survey respondents were below the age of 45; as noted previously, the survey tended to slightly overrepresent younger people when compared to the general Texas population. The overwhelming majority of participants indicated owning a smartphone with a reliable connection to high-speed internet, and only 13 percent reported being among the last of their peers to adopt new technology or not adopting new technology at all. Because the survey was conducted online, the survey methodology likely favored populations who spend more time online and have better knowledge of emerging technologies such as smartphones. However, with over 80 percent of all Americans having access to the internet in 2017, and with the percentage of Americans accessing the internet via a cell phone rapidly increasing (Greenberg-Worisek et al., 2019), online surveys should be more accessible to the wider population.

All but 1 percent of the respondents self-identified as either male or female, with females tending to be slightly overrepresented in the sample with respect to the rest of the Texas population. The low percentage of respondents identifying themselves as third gender or nonbinary may be due to fewer of these individuals residing in Texas survey cities or feeling uncomfortable declaring their true gender because of the anti-LGBTQ climate and policies in the state. For example, according to a research brief published by GLSEN in 2018, Texas is one of only a handful of states that "explicitly prohibit the positive portrayal of homosexuality in schools through specific education laws, often referred to as "no promo homo" laws because they mandate "no promotion of homosexuality", and as a result, LGTBQ youth are more likely to face a hostile school environment and bullying and have less access to support groups (GLSEN, 2018; Russell et al., 2021; Fields & Wotipka, 2022). Adoption of laws like these would make it more likely for members of the LGBTQ community to live in states that are more accepting of them and less likely for them to reveal their gender and sexual orientation.

The largest racial group in the sample included those respondents who identified as White or Caucasian, consistent with the general Texas population. The only other racial group that exceeded a 10 percent share of the sample was African Americans. Just over one-third of all participants said they were of Hispanic, Latin, or Spanish origin, owing to Texas' large Hispanic population. This large Hispanic-origin population likely contributes to the fact that only around two-thirds of the sample spoke only English at home; one-third of the sample size spoke either another language or a combination of English and another language at home, corresponding roughly to the proportion of Hispanic respondents.

The most common disability afflicting the survey respondents was serious difficulty with walking or climbing stairs; this disability type was indicated by a majority of respondents who said they had some sort of disability. Respondents who suffered from difficulty walking or climbing stairs tended to be older, with a median age of 48 and a third-quartile age of 61. These were the highest median and third-quartile age values across all disabilities, which intuitively makes sense—older citizens are more likely to have difficulty performing physical activity due to health issues related to their age. The disability group with the second-highest median and third-quartile age values (40 and 58, respectively) included those respondents who said they had deafness or difficulty hearing (approximately one-third of people who said they had some sort of disability). This can also be attributed to the health effects of aging; people tend to lose hearing as they age. A quarter of respondents who said they had some disability preventing them from traveling alone had median and third-quartile ages of 40 and 54, respectively. Responses regarding the remaining three disability types had similar distributions.

Almost 80 percent of participants said they had some sort of education or training post-high school, with a majority having completed a college degree. This is not unusual because college enrollment had been steadily increasing since the 1980s before flatlining and slightly decreasing over the past decade. Nonetheless, the proportion of college-educated people in the sample was slightly overrepresented compared to the general

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Texas population (Texas Public Education Information Resource, 2022). Conversely, the proportion of higher-income households (those respondents making $100,000 annually or more) was slightly underrepresented in the sample, as noted earlier. Because Qualtrics offers financial incentives to help with recruiting for their surveys, lower-income individuals might be more likely to find it worth their time to participate in the surveys than their higher-income peers, potentially accounting for some of this difference.

There was a roughly even split between single and married participants, with married participants slightly outnumbering single participants. A quarter of respondents who were single said they also had a child or dependent, matching trends in the increasing rates and social acceptance of single-parent households (Weinraub et al., 2002). Respondents who had children living in the house with them typically had younger children, with most reporting children under the age of 12. The overwhelming majority of participants said they were living independently of their parents, with only 15 percent saying they lived with their parents in either a rented or owned home. Of those participants who responded *other* to the living situation question, the most common answer they gave (if they chose to not leave it blank) was they were living with either a friend or a family member that was not their parent. Several of those same respondents also said they were experiencing homelessness.

Over 90 percent of participants were either from an urban or suburban residential area, with less than 6 percent of the population saying they came from a rural area. This gap may be explained in part by the lack of internet access in rural areas, limiting subsequent participation in an online survey. Additionally, the survey question design allowed respondents to self-classify the type of area in which they live, meaning some respondents in small towns surrounded by rural areas may have indicated urban or suburban instead. However, ever-increasing access to broadband in rural areas (Greenberg-Worisek et al., 2019) may reduce some of these effects.

Reported ownership of personal vehicles by respondents was high, likely due to the large geographic size of Texas and the concomitant lack of public transportation. Around 85 percent of respondents said they both had a driver's license and owned some personal vehicle. Of those respondents who were employed, only half said they were strictly working outside of the home, with the other half saying they either worked exclusively from home or had some sort of hybrid workplace. Such a large increase in the number of people working from home can be attributed to the COVID-19 pandemic, as employers implemented work-from-home policies for any nonessential services to try to mitigate the spread of the virus.

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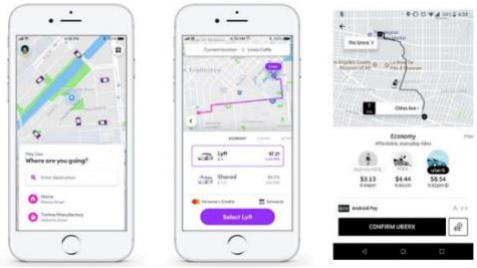
Chapter 4. Survey Data Analysis: Findings and Discussion

The researchers utilized a mix of descriptive statistics and statistical inferential techniques to analyze the survey data. The main focus of this analysis was to examine trends in on-demand transportation services (particularly TNCs and microtransit services), as well as sharing or pooling behavior through these services. Barriers and solutions to encourage sharing or pooling were examined together with potential improvements that could be implemented by policymakers and agencies to make sharing or pooling a trip more attractive for individual travel needs. The survey respondents were asked various questions regarding on-demand transportation services to understand overall trends in usage, behavior, and perceptions.

To help elucidate the survey results, Table 4 defines (potentially new) terminology introduced in the survey.

Table 4. New Terminology and Images Used in the Shared Mobility Survey

Transportation network company	Taxi-like service (e.g., Uber, Lyft, and Alto) that provides on-demand access to a ride through ride-hailing, typically through a smartphone app. Rides are offered by drivers using their personal vehicles. The cost of a ride depends on the distance and time of travel. These services can also be provided as a shared service with other passengers (e.g., UberPool/Uber Express Pool and Lyft Line/Lyft Share).	
Microtransit	On-demand transit service that groups riders with trip requests, typically through a smartphone app. Rides are offered in shuttles or vans. Microtransit services can be provided as part of a broader public transit system or through a private company.	
Bikesharing or e-scooter sharing	Services offering publicly available bikes or e-scooters accessed through either a smartphone app or a kiosk at the docking location. The price for the rental typically includes a base charge plus a minute/hourly rate.	

The following sections present the detailed findings of the survey.

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Transportation Mode Use

The first set of survey questions was designed to elicit general information about a participant's behavior regarding each of the following 12 modes of travel:

- Drive a personal vehicle.
- Ride in a personal vehicle of someone you live with or know.
- Walk.
- Ride a personal bicycle or e-scooter.
- Use bikesharing or e-scooter-sharing services.
- Use ride-hailing services through TNCs (e.g., Uber or Lyft).
- Use taxi services.
- Use carsharing/carpooling services.
- Take public transit buses (traditional scheduled service).
- Take public transit trains/light rail.
- Use demand-responsive transit, including paratransit services (need to reserve a trip).
- Use on-demand transit, including microtransit services.

Usage Characteristics

Individuals often use a wide variety of transportation modes. The results from this study's shared mobility survey confirmed this phenomenon. As expected, the vast majority of respondents indicated driving a personal vehicle (82 percent) and riding in the personal vehicle of someone they live with or know (67 percent) when traveling in their local area. Among those respondents who indicated driving a personal vehicle at the time of the survey, nearly 9 in 10 respondents said they used it for almost every trip. Walking was the only other mode of transportation that was used by a considerable proportion of respondents (but still not frequently). Around 71 percent of respondents reported walking, but 60 percent of those individuals indicated only occasional walking and 12 percent indicated almost never walking.

Regarding the use of TNCs and public transit, the survey results showed a higher tendency of using TNCs compared to traditional public transportation, likely as a result of the lack of transit frequency or access in the 10 Texas cities in the study area. Around 44 percent indicated using ride-hailing services through TNCs (e.g., Uber or Lyft), while 33 percent reported taking a public transit bus with a traditional schedule, and 24 percent reported taking public transit trains or light rail. Survey respondents indicated using TNCs only occasionally rather than for regular travel needs, which is consistent with earlier studies (Brown, 2018; Dong et al., 2021). Slightly more than one-third of transit users revealed using public transportation almost every time they traveled around their local area, compared to about one-quarter of TNC users who said they used TNCs almost every trip.

The remaining transportation modes were used much less frequently, with emerging mobility services accounting for 13–15 percent of use. On-demand transit (including microtransit services), demand-responsive transit (including paratransit services), and shared micromobility services (including bikesharing and e-scooter sharing) were among the least popular modes of emerging mobility services.

The time of day/day of week and trip purpose were among the important trip characteristics affecting transportation mode choice. Figure 2 and Figure 3 present the transportation mode usage reported by respondents as a function of the time of day/day of week and the trip purpose, respectively.

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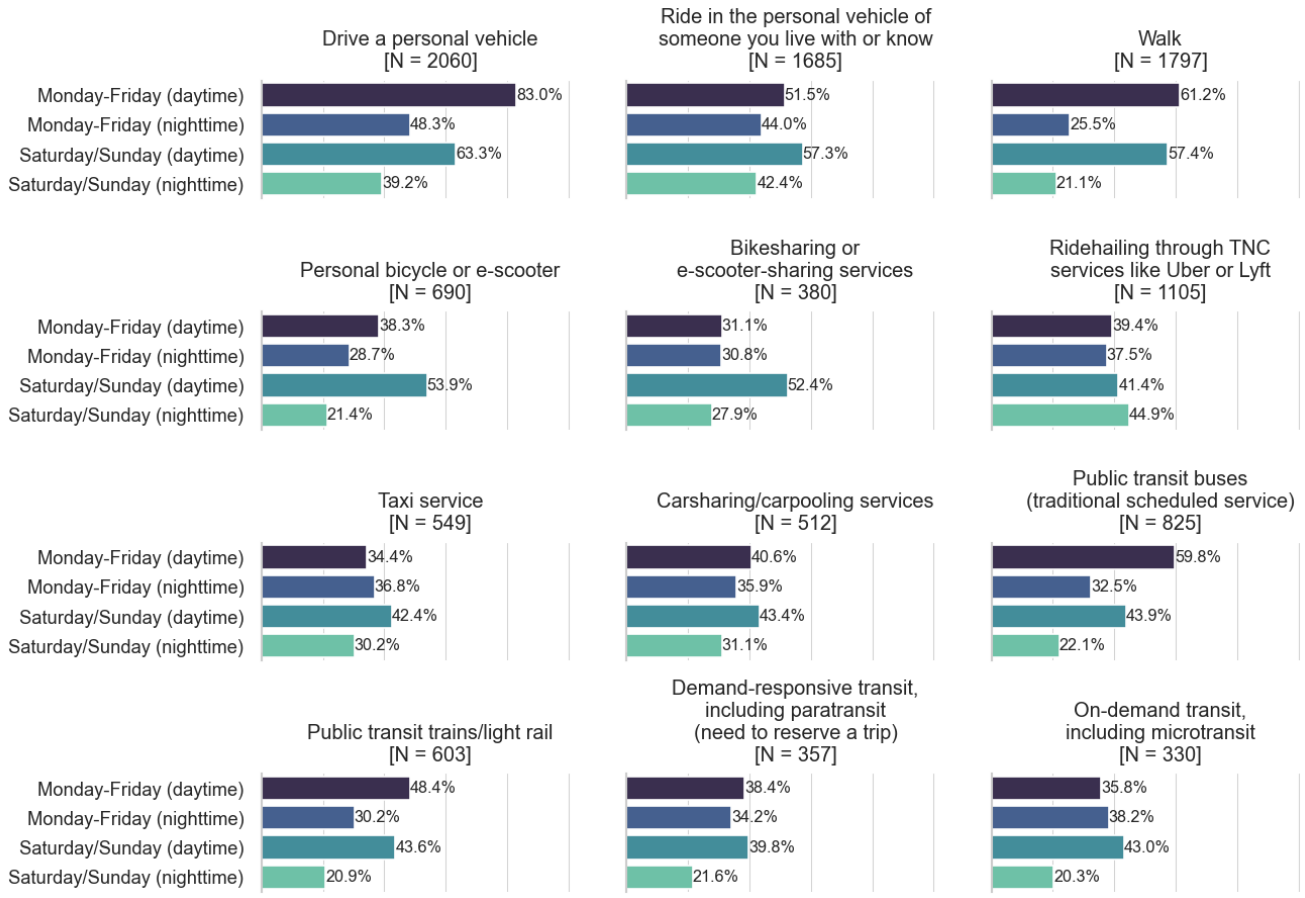

Figure 2. Local area transportation mode usage by time of day and day of week.

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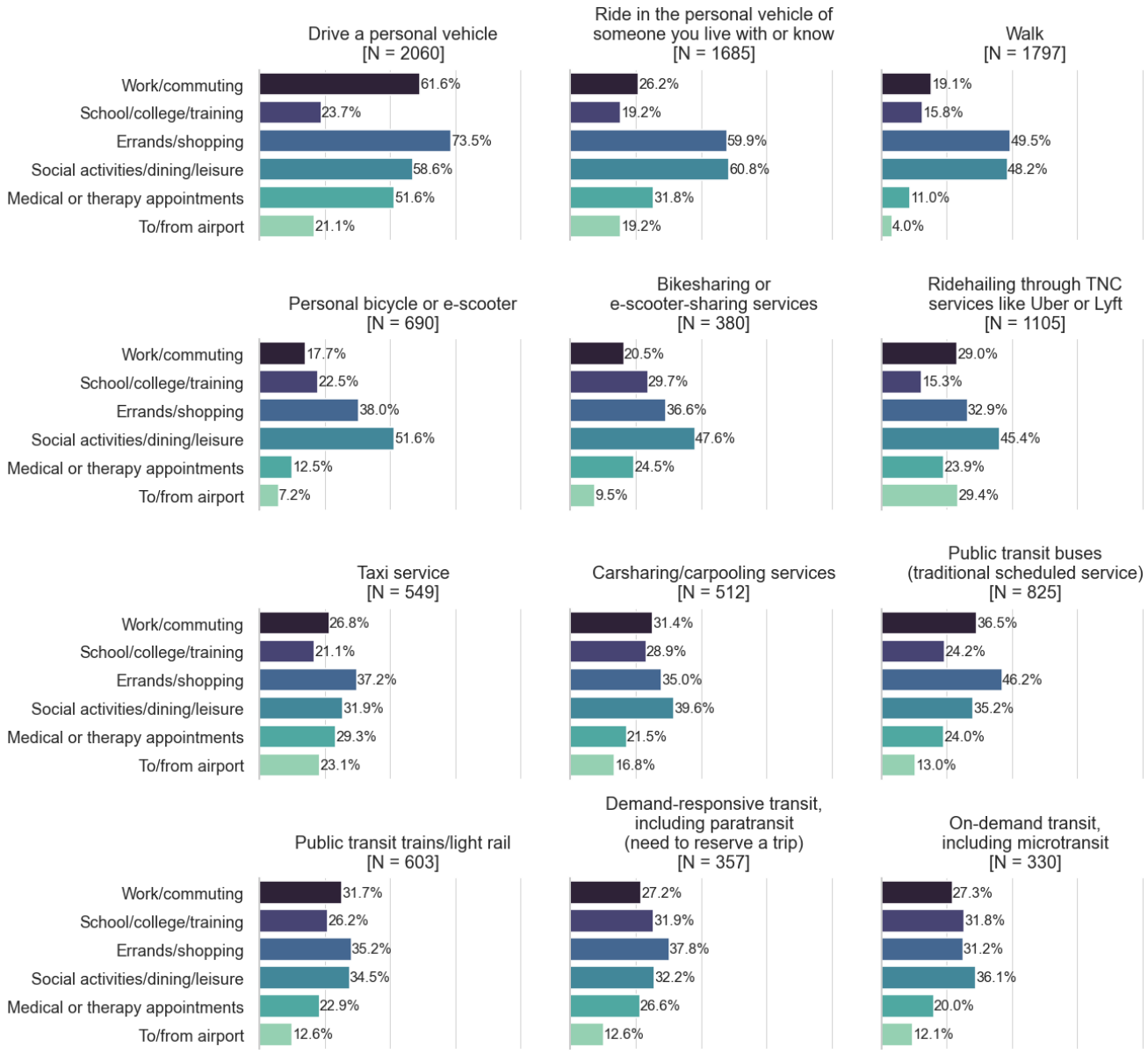

Figure 3. Local area transportation mode usage by trip purpose.

Not surprisingly, most driving trips (with a personal vehicle) took place during the day on weekdays. This was also the case for the traditional public transit and walking modes. In general, respondents were more likely to travel during the day instead of at night; the preference to travel during the day was strongest among pedestrians, likely due to the safety issues related to walking at night. The majority of respondents who indicated using ride-hailing services through TNCs preferred using these services on weekend nights—making TNCs the only mode of transportation with a higher preference for nighttime usage. This finding can be explained by the fact that the most common trip purpose for TNCs is attending social activities, which tend to occur on weekends when people are free from work and at night when establishments such as bars and nightclubs see more customers. An analysis of seven major U.S. metropolitan areas found that going to bars

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and parties (38 percent) was the most common trip purpose for TNC users, confirming this theory (Clewlow & Mishra, 2017). The use of shared micromobility services was also highest on the weekends but during the day, likely supporting a different set of social activities that tend to occur on weekends. The use of other shared transportation services (i.e., taxi services, on-demand transit, demand-responsive transit, and carsharing/carpooling services) was also slightly higher during the day on weekends compared to weekdays and was lowest during the night on weekends.

Regarding trip purpose, errands/shopping-related trips were the most frequent, followed by work/commuting-related trips and trips for social activities/dining/leisure among respondents who indicated driving their personal vehicle for local travel. For personal or shared micromobility service use, the most common trip purpose was social activities/dining/leisure, which is consistent with previous studies. For example, among users of Bicimad (Madrid's public and station-based bikesharing service in Spain), leisure activities were among the most common uses of the service, and among those who used Bicimad in conjunction with some other dockless shared service (where users can leave a bike at any location within a geographic area rather than return it to a fixed station), leisure activities were the most frequent trip purpose (Arias-Molinares et al., 2021). The same pattern was observed for ride-hailing services offered through TNCs in this study, as well as some other studies. After TNC services were adopted in Boston, Massachusetts, and Philadelphia, Pennsylvania, recreation and social activities saw the biggest increase by far in the number of trips taken (Dong et al., 2021). In a literature review of ride-hailing behavior, studies consistently found that leisure and social activities were the most commonly cited trip purpose for using ride-hailing services (Tirachini, 2020). Another study that analyzed TNC and taxi use in San Francisco, California, found that for both modes of transportation, social activities and going out at night were by far the most popular use of the respective services (Rayle et al., 2016). This latter finding indicating increased TNC use for social activities, along with this study's previous finding indicating increased TNC use on weekends, suggests that people would prefer not to drive a car after a social event that might involve drinking alcohol or feeling tired.

In addition, the survey respondents reported TNCs as their primary mode of transportation to travel to or from airports; not surprisingly, all other modes of transportation for this same purpose had much lower reported usage. When customers of ridesourcing services in San Francisco, California, were surveyed, the third most common trip purpose cited was to travel to/from the airport, with 4 percent saying they used ridesourcing for airport travel, compared to 23 percent who said they used a taxi service (Rayle et al., 2016). The 2019 Washington-Baltimore Regional Air Passenger Survey found that 24 percent of respondents used TNCs as their mode of access to the region's airports, second only to using a personal vehicle or rental car, with taxi services coming in third at 9 percent (Koudounas et al., 2020). Because most people do not regularly travel to the airport, it makes sense that this would be the least preferred trip purpose for all modes besides TNCs and taxis. If there is no transit access, taking a car is the most logical way to get to and from the airport because people often travel with bags and luggage that may be difficult to carry on a bike/e-scooter or walk with. Airports also typically charge parking fees for leaving a car overnight. Using a TNC or taxi service eliminates the hassle and cost of parking. The convenience and relatively low cost of TNC and taxi services likely explain why these two modes tend to be the most common methods of transportation to and from the airport.

User Characteristics

The results indicated that females tend to utilize any transportation mode less frequently than males do, with the exception of traveling in the personal vehicles of people they live with or know. This result potentially reflects the role of women as primary caregivers—also noted by Botek (2022) based on the Caregiving in the U.S. 2020 report by the National Alliance for Caregiving and the AARP Public Policy Institute—as well as their

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safety concerns for riding in other vehicles. While keeping in mind the relatively small sample size of this group, almost all respondents who self-identified as nonbinary/third gender also indicated a preference for riding with others that they live with or know. This result implies a need for additional research focusing on gender differences and addressing disparities in transportation while also highlighting potential obstacles and safety concerns faced by this unique population group when traveling (McDonnell, 2019; Naidu, 2020; Quinan, 2022). In terms of TNC use, the findings revealed slight gender differences, with the highest percentage of use among individuals who self-identified as nonbinary/third gender (53 percent) followed by males (48 percent); females had the lowest percentage of use (41 percent).

Use of TNCs was also found to be slightly more popular among non-White populations, with Native Americans or Alaska Natives (53 percent) being the most likely to use TNCs, followed by Asians (51 percent), and African Americans (50 percent). Whites were less likely than other races to choose alternative and emerging modes of transportation, preferring instead to drive. Asians and Native Hawaiian/other Pacific Islanders were more likely to travel by active modes (including walking and micromobility options of biking and e-scooter use). An intriguing observation was made regarding personal versus shared micromobility use. According to the findings, Asians viewed personal bicycles or e-scooters more favorably than Native Hawaiian/other Pacific Islanders (44 percent versus 33 percent), whereas the opposite trend was observed for shared micromobility services (Asians at 30 percent versus Native Hawaiian/other Pacific Islanders at 33 percent).

Total household income was also influential in transportation mode choices. The likelihood of using micromobility services was observed to increase as income increased. For example, more than half of those respondents who indicated using personal bicycles or e-scooters in their local area were from households earning more than $150,000; wealthy neighborhoods likely provide residents with the ability to travel safely and comfortably using these modes. A similar increase in the use of shared micromobility services was also observed among high-income respondents. Conversely, traditional public transit bus use was highest among respondents from households with a total income of less than $25,000, probably owing to their low cost in comparison to buying a personal vehicle. Interestingly, results showed a significantly higher use of public transportation's trains or light rail among respondents from households earning over $150,000. Given the potential impact of light rail transit on land development (Lee & Sener, 2017), which could result in an increase in property values and unintended consequences like gentrification (Chava & Renne, 2022; Talbot, 2021), this latter result, while intriguing, may not be all that surprising. Additionally, respondents from higher-income households reported using TNCs more frequently.

Finally, half of TNC users reported living in urban areas, renting homes or apartments, and lacking access to a personal vehicle. More than 50 percent of TNC users claimed to be early adopters of technology. Last, the likelihood of using ride-hailing services through TNCs increased as educational levels increased.

Impact of the COVID-19 Pandemic

The survey included two questions that aimed to examine the impact of the COVID-19 pandemic on participants' use of transportation modes. First, survey respondents were asked if their prior (pre-COVID) use of the different modes of transportation differed from their current use. Next, they were asked how they anticipated their use of these modes would change once COVID-19 was no longer a threat (post-COVID).

Based on these two survey questions, six critical travel profiles were identified. Figure 4 depicts these six travel profiles, and Table 5 summarizes the associated numerical results. The findings provided interesting insights based on these different profiles.

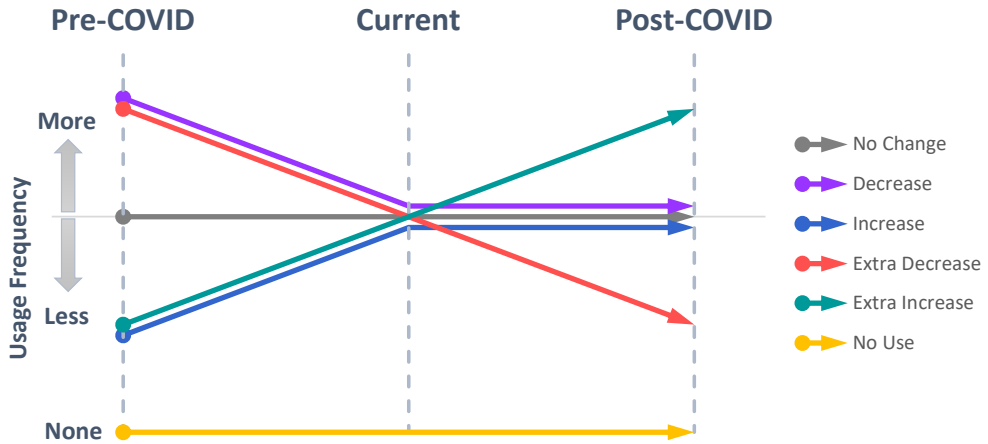

Figure 4. Travel profiles showing the COVID-19 pandemic impact on transportation mode usage.

Table 5. Numerical Results Showing the COVID-19 Pandemic Impact on Transportation Mode Usage

Mode/Impact	No Change	Extra Decrease	Decrease	No Use	Increase	Extra Increase
Drive a personal vehicle	38.8%	1.7%	11.1%	6.5%	6.5%	4.6%
Ride in the personal vehicle of someone you live with or know	36.5%	2.7%	8.3%	8.5%	9.2%	4.6%
Walk	31.7%	3.5%	8.7%	12.0%	8.3%	4.6%
Personal bicycle or e-scooter	14.0%	2.0%	4.0%	44.9%	4.8%	2.7%
Bikesharing or e-scooter-sharing services	11.5%	1.9%	3.1%	52.6%	3.6%	2.1%
Ride-hailing through TNC services like Uber or Lyft	16.2%	2.4%	5.5%	33.6%	6.2%	3.8%
Taxi service	12.2%	1.4%	4.3%	48.5%	4.4%	2.7%
Carsharing/carpooling services	11.2%	1.7%	3.2%	50.9%	3.8%	2.2%
Public transit buses (traditional scheduled service)	13.2%	2.0%	5.1%	42.5%	5.2%	2.4%
Public transit trains/light rail	11.5%	1.7%	4.2%	49.6%	4.3%	2.3%
Demand-responsive transit, including paratransit (need to reserve a trip)	9.9%	1.6%	3.2%	56.9%	3.9%	2.2%
On-demand transit, including microtransit	10.1%	1.3%	2.8%	58.5%	3.4%	1.4%

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The mode of travel that saw the largest overall decrease in usage—including respondents who reported currently using a particular mode less frequently than during pre-COVID but who intended to continue to use the same mode either at the same rate or a less frequent rate (below current levels) in the future (post-COVID)—was driving a personal vehicle. During the pandemic, many businesses shut down and tried to make as many operations virtual as possible, with nonessential workers working either fully from home or in a hybrid system. Texas is a car-centric state where most people drive a personal vehicle in their daily commute to work; this would explain the substantial decrease in personal vehicle usage during the COVID-19 pandemic. Many employers are now offering workers the option of a permanent work-from-home or hybrid system, allowing them to avoid a long daily commute. This phenomenon may explain the expectation of a continued decline in the use of personal vehicles post-COVID.

The car-centric nature of Texas is exemplified by the percentage of *no use* responses for the various modes of travel (i.e., respondents who reported not using a mode before COVID-19 and who did not plan on using the mode in the future after COVID-19). Driving a personal vehicle and riding in the vehicle of someone known had the lowest percentages of *no use* responses; walking also had a low percentage of *no use* responses (12 percent). For every other mode of transportation, the percentages of *no use* responses jumped significantly, implying that Texans are mostly not using these other modes and do not plan to in the future. The small percentage of respondents who said they would increase their usage of shared services and public transit was less than the percentage of respondents who said they would increase how much they drive a personal vehicle. The two modes that will see the largest increase in usage, based on survey findings, are riding in the personal vehicle of someone known and walking, which may offer some environmental benefits compared to driving solo.

Service Availability

A potential reason for not using a particular transportation service is a lack of access to the corresponding service in the area; this could also be due to people perceiving the service as not available even when it is in their area. Respondents who indicated not using a particular service were asked a follow-up question regarding local service availability. Figure 5 presents the availability of public transit, micromobility services, and on-demand transportation services in the study area.

Almost two-thirds of the respondents indicated the availability of TNCs and public transit buses in their area, while the reported availabilities of other types of transit and shared mobility services were much lower. At least 60 percent of respondents who did not use micromobility or carsharing services indicated that the corresponding service was either not available or they were not sure whether the service was available in their area. Reported availabilities were even lower for other on-demand transportation services, including demand-responsive and on-demand transit services, with only about one-quarter of corresponding respondents indicating the service was either available or they were aware of it.

The responses revealed some demographic differences. For example, the availability of TNCs was highest among non-White respondents (70 percent), indicating that TNCs were generally available in their area if they wanted to use them. Native Americans, on the other hand, reported having less access to TNCs than other races. Non-White population groups had the lowest access to other emerging mobility services, such as micromobility and microtransit services. In conjunction with previous findings that showed a higher tendency to use new and emerging mobility services among non-White users, these findings are critical, requiring policies and improvements to increase access to and use of new mobility services among these demographic groups. Lower-income households also experienced a lack of access to new mobility services. For example, respondents

from households making under $25,000 a year more often reported not having access to such services. Effective policy strategies are essential when designing and implementing such transportation services to ensure equal access for all demographic groups.

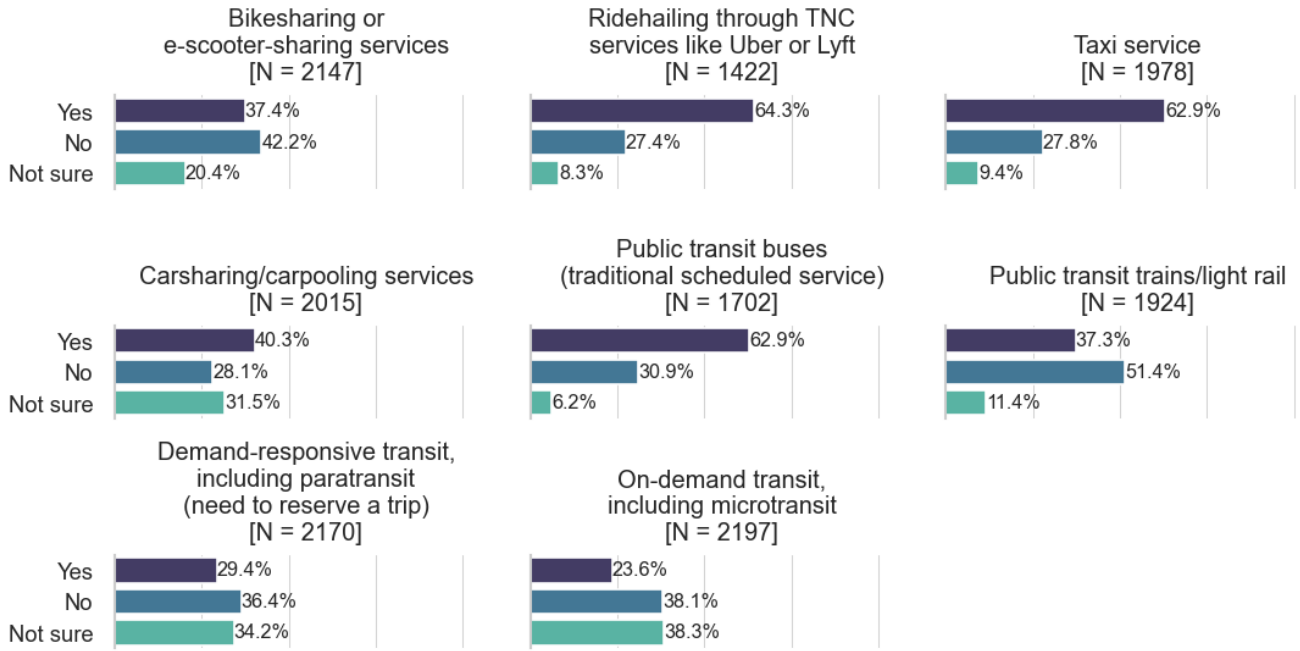

Figure 5. Availability of transportation services for nonusers.

On-Demand Transportation Services

Several survey questions sought to examine respondents' attitudes toward on-demand transportation services, including TNCs (e.g., Uber and Lyft), taxis, and on-demand transit (e.g., microtransit), as well as the practice of sharing rides on such services.

Attitudes toward On-Demand Transportation Services

The first few survey questions were intended to capture overall attitudes toward on-demand transportation services. Survey participants were asked, "What is your overall attitude toward the following on-demand services?" Figure 6 presents the results.

Around 65 percent of respondents had a positive attitude toward TNCs, and less than 10 percent had a negative attitude. The findings indicated a more negative attitude toward taxis. Understandably, given its recent introduction, more than half of survey participants were hesitant to express either a favorable or unfavorable opinion of on-demand transit services including microtransit.

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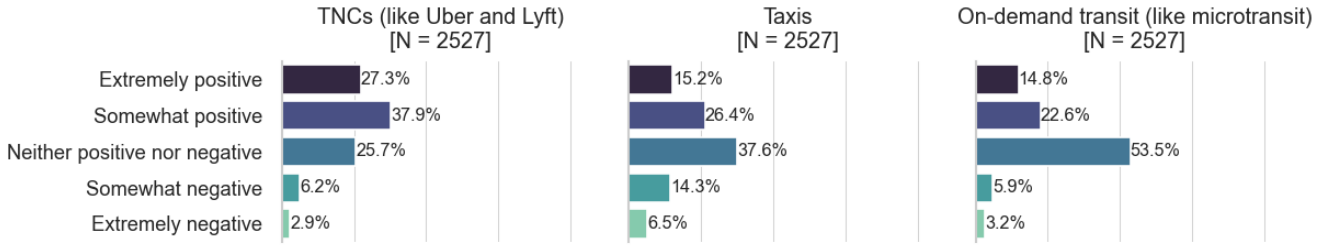

Figure 6. Attitudes toward on-demand transportation services.

Table 6 details the attitudes toward the three on-demand transportation services included in the survey (TNCs, taxis, and on-demand transit) based on various sociodemographic characteristics of the survey participants. A 5-point Likert scale was used to convert the qualitative responses to numerical values: *extremely positive* was assigned a numerical value of 2, *somewhat positive* was assigned a numerical value of 1, and so on until *extremely negative* was assigned a numerical value of −2. For each population of interest, the average score was calculated, and a Kruskal-Wallis test was conducted to determine whether the mean score was the same across all populations for each type of service.

Across all three on-demand services, respondents who identified themselves as male had significantly higher opinions toward those services than respondents who identified as female or nonbinary/third gender, with the nonbinary/third-gender passengers having the most negative perception of these services. Earlier studies provided critical insights into some potential reasons for lower opinions of these services among females and nonbinary/third-gender individuals compared to their male counterparts. A study conducted by the National Bureau of Economic Research (NBER) in Boston found that female passengers were more likely to be taken on longer and more complex routes while using TNCs so that drivers could charge extra fees (Ge et al., 2016). According to their study, some female riders also felt their drivers were overly chatty and were attempting to flirt with them. In China, the unwanted sexual attention and higher risk of sexual assault may explain why female TNC service users (through DiDi) perceived more physical risk than male users and were more likely to discontinue use of the service as a result (Ma, Zhang, et al., 2019). According to a study by Panjwani (2018), both cisgender and transgender women in Karachi, Pakistan, said they faced the “risk of being called at, groped, bothered, or sexually assaulted” in taxis and thus preferred open vehicles such as rickshaws instead. Transwomen also reported that when using Careem (a ridesharing service operating primarily in South Asia and the Middle East), drivers would often ignore their requests for return rides (Panjwani, 2018).

Respondents older than 65 tended to have the least favorable opinions toward TNCs compared to other age brackets. Many studies have shown repeatedly that younger people tend to use TNCs more frequently than older people. An analysis of TNC users in California found that older millennials (aged 25 to 34 in 2015) were most likely to use ride-hailing services (Circella et al., 2018). Persons in that same cohort would be between the ages of 35 and 44 in 2022, which would explain why that group, along with those persons aged 25 to 34, have the highest opinions toward TNCs. Many other studies (e.g., Clewlow & Mishra, 2017; Rayle et al., 2016) corroborate the fact that younger users find TNCs more appealing and tend to use them more frequently than older users.

Table 6. Attitudes toward On-Demand Transportation Services Based on Select Characteristics

Variable	Category	TNCs		Taxis		On-Demand Transit	
		Mean	p-value	Mean	p-value	Mean	p-value
Gender	Male	0.908	<0.001	0.495	<0.001	0.593	<0.001
	Female	0.740		0.153		0.262	
	Nonbinary/third gender	0.118		-0.176		-0.059	
Age	18–24	0.737	<0.001	0.072	<0.001	0.209	<0.001
	25–34	0.912		0.283		0.441	
	35–44	0.919		0.329		0.478	
	45–54	0.800		0.175		0.334	
	55–64	0.758		0.398		0.404	
	65 or over	0.548		0.496		0.449	
Race	Native American Indian or Alaska Native	0.625	<0.001	0.346	<0.001	0.529	<0.001
	Asian	1.017		0.819		0.828	
	Black or African American	0.933		0.425		0.510	
	Native Hawaiian or Other Pacific Islanders	0.800		0.967		0.767	
	White or Caucasian	0.750		0.190		0.308	
	Other	0.844		0.134		0.274	
	Prefer not to answer	0.407		-0.278		-0.056	
Hispanic, Latin, or Spanish Origin	Yes	0.887	0.003	0.370	0.004	0.463	0.003
	No	0.759		0.251		0.362	
Household Income	Less than $25,000	0.671	<0.001	0.118	<0.001	0.242	<0.001
	$25,000 to $49,999	0.705		0.062		0.235	
	$50,000 to $74,999	0.794		0.149		0.278	
	$75,000 to $99,999	0.892		0.527		0.485	
	$100,000 to $149,999	0.994		0.630		0.695	
	$150,000 or more	0.992		0.710		0.853	
	Prefer not to answer	0.500		0.182		0.068	
Disability	No disabilities	0.835	0.022	0.309	0.194	0.422	0.018
	Have one or more disability	0.691		0.239		0.311	
Technology Adoption	Early adopter	1.037	<0.001	0.522	<0.001	0.661	<0.001
	Late adopter	0.717		0.130		0.241	
	Laggard	0.344		0.105		0.075	
Residential Area Type	Urban	0.895	<0.001	0.403	<0.001	0.522	<0.001
	Suburban	0.721		0.187		0.271	
	Rural	0.730		0.177		0.291	
	Not sure	0.494		0.060		0.157	

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Technology usage could also be linked with age in this analysis. The most favorable opinion of TNCs across all groups was observed for respondents who said they were among the first to adopt new technology (i.e., early adopters). These early adopters had a median age of 36, whereas respondents who tended to either be the last among their friends and family to adopt new technology (i.e., late adopters) or did not adopt new technology at all (i.e., laggards) had a median age of 48. Because younger people might be more familiar with technology, younger riders tend to view technology as a facilitator of transportation access, while older riders consider it a barrier to such access (Bayne et al., 2021). This perspective may explain why respondents aged 65 and above had the lowest opinions toward TNCs but the highest opinions of taxis. Taxis can oftentimes be hailed using hand gestures from the side of the road, avoiding the need for smartphones and other technology that may be confusing to older commuters. Younger travelers, who might be more comfortable using a ride-hailing app rather than running after and flagging down a taxi, might hence have lower opinions of taxis than TNCs.

Among all races, Asians tended to have the highest opinion toward TNCs (the second highest opinion among all groups), followed closely by African Americans. The latter result is somewhat surprising due to the discrimination that African Americans often reported facing from TNC drivers. The NBER found that in Seattle, Washington, Black riders waited statistically significantly longer than White riders (Ge et al., 2016). This study also indicated various results identifying a pattern of discrimination. For instance, users with more Black-sounding names typically experienced more ride cancellations than those respondents with traditional White-sounding names. These practices were observed in taxi services as well, with the first taxi stopping three times as often for White riders than for Black riders. As a result, taxis were viewed more negatively by Black respondents than TNCs. On the other hand, other studies (e.g., Smith, 2016) have shown that the use of ride-hailing services does not substantially differ across racial lines, with White, Black, and Latino riders using them at similar rates.

Multiple studies have concluded that individuals with higher incomes and education levels tend to use on-demand ride services at a higher level (e.g., Circella et al., 2018; Vinayak et al., 2018). Although TNCs tend to be cheaper than conventional taxis, they may still be a financial luxury for respondents in the lower income brackets. This can be seen in the shared mobility survey data; as incomes increase, positive attitudes toward TNCs increase. However, even respondents in the lowest income brackets had a much higher opinion of TNCs compared to taxis, likely owing to the cheaper fares of TNCs. All three on-demand services showed a positive correlation between income level and attitude.

Respondents who do not suffer from any disabilities had consistently higher opinions of on-demand services than respondents who reported one or more disability, although this difference was not statistically significant at the 0.05 level for taxis. Persons with disabilities may require mobility devices, such as wheelchairs, or service animals to help them with their daily activities. Oftentimes, these devices require either special vehicles or vehicle modifications to allow disabled passengers on board, which some services like TNCs may not have, particularly if they do not typically give rides to disabled passengers. Due to these inconveniences, individuals with disabilities may feel uncomfortable trying to use these services, and drivers may feel that they cannot accommodate rides for this population group. This finding highlights the importance of developing policies and strategies to ensure services are accessible for all, including people with disabilities.

Prior studies have shown that persons who live a more urban lifestyle tend to use TNCs more frequently (Circella et al., 2018; Vinayak et al., 2018). Because TNCs require a large pool of riders and drivers to remain profitable, having a base of operations in densely populated urban areas makes sense. Farther away from these population centers, any on-demand transportation service will struggle to find drivers to hire and riders to sell their services to. This required proximity to population centers may explain why rural respondents were found

to have comparable neutral opinions toward taxis and on-demand transit, as well as lower mean attitude scores than respondents in urban and suburban areas.

Positive and Negative Aspects of On-Demand Transportation Services

All survey participants were presented with a list of options for each of the three types of on-demand services (TNCs, taxis, and on-demand transit) and asked to choose up to three aspects for each type of service that they personally found positive. Table 7 lists the top five positive aspects identified for each service type.

Table 7. Top Five Positive Aspects of On-Demand Transportation Services

TNCs	Taxis	On-Demand Transit
Don't have to drive (29.6%)	Don't have to drive (32.6%)	Don't have to drive (26.9%)
Electronic payment—no cash (27.9%)	Don't need to own my own car (27.7%)	Don't need to own my own car (22.2%)
Convenience (27.1%)	Convenience (19.6%)	Convenience (16.3%)
Don't need to own my own car (22.6%)	Independence—allows me to get around town (17.8%)	Independence—allows me to get around town (16.0%)
Cheaper than taxi (22.3%)	Dependable (15.0%)	Cheaper than taxi (15.6%)

Regardless of the service type, respondents cited not having to drive as the most appealing aspect of using these services. Similarly, not needing to own a car and convenience were common positive aspects shared by all three services. Unique to TNCs, respondents emphasized the importance of not having to pay with cash but instead being able to pay electronically for fares. The 2021 Diary of Consumer Payment Choice conducted by the Federal Reserve Bank of San Francisco found that cash use accounted for only 19 percent of all payments in 2020, down 7 percent from 2019 (Coyle et al., 2021). As more people move away from cash to other forms of financial transactions, companies that can take advantage of this shift will become more appreciated by consumers. The convenience of paying for TNC services electronically reflects a growing trend in the larger marketplace, but significant efforts need to be undertaken to improve access to digital payments across different demographic groups. Finally, affordability was identified as an important positive aspect of TNCs and on-demand transit, with respondents noting that these modes are cheaper to use than taxis.

Respondents were also given the option of indicating that they personally find nothing positive about these services. When compared to other on-demand transportation services, the results showed that TNCs were viewed more positively by respondents. While approximately 13 percent of respondents did not find anything positive about TNCs, 22 percent and 24 percent of respondents did not find anything positive about taxis and on-demand transit such as microtransit, respectively. The latter result for on-demand transit options was likely due to the relatively limited availability and understanding or awareness of these services in the region.

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Survey participants were next presented with a list of options and asked to select the most significant issues that make it hard for them personally to use any on-demand transportation services. Figure 7 shows a ranked list of these results. The top three issues related to safety, affordability, and sanitation. Around 18 percent of survey participants indicated not having any issues.

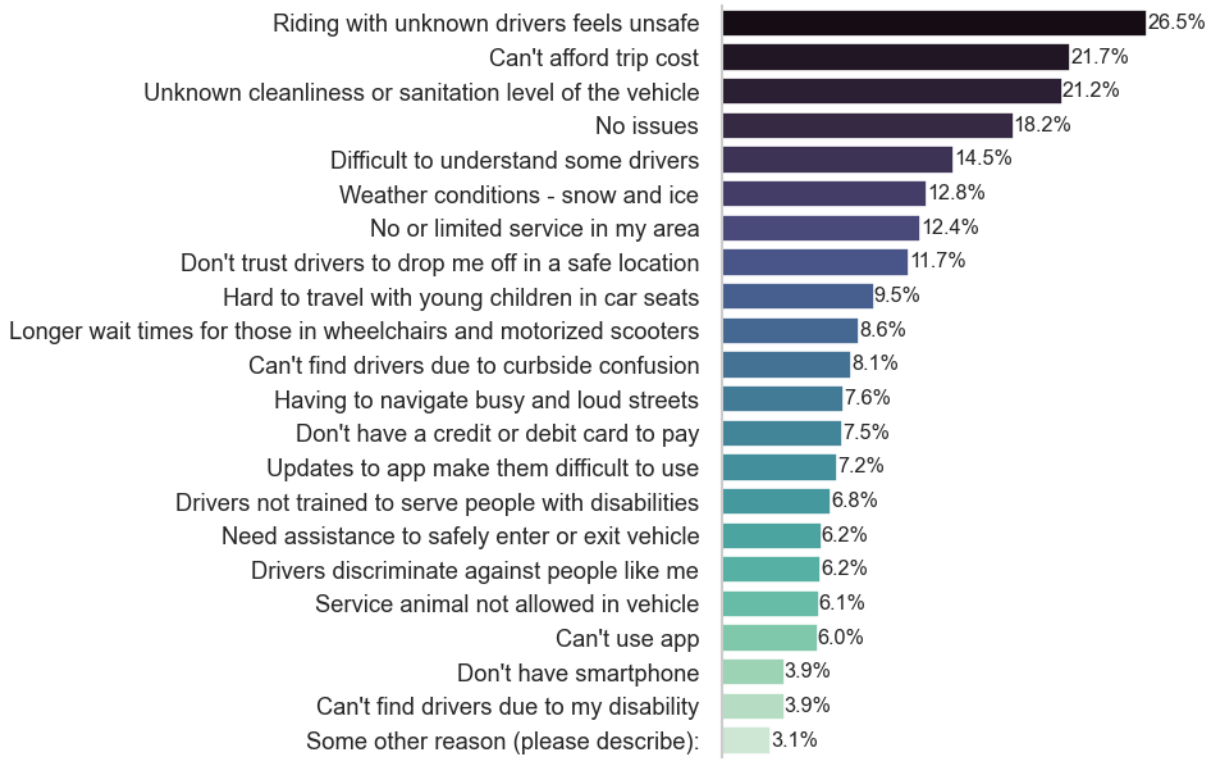

Figure 7. Issues that make it hard to use on-demand transportation services.

The top three issues were the same across gender categories and income levels, although the order varied. In terms of gender, feeling unsafe when riding with unknown drivers was the top issue among females (32 percent) and nonbinary/third gender (41 percent), which is consistent with the prior research. Prior studies have widely cited safety concerns (due to unknown drivers or passengers) as a significant barrier to using TNCs, particularly for females compared to males (Ma, Zhang, et al., 2019; Panjwani, 2018). Among these same gender groups, not being able to afford the cost of the trip and unknown cleanliness or sanitation level of the vehicle were also frequently cited issues by respondents (around 23 percent for females and 35 percent for nonbinary/third gender). This order changed slightly among males, with sanitation rated as the top issue (20 percent), followed by safety (19 percent), and affordability (18 percent). In terms of income effects, respondents in the lowest income bracket (less than $25,000) were most concerned about affordability, while respondents in the highest income bracket (more than $150,000) were most concerned about sanitation. On the other hand, respondents in the middle-income brackets were most concerned about safety.

A similar pattern was observed based on residential area type, with safety being the primary concern for respondents who lived in urban and suburban areas. While safety remained one of the top three issues, affordability (33 percent), followed by no or limited service in the area (27 percent), ranked higher for

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respondents who lived in rural areas. This finding underscores the need to improve service availability and access throughout the region.

Shared-Ride Services

As previously mentioned, one of the primary goals of this study was to examine attitudes, perceptions, barriers, and solutions toward sharing a ride. The distinction between *shared rides* and *pooled rides* while using on-demand transportation services was made to survey participants as follows:

- Shared ride: A ride shared on public transit or via a private service with a stranger (or multiple strangers) rather than a companion or friend.
- Pooled ride: A ride through a shared on-demand service that is grouped together (pooled) with another ride, usually based on current proximity or common travel direction/destination between the rides.

Attitudes, Perceptions, Usage Patterns, and Improvements

Researchers conducted various analyses to examine shared-ride services as described below:

1. Initially, using the Kruskal Wallis test, researchers explored the attitudes toward shared-ride services, which helped establish an overall understanding of participants' attitudes toward shared-ride services.
2. Next, the use of share-ride services was analyzed based on the survey question that asked, "Have you ever shared, split, or pooled a ride using a TNC, taxi, or on-demand transit service?" Of the 2,527 survey participants, 1,459 (58 percent) said *no*, while 1,068 (42 percent) said *yes*. Out of the 1,068 people who indicated using shared-ride services, around 2 percent indicated using them on a daily basis, and more than half indicated using them only a couple of times ever. Figure 8 summarizes these results. However, not all of these respondents were current users of on-demand transportation services (TNCs, taxis, and on-demand transit). At the time of the survey, 1,337 people (53 percent) said they currently used one or more on-demand transportation services. Of these current users, 730 (55 percent) said they had shared rides while using these services. Researchers developed a binary logistic regression model to investigate the factors influencing the likelihood of sharing a ride when utilizing TNCs, taxis, or on-demand transit services.

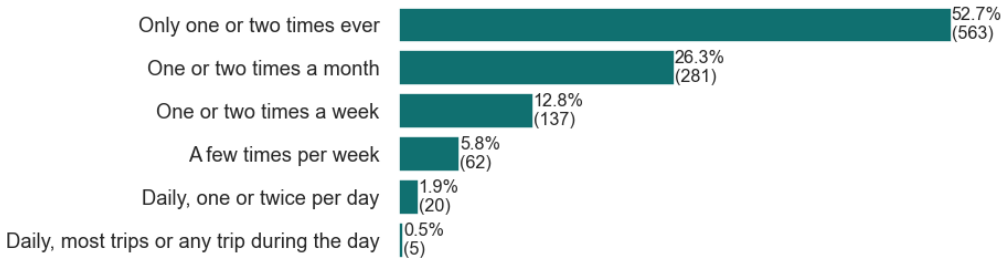

Figure 8. Frequency of using a shared-ride service among on-demand transportation users.

3. Several questions were designed to identify factors that positively or negatively affected individuals' satisfaction/dissatisfaction with sharing a ride. The next set of analyses focused on examining the positive and negative aspects of shared-ride services.
4. Additional questions were investigated to better understand the trip-related characteristics of shared-ride services in terms of day of week and time of day for various trip purposes, as well as shared vehicle

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occupancy. These questions were posed to respondents who indicated that they had previously shared a ride or were willing to share a ride while using on-demand transportation services.

5. Subsequently, several questions were posed to examine changes that could be made to improve shared-ride services and encourage individuals to use them. A comprehensive examination was conducted to assess potential improvements, including operational enhancements, government policies, and employer programs.

A condensed discussion of the results and implications derived from the aforementioned analyses is presented in the final section of the report: Summary and Conclusions.

- A comprehensive analysis of the survey data and detailed discussion of the results regarding shared-ride services, as described above, can also be found in the research paper titled '*Driving Sustainable Transportation: Insights and Strategies for Shared-Rides Services'* by Sener et al. (2023a).

Potential Improvements by Group

The results of the aforementioned analyses reflect the aggregate responses from all respondents. Researchers also considered the rank order of these responses from disaggregated respondent groups to support the development of targeted policies that could incentivize marginalized groups into sharing a ride. Addressing the specific concerns of various groups could yield a higher likelihood of success in getting them to choose pooled options.

To confirm whether the survey responses for specific questions of interest differed across social groups, researchers used Pearson's chi-square test for homogeneity of proportions. The null hypothesis was that the proportion of respondents who chose a particular answer for a question was the same across all populations, with the alternative hypothesis being that at least one of the populations had a proportion that was different from the others. When there was only one degree of freedom (i.e., only two comparison groups), researchers used Yates' continuity correction.

- The results of this gender-based analysis are available in the research paper titled '*Gender Gaps in Improvements to Shared-Ride Services: Insights from a Shared Mobility Survey*' by Sener et al. (2023b).

The corresponding results based on residential area type differences are presented below. Table 8, Table 9, and Table 10 summarize the differences in responses by residential area type (urban, suburban, or rural) to potential improvements to shared-ride services related to operational improvements, government policies, and employer programs, respectively, including the respective sample counts and proportions for each group, the $\chi^2_{(k-1)}$ test statistics, and the corresponding p-values.

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Table 8. Residential Area Differences Regarding Operational Improvements to Shared-Ride Services

Operational Improvement	Count			Proportion			χ^2-statistic	p-value
	Urban	Suburban	Rural	Urban	Suburban	Rural		
Designated boarding zones	176	108	11	0.135	0.108	0.078	6.293	0.043
Guaranteed time window	394	296	36	0.302	0.297	0.255	1.310	0.519
Guaranteed limit on additional stops	372	287	29	0.285	0.288	0.206	4.280	0.118
Financial reimbursement if trip goes past estimated travel time	406	273	40	0.311	0.274	0.284	3.817	0.148
Priority preference option	229	132	15	0.175	0.132	0.106	10.600	0.005
Sequential drop-offs in order of boarding	224	127	14	0.172	0.127	0.099	11.620	0.003
Viewable name, gender, and age of the other passengers	236	172	23	0.181	0.173	0.163	0.441	0.802
Viewable picture of the other passengers	221	157	26	0.169	0.157	0.184	0.961	0.619
Preference option for gender of the other passengers	234	154	28	0.179	0.154	0.199	3.297	0.192
Rating option for passengers/viewable ratings of other passengers	242	167	25	0.185	0.168	0.177	1.226	0.542
Company vetting of other passengers	237	178	18	0.181	0.179	0.128	2.549	0.280
Match option with other passengers from a trusted network	250	185	32	0.191	0.186	0.227	1.372	0.504
Current location broadcasts during a trip to a trusted person	317	240	38	0.243	0.241	0.270	0.564	0.754
On-call concierge number or helpline	274	191	30	0.21	0.192	0.213	1.260	0.533
Formal code of conduct for passengers	295	242	33	0.226	0.243	0.234	0.898	0.638
Onboard video surveillance	333	283	47	0.255	0.284	0.333	5.299	0.071
None of the above	151	159	20	0.116	0.159	0.142	9.371	0.009

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Table 9. Residential Area Differences Regarding Government Policies for Shared-Ride Services

Government Policy	Count			Proportion			χ^2-statistic	p-value
	Urban	Suburban	Rural	Urban	Suburban	Rural		
Creating designated boarding zones at busy intersections/curbside areas	232	143	23	0.178	0.143	0.163	4.854	0.088
Improving sidewalks and intersections at key destination areas	242	183	27	0.185	0.184	0.191	0.054	0.973
Implementing surveillance and security at designated boarding zones	356	275	42	0.273	0.276	0.298	0.41	0.815
Reducing local traffic speeds to improve safety for pedestrians	187	130	15	0.143	0.13	0.106	1.895	0.388
Adding high-occupancy lanes or priority lanes for pooled vehicle travel	237	156	26	0.181	0.156	0.184	2.665	0.264
Providing traffic signal priority for pooled vehicle travel	167	119	15	0.128	0.119	0.106	0.769	0.681
Allowing for pretax benefits to be used for shared-ride trips	200	115	21	0.153	0.115	0.149	6.976	0.031
Providing a direct subsidy to users who take shared-ride trips	246	155	18	0.188	0.155	0.128	6.326	0.042
Creating tax advantages for employers who have shared-ride programs	216	146	18	0.165	0.146	0.128	2.429	0.297
Regulating private transportation providers to report safety incidents within shared-ride vehicles	272	187	28	0.208	0.188	0.199	1.52	0.468
Regulating private transportation providers to make service more available in my community	215	146	26	0.165	0.146	0.184	2.165	0.339
Regulating the sale or use of data generated from apps	203	174	20	0.155	0.175	0.142	1.98	0.371
Regulating fixed fares between more destinations	295	221	29	0.226	0.222	0.206	0.317	0.853
Creating better service connections to rail or bus transit service hubs	278	186	28	0.213	0.187	0.199	2.44	0.295
Subsidizing the cost of shared-ride trips that connect to transit hubs	303	204	24	0.232	0.205	0.17	4.443	0.108
None of the above would make me more likely to share a trip with a stranger	138	351	0	0.13	0.244	0	49.924	<0.001

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Table 10. Residential Area Differences Regarding Employer Programs for Shared-Ride Services

Employer Program	Count			Proportion			χ^2-statistic	p-value
	Urban	Suburban	Rural	Urban	Suburban	Rural		
Creating designated boarding zones at my workplace	253	166	28	0.194	0.166	0.199	3.05	0.218
Implementing surveillance and security at designated boarding zones	355	310	42	0.272	0.311	0.298	4.26	0.119
Partnering with on-demand service providers to improve service availability at their locations	270	183	27	0.207	0.184	0.191	1.949	0.377
Creating rewards programs for taking shared-ride trips	454	322	50	0.348	0.323	0.355	1.721	0.423
Providing a direct subsidy for taking shared-ride trips	309	198	29	0.237	0.199	0.206	4.932	0.085
Providing a parking cash-out program for taking shared-ride trips	286	183	22	0.219	0.184	0.156	6.3	0.043
Creating programs for sharing rides with other coworkers or known networks of people	320	243	30	0.245	0.244	0.213	0.732	0.694
Providing a guaranteed ride home program as a backup transportation option	382	287	37	0.292	0.288	0.262	0.569	0.752
Permitting flexible working hours for commuting to/from work	380	249	40	0.291	0.25	0.284	4.906	0.086
Permitting flexible work-from-home schedules for some days during the week	361	230	30	0.276	0.231	0.213	7.585	0.023
None of the above would make me more likely to share a trip with a stranger	207	225	28	0.158	0.226	0.199	16.805	<0.001

Researchers observed fewer differences among residential area types for the various operational improvements (few showed statistical significance at the 0.05 level). All three operational improvements that were significant—designated boarding zones, priority preference options, and sequential drop-offs in order of boarding—were preferred most by urban residents, followed by suburban and rural residents. Two of these improvements (priority preference options and sequential drop-offs in order of boarding) relate to ensuring that users are not inconvenienced with excessive travel times when choosing the pooled option; the third improvement (designated boarding zones) likely relates more to safety, with travelers possibly feeling safer in public areas with others as witnesses/deterrents to anything that could cause them harm. These designated boarding zones could also have features such as bright lights, clear signs, and video surveillance that would give traveler's an increased sense of security. Because 45 percent of all urban residents said that they had at some point pooled a ride through some on-demand service, compared to 41 percent of suburban residents and 34 percent of rural residents, urban residents may be more open-minded toward pooled rides. Thus, the proposed operational improvements would likely have a bigger impact on them than on suburban and rural respondents.

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This is reflected in the data, with urban participants much less likely to say none of the operational improvements would make ridesharing more appealing.

Only two government policies—both related to regulating cost—were significant across the three groups (pretax benefits and direct subsidies for shared trips). The results are not quite conclusive because suburban and rural residential area responses alternate between having the second and third highest proportion, but for both policies, urban residents had the highest proportion of respondents who said they would find ridesharing more appealing as a result. This result is somewhat surprising because approximately 58 percent of rural residents reported earning less than $50,000, while around 41 percent of both urban and suburban residents reported earning less than $50,000. Because rural residents tended to have lower incomes than their urban and suburban counterparts, the policies that reduced the cost of shared rides should theoretically have been more appealing to them. However, this was not the case, meaning that even reduced costs may not bridge the gap in shared-ride service usage. Due to the dispersed nature of rural communities and the likelihood of fewer drivers operating within them, they tend to experience higher prices. These prices might remain financially unfeasible, even with the inclusion of subsidies. An alternative explanation could simply be that urban, and to a lesser extent suburban, residents have more access to on-demand services (and a higher perception of their reliability) than rural residents; the higher and denser populations in urban centers offer greater potential for profitable operation of these services. More access to on-demand services would mean more opportunities for and an increased likelihood of sharing a ride through an on-demand service.

This phenomenon was also observed when considering potential employer programs for ridesharing. The proposed program to provide parking cash-outs in exchange for sharing rides was most appealing to urban residents, followed by suburban and rural residents. For employees who are offered free or subsidized parking, a parking cash-out program would offer them a cash equivalent if using an alternative means of travel rather than taking up a parking spot with a personal vehicle. These programs would make the most sense in dense urban areas with limited parking; rural residents are less likely to need to pay for parking, making the cash-out program option less appealing to them. Similarly, allowing for flexible work-from-home schedules for some days of the week was most appealing to urban residents, followed by suburban and rural residents.

Across all three sets of recommendations (operational improvements, government policies, and employer programs), statistically significant differences were observed across the residential area types for respondents indicating that none of the recommendations would make it more likely for them to share a ride. Consistently, suburban respondents were most likely to agree with that statement, followed by rural and then urban respondents.

Intent to Use Shared-Ride Services If Improved

In the next set of questions, the primary goal was to analyze who, when, and for what trip purpose individuals would be more likely to share/split/pool rides with other strangers if the changes most important to them related to operational improvements, government policies, or employer programs (as indicated in the previous questions) were implemented.

Among the sample of respondents, 273 individuals said they would never consider sharing a ride through an on-demand service, even if any of the recommendations provided to them, or any recommendations they themselves wanted to see, were implemented. The remaining 2,254 individuals were asked for what types of trips and under what circumstances (any trip, only if not in a hurry, or never) they would consider splitting a ride. Figure 9 presents the results.

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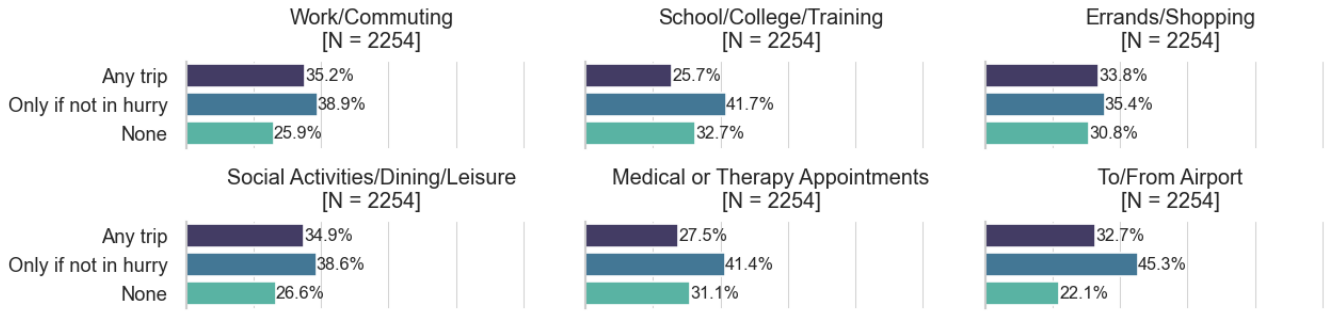

Figure 9. Trip types and circumstances for splitting rides through an on-demand service.

Taxis and ride-hailing through TNCs were previously shown to be the two most popular means of getting to the airport (Figure 3), and prior research has shown that people typically tend to rely on those modes more so than others when traveling to the airport (Koudounas et al., 2020; Rayle et al., 2016). Because airport trips tend to be very time sensitive (i.e., planes depart and arrive according to strict schedules that cannot typically be adjusted for one passenger's convenience), people may be hesitant to share rides with strangers because of the added uncertainty of their trip time. This risk can be mitigated if people plan ahead and arrive at the airport early, an action that is possible because flights are usually booked in advance and follow exact schedules. Consistent with this logic, the largest proportion of respondents in the survey said they would only share a ride to/from the airport if they were not in a hurry, and 22 percent said they would avoid sharing a ride entirely.

The same time-sensitive nature of air travel may explain why the largest share of respondents said they would never share a ride when commuting to school, college, or some other form of job training. Classes typically have exact meeting times, and students may be penalized for late attendance, especially on exam days. Thus, students would be hesitant to add any extra time to their commute.

Thirty-one percent of respondents said that they would never share a trip to medical or therapy appointments (the second highest proportion following school/college/training). There could be several reasons for this finding. For example, not everyone may be comfortable sharing personal medical information, particularly with strangers, which may inadvertently occur on a trip to the doctor's office or hospital. Even if nothing is said, people might automatically feel self-conscious on a medical trip because fellow passengers will likely think there is something wrong with them by the very nature of the trip type (i.e., for a medical appointment). Also, if people are going to a medical appointment, they may have some injury or disability that makes sharing a ride with others impractical (e.g., a mobility device that takes up space in a car). People who are going to the doctor due to a contagious illness may not want to risk spreading the disease among strangers. Finally, people who are experiencing a medical emergency would want to head to the hospital as fast as possible; picking up strangers along the way may have dire consequences in such scenarios.

Errands and social activities are usually not as time-sensitive in their nature as the previously mentioned trips. As such, larger proportions of respondents reported a willingness to share rides with strangers for these types of trips.

For each trip type for which respondents were willing to share rides for either any trip or whenever they were not in a hurry, respondents were then asked what time of day and what day of the week they would be willing to share rides. Across all trip types, sharing a ride only at night consistently had the lowest share of responses. This intuitively makes sense because people are typically more worried about strangers at night; decreased visibility and fewer bystanders increase people's feelings of anxiety and fear. People who are comfortable

sharing rides with strangers at night would most likely be willing to also share rides during the day because travel is seen as safer during the day than at night. Consistent with this logic, most respondents indicated a willingness to share only during the day; the least popular time of day for ridesharing, regardless of the day of the week (i.e., weekdays or weekends), was at night. The proportions were similar for weekends and weekdays, implying that people's preferences have more to do with the time of day than the day of the week.

Those traveling to and from the airport were most likely to be willing to share rides any time of the day. Because flights can occur at any time of the day, respondents who were already willing to share a ride may be insensitive to the time of the day. In contrast, the largest proportion of respondents who would share only during the day and the smallest proportion of respondents who would not share a ride at any time were observed for commuting trips to work and to school. Most people go to work and class during the day, so traveling at night would be unnecessary. The largest proportion of respondents who would only share a ride at night was observed for trips involving social activities. People partaking in social activities would typically use on-demand services like Uber and Lyft at night because that is when most people have time off from work and school and when most social activities like parties and trips to bars occur. In most of these cases, the time of day that respondents reported being willing to share a ride corresponded to the time of day when certain trip types were most likely to occur.

Shared-Ride Services versus Other Transportation Modes

Motivated by the ongoing discussion over whether on-demand and shared-ride services substitute or complement existing methods of mass transit, participants were asked what mode of transportation they would take if they were not sharing a trip on on-demand transportation.

The increased access to personal vehicles via these emerging forms of ridesharing technology should lead to a reduction in the use of SOVs and not multiperson transit. For example, if people choose to hail a ride through a TNC instead of taking the bus, even if the TNC ride is shared, many of the benefits of shared rides (less traffic, less pollution, etc.) will be negated. The literature provides mixed results on this topic, as discussed earlier. One study found that people who routinely used many shared modes, such as bikesharing, carsharing, and ridesourcing, were more likely to use public transit and own fewer cars (Shared-Use Mobility Center, 2016). This same study also found that shared modes complement public transit because they are most often used for social trips at night when public transit runs infrequently or not at all. In addition, respondents who frequently used ridesourcing appeared to be automobile-centric, with 34 percent saying they would drive alone or with a friend and 24 percent saying they would use carsharing. However, another study found that ridesharing replaced personal cars only in cities where households relied primarily on driving and not public transit, resulting in very little change, if any, on VMT and greenhouse gas emissions; however, in cities where transit use was more prevalent, ridesharing increased VMT and emissions because it encouraged people to switch from public transit to ridesharing (Leard & Xing, 2020). The true nature of the relationship between emerging shared services and traditional public transit can be rather complex and was thus of interest in this study.

Figure 10 shows the transportation modes most often substituted for shared-ride options through on-demand transportation services by trip purpose. While the majority of survey participants indicated that they would use a personal vehicle instead of shared-ride services (either driving or riding with someone else), the percentage of participants who said they would walk, bike, or take public transit was also fairly high. This latter finding is addressed in the literature, where one of the detrimental effects of the rising ride-hailing industry is a reduction in public health benefits due to many groups, particularly women, choosing to substitute active travel or transit usage with ride-hailing (Lavieri & Bhat, 2018). The reason women in particular may feel the need to

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substitute active travel and transit usage for ride-hailing is likely due to the myriad of safety reasons discussed previously.

It is interesting but not surprising that over 30 percent of respondents indicated that they would use either a TNC or taxi to travel alone to and from the airport—considering those two are the second and third most common modes, respectively, of airport travel (Koudounas et al., 2020). It makes sense that the most commonly substituted modes for airport travel are all related to cars because people typically carry luggage with them when traveling to and from the airport, and luggage is difficult to walk with or take on public transit. Similarly, for social activities and leisure, especially activities involving alcohol at night, using a TNC or taxi service, albeit alone, makes sense as a popular choice because people may not wish to drive at such times of the day or while intoxicated.

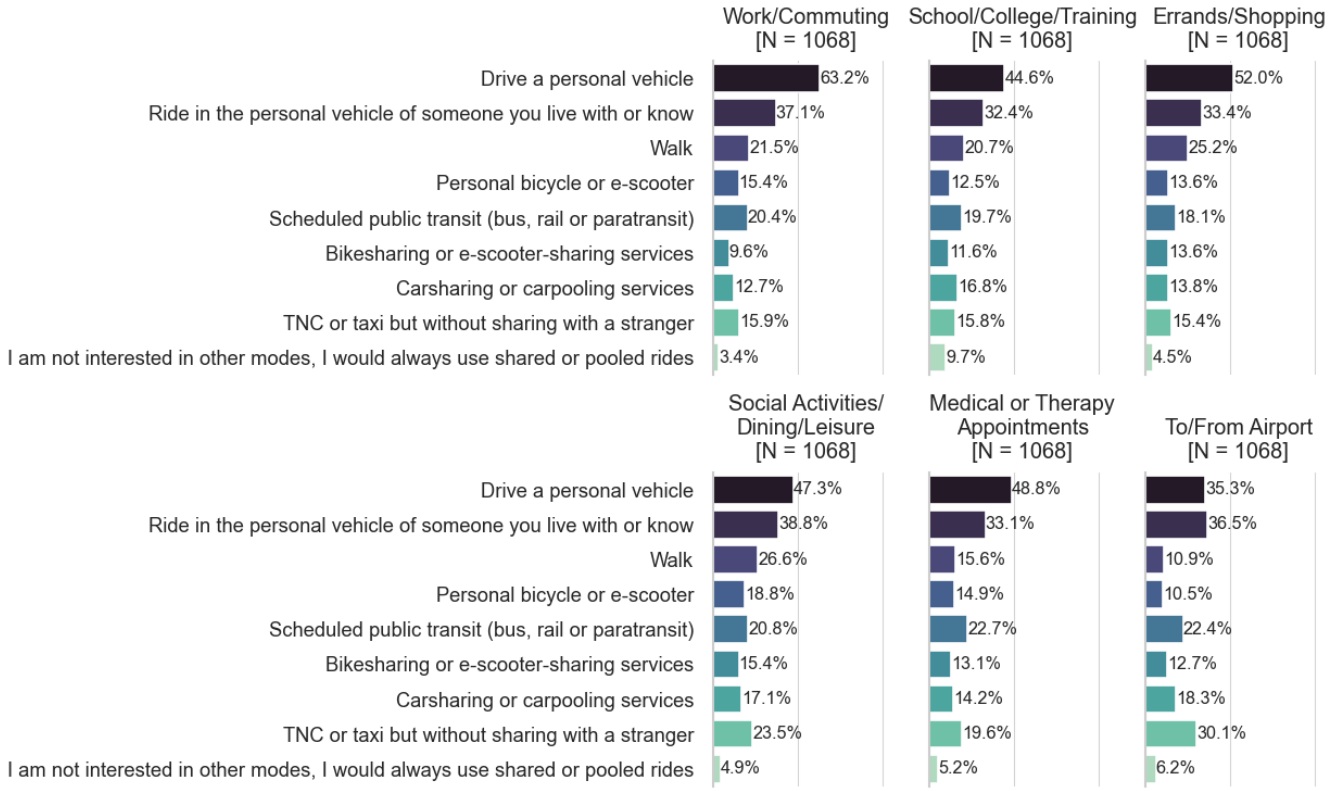

Figure 10. Substitute transportation modes for shared-ride services by trip purpose.

Self-Driving Vehicles and Shared Rides

The final set of survey questions related to self-driving vehicles, providing an overall understanding of respondents' acceptance of self-driving vehicles; their willingness to ride in a self-driving vehicle through on-demand transit, taxi, or TNC services; and their willingness to share a ride with another passenger in a self-driving vehicle through on-demand transportation services.

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Familiarity and Attitudes toward Self-Driving Vehicles

Because self-driving vehicles are a new technology that have yet to be widely implemented, researchers felt it would be helpful to first measure respondents' familiarity and attitudes toward self-driving vehicles before considering the effects of self-driving vehicles in conjunction with on-demand transportation and shared rides.

Figure 11 displays the respondents' familiarity with self-driving vehicles. Roughly four-fifths of respondents said they had at least some degree of familiarity with self-driving vehicles, indicating that these vehicles are not just some fringe technologies but something that is slowly entering public consciousness. This marks an increase in public awareness from a 2014 study that found that approximately 71 percent of all U.S. respondents were familiar with autonomous vehicles (Schoettle & Sivak, 2014).

Figure 11. Familiarity with self-driving vehicles.

Table 11 details respondent attitudes toward self-driving vehicles across various sociodemographic characteristics of the survey sample. As in previous analyses, a 5-point Likert scale was used to convert the qualitative responses to numerical values: *extremely positive* was assigned a numerical value of 2, *somewhat positive* was assigned a numerical value of 1, and so on until *extremely negative* was assigned a numerical value of −2. For each population of interest, the average score was calculated, and a Kruskal-Wallis test was conducted to determine whether the mean score was the same across all populations.

Male respondents had higher opinions toward self-driving vehicles than female respondents. Females were more neutral in their opinions, with more than one-third of them saying they had neither a positive nor negative attitude toward self-driving vehicles (the most common response). Men were more likely to have strong opinions either way; 31 percent of male respondents indicated either *extremely positive* or *extremely negative* when asked about their attitudes toward self-driving vehicles compared to 23 percent of female respondents. An earlier online survey of residents in Austin, Texas, found that men were more likely than women to be enthusiasts—individuals who were extremely likely to use autonomous vehicles if they were available on the market for purchase or rent (Zmud & Sener, 2016). When a similar study was extended to include multiple Texas cities, males consistently expressed a higher intent to use self-driving vehicles compared to females (Sener et al., 2018). Because males appear to be more likely than females to use self-driving vehicles, it stands to reason that they also have more positive attitudes toward them (more positive attitudes are expected to result in higher intended use).

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Table 11. Attitudes toward Self-Driving Vehicles Based on Select Characteristics

Variable	Categories	Self-Driving Vehicles	
		Mean	p-value
Gender	Male	0.600	<0.001
	Female	0.026	
	Nonbinary/third gender*	N/A	
Age	18–24	0.373	<0.001
	25–34	0.516	
	35–44	0.451	
	45–54	0.022	
	55–64	−0.044	
	65 or over	−0.065	
Race	Native American Indian or Alaska Native	0.538	<0.001
	Asian	0.884	
	Black or African American	0.464	
	Native Hawaiian or Other Pacific Islanders*	N/A	
	White or Caucasian	0.062	
	Other	0.306	
	Prefer not to answer	0.204	
Hispanic, Latin, or Spanish Origin	Yes	0.403	<0.001
	No	0.186	
Household Income	Less than $25,000	0.021	<0.001
	$25,000 to $49,999	0.065	
	$50,000 to $74,999	0.130	
	$75,000 to $99,999	0.413	
	$100,000 to $149,999	0.618	
	$150,000 or more	0.776	
	Prefer not to answer	0.250	
Disability	No disabilities	0.305	0.002
	Have one or more disability	0.112	
Technology Adoption	Early adopter	0.790	<0.001
	Late adopter	−0.048	
	Laggard	−0.395	
Residential Area Type	Urban	0.406	<0.001
	Suburban	0.116	
	Rural	−0.007	
	Not sure	0.241	

**Excluded from analysis because the sample size was too small.*

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Researchers observed a clear negative correlation between age and attitude, with respondents in the older cohorts having lower opinions (i.e., lower mean scores) of self-driving vehicles than respondents in the younger cohorts. This result was consistent with various studies in the field. For example, a study conducted across the United States, United Kingdom, and Australia found that younger respondents were more interested in having self-driving technology installed in their vehicles and less likely to say they would not ride in an autonomous vehicle (Schoettle & Sivak, 2014). Another study also found that younger people were more likely to be early users of autonomous-vehicle technology, and individuals who were more tech savvy were more likely to embrace autonomous-vehicle and shared autonomous-vehicle technology in the future (Lavieri, 2018).

As mentioned previously, respondents who said that they were early adopters of technology were younger on average than respondents who lagged in using new technology. A survey of 107 likely adopters of autonomous vehicles in Berkeley, California, found that respondents who were early adopters of new technology were more likely to use a self-driving taxi, retrofit their cars with self-driving technology, and support more infrastructure to facilitate the use of self-driving cars (Howard & Dai, 2014).

This age-technology trend is also reflected in this study; respondents who were the earliest users of new technology had one of the highest mean scores across all demographic groups, reflecting a high opinion of self-driving vehicles. While many new advancements are being made in the field of autonomous vehicles, it is still an emerging technology that has yet to be widely adopted by the general public. It is reasonable to expect that respondents who are most technologically savvy, and who are typically younger, would also be the most interested in and likely to use self-driving vehicles. These same respondents were also expected to have the highest opinions toward self-driving vehicles because they tend to have the highest opinions toward new technology in general.

Across all sociodemographic variables considered, Asians had the most positive attitudes toward self-driving vehicles. This finding is consistent with previous results regarding attitudes toward on-demand and shared-ride services; Asians had the highest score among all racial groups and one of the highest scores among all sociodemographic characteristics. In a study conducted in Berkeley, California, Asians were less likely to be concerned about issues related to autonomous vehicles, such as control and cost of the vehicle, and they also valued the increased equity in transportation and mobility for the impaired that self-driving vehicles provided much more than their White counterparts did (Howard & Dai, 2014). Hispanics were also found to value increased mobility more than non-Hispanics, reflected in the current study through more positive attitudes toward self-driving vehicles. Among all racial groups, Asians appear to be the most open to new technologies and emerging mobilities; almost two-thirds of all Asians reported that they are among the earliest users of new technology, a much larger proportion than any other race. Native American Indian or Alaska Native and Black or African American respondents also had much higher opinions of self-driving vehicles than White or Caucasian respondents, whose opinions of self-driving vehicles remained lower than their opinions of any other mode of transportation besides taxis.

Income was positively correlated with attitudes toward self-driving vehicles; as income levels increased, attitudes toward self-driving vehicles became more positive. An online survey across 109 countries found that willingness to pay for automated driving technology was highest among respondents with the highest income, with a positive Spearman correlation at the 0.001 significance level (Kyriakidis et al., 2015). In their Berkeley, California, study, Howard and Dai (2014) also found that higher-income respondents were more interested in self-driving technology than lower-income respondents, with two-thirds of all respondents citing cost as a major concern. As with all technologies in their infancy, autonomous vehicles are expected to typically cost more than traditional vehicles, although this gap likely will shrink as more research and development is

conducted in the field. Thus, as is expected with most emerging technologies, autonomous vehicles are considered a luxury that only individuals in the highest income brackets can afford. Because costs are a concern, the costs associated with self-driving technology likely affected the opinions of lower-income respondents.

Respondents with disabilities indicated that self-driving vehicles were their least preferred mode of transportation, compared to the three on-demand services and shared-ride options considered previously. Because a person with a disability may need help entering and exiting a vehicle (or while riding in a car), they may prefer a driver who could help them if needed. In the event of some sort of emergency, having a driver who could assist would be appealing to a disabled passenger. Theoretically, self-driving vehicles could include features that would make them more accessible to respondents with disabilities, but for now, disabled individuals may be hesitant to use them.

Attractive Features of Self-Driving Vehicles

All survey participants were asked what factors would attract them to take a trip in a self-driving vehicle. Figure 12 summarizes their responses.

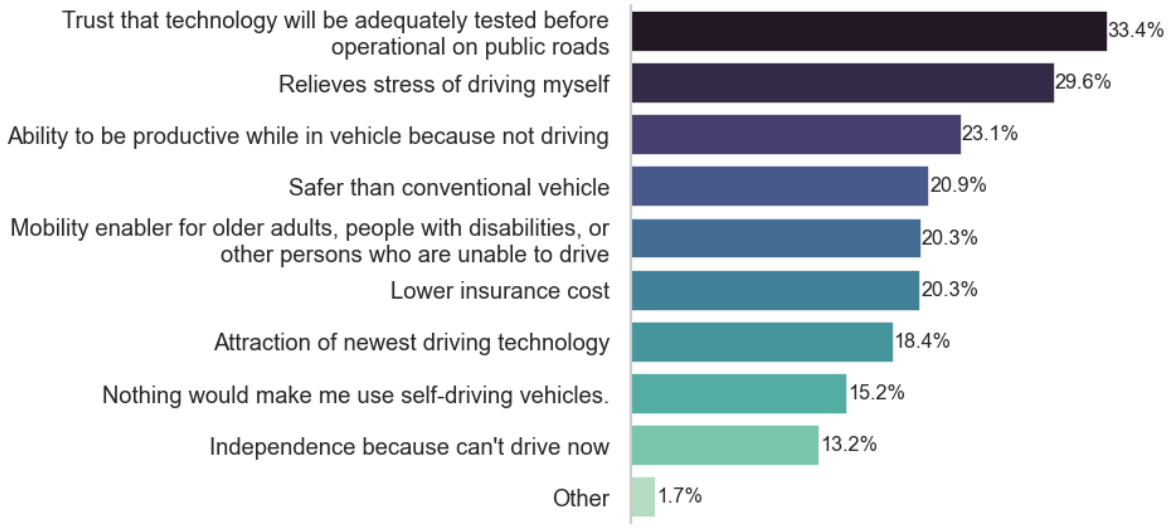

Figure 12. Attractive features of self-driving vehicles.

The top-ranked response—with one-third of all respondents choosing it—was that people could trust that any new self-driving technology would be adequately tested before being allowed to be operated on public roads. The role of trust in the potential use of self-driving vehicles has been previously acknowledged in many studies. A 2017 online survey found that trust had a statistically significant effect on the adoption of driverless cars (Kaur & Rampersand, 2018), including the belief that "driverless cars have enough safeguards to make me feel comfortable using it" and "in general driverless cars provide a robust and safe mode of transport." Respondents in that study also felt assured that governments and private industry would protect them from any problems arising from driverless cars. Because self-driving vehicles are a new technology, some hesitancy among consumers to use them is naturally expected. People would prefer adequate testing and knowledge of the technology before using it. If people are convinced that the technology is safe for them to use, they are more likely to use it—a philosophy that is true for all new ideas.

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The second most common factor attracting people to take a trip in a self-driving vehicle was the reduction in stress from not having to drive. Currently, the commute to work can be stressful to drivers, with worries being compounded if there is a lot of traffic and unpredictability. Driving in traffic leads to higher levels of stress, anger, and anxiety in commuters, which in turn have measurable negative impacts on health (Evans et al., 2002). If a self-driving vehicle assumes the responsibility of driving, workers have one less thing to worry about on their way to/from the office. They can relax without having to be hypervigilant and focused on the road and possibly work on other things that would save them time and stress in the future—all positive aspects of self-driving vehicles that have been mentioned in many previous studies. In fact, the ability to be productive in the car while not driving was found to be the third most attractive feature for respondents (23 percent). These results are consistent with the literature. Respondents in a study in Austin, Texas, regardless of age, said that relieving the stress of driving is one of the top reasons they would likely ride in a self-driving vehicle for everyday use (Zmud et al., 2016). This same study also found that for respondents aged 30–45 (typically of working age with full-time jobs), the ability to be productive while traveling in a car was a primary reason for their intent to use self-driving vehicles.

Factors associated with safety, mobility, cost savings, or novelty/attraction ranked in the middle. The lowest ranked factor (13.2 percent) related to the newfound independence afforded to respondents currently unable to drive. This finding could be explained by the car-centric nature of Texas; around 85 percent of survey respondents said they own a personal vehicle and have a driver's license, leaving approximately 15 percent of respondents who may gain independence with self-driving vehicles. More than 15 percent of all respondents said that nothing would make them likely to use autonomous vehicles.

Using On-Demand Transportation and Shared-Ride Services with a Self-Driving Vehicle

Respondents were next asked whether they would be willing to use self-driving vehicles through TNCs and other on-demand transportation services, and if so, whether they would be willing to also share rides in them.

A slight majority (53 percent) of respondents said they would be willing to ride in a self-driving vehicle through one of the on-demand transportation services. Of those willing respondents, 77 percent said they would also be willing to share the ride with other passengers. If consumers can be convinced to use self-driving vehicles for on-demand transportation, they might also be convinced to share the ride.

The 1,015 respondents who said they would share rides in self-driving vehicles were then asked what factors would affect their decision to do so. Figure 13 summarizes these results. The top four factors—each identified by more than 30 percent of respondents—related to not being in a rush (ranked first at 38.3 percent), speed relative to other transportation modes, monetary savings, and travel time reliability (ranked fourth at 31.6 percent).

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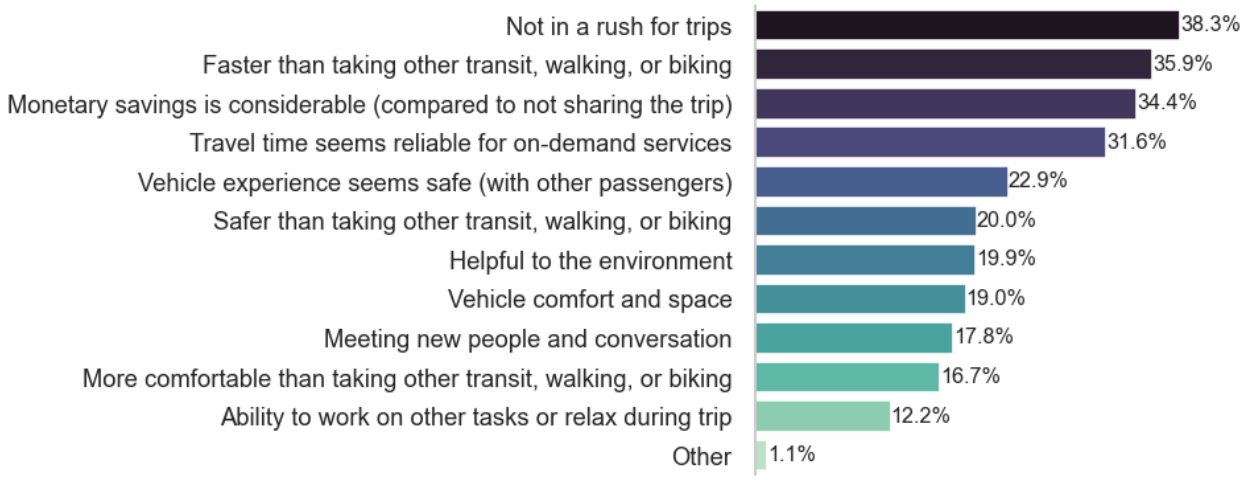

Figure 13. Attractive features of shared rides in self-driving vehicles.

Travel time is an important consideration for all travelers, and sharing a vehicle with someone else has the potential to increase the trip time and delay arrival at a passenger's destination. A study by Gurumurthy and Kockelman (2020) found that as the delay to their trip time increased, people were less likely to be willing to share a ride in an autonomous vehicle. Interestingly, they found that 37.5 percent of Americans and 35.1 percent of Texans were unwilling to use a shared autonomous vehicle even if no additional time was accrued on their trip. The same study also found that respondents were more willing to share rides in autonomous vehicles during the middle of the day and at night (when traffic is at its lowest), which corresponds to this study's findings that 38 percent of respondents would consider sharing trips when they are not in a rush. Because self-driving vehicles do not have drivers, transportation services can save on the cost of paying wages, which in theory would also mean lower costs for riders. Sharing vehicles can add to those savings since multiple passengers can be serviced by one vehicle, and vehicles can communicate dynamically with each other to optimize routes and prevent crashes, and generate savings in fuel and insurance costs. Among the respondents in this study, 34 percent said the monetary savings were considerable enough to convince them to share a ride in a self-driving vehicle. This finding is consistent with findings presented previously in this report that showed that respondents cared deeply about the costs of on-demand and shared services and favored policies that would make them more financially viable. While Howard and Dai (2014) found that cost was a major concern for most users, another study conducted at Worcester Polytechnic Institute found that people cared most about safety, followed by the legal complexities surrounding autonomous vehicles, with cost being of least concern (Jardim et al., 2013). This study's findings, as well as findings from select prior studies, contradict the findings from Jardim et al. (2013), suggesting that considerable monetary savings are more attractive than a safe vehicle experience and safety compared to other modes.

Sharing rides as a way to help the environment was selected by 20 percent of respondents as an appealing feature, owing to the potential reduction in air pollution caused by a smaller number of vehicles on the road. A study by Lavieri (2018) found that a propensity for a greener lifestyle was positively associated with the use of shared autonomous vehicles. For those respondents who are environmentally conscious, the use of a shared autonomous vehicle would make more sense than a single-occupant vehicle.

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Potential Improvements to Shared-Ride Services with Self-Driving Vehicles

Respondents who were willing to ride in a self-driving vehicle for an on-demand transit, taxi, or TNC service were presented with a list of potential improvements to shared-ride services with self-driving vehicles and asked which changes, if any, would make them likely or more likely to share rides with strangers in a self-driving vehicle. Table 12 provides the top five recommendations for respondents who indicated a willingness to share a ride in a self-driving vehicle through on-demand transportation services, as well as respondents who were not willing to share a ride.

Table 12. Top Five Recommendations to Improve a Self-Driving Service

Willing to Share a Ride in a Self-Driving Service	Introduce video surveillance on board vehicles (36%)
	Introduce and enforce a formal code of conduct for passengers to follow (33%)
	Broadcast my current location during my trip to a family member or trusted friend (for safety) (33%)
	Add the ability to match with other passengers from a trusted network like school, workplace, or social group to the app (31%)
	Provide an on-call concierge number or helpline in case there are safety issues (30%)
Not Willing to Share a Ride in a Self-Driving Service	Introduce video surveillance on board vehicles (34%)
	Broadcast my current location during my trip to a family member or trusted friend (for safety) (28%)
	Add the ability to match with other passengers from a trusted network like school, workplace, or social group to the app (26%)
	Introduce and enforce a formal code of conduct for passengers to follow (26%)
	Provide an on-call concierge number or helpline in case there are safety issues (24%)

Pearson's chi-square test for homogeneity of proportions was again used to determine if the proportions of respondents who indicated that a particular improvement would increase their likelihood of sharing trips with strangers differed between respondents willing and unwilling to share rides. Table 13 summarizes the results of these tests.

At the 0.05 significance level, three potential improvements were significant: allowing riders to see a picture of the other passengers in the app, providing an on-call concierge number or helpline in case there are issues, and enforcing a formal code of conduct for passengers to follow. For all three of these improvements, the proportions were higher for respondents who were willing to share rides than respondents who were unwilling to share rides. Essentially, all the proposed improvements either had the same effect on both groups or would simply make respondents who were already willing to share rides even more likely to share rides. The proportion of respondents who said that a particular improvement would make them more likely to share a ride was lower for all improvements when respondents were already willing to share a ride. A significantly

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higher proportion of respondents unwilling to share a ride said that none of the improvements would make them more likely to share a ride in a self-driving vehicle than respondents willing to share a ride.

Excluding the 61 respondents who said that nothing would increase their likelihood of sharing a ride in a self-driving vehicle, respondents were asked how likely they were to use self-driving vehicles in the future if the improvements most important to them were implemented. Around 60 percent of respondents said they were either likely or extremely likely to use self-driving vehicles, a very promising number. However, a fairly large proportion of respondents (around 29 percent) remained unlikely or extremely unlikely to use self-driving vehicles even after any improvements to the system, showing that it may still be an uphill battle to change public perception toward this new technology for certain segments of the population.

Table 13. Differences between Willing and Unwilling Ridesharers Regarding Improvements to Self-Driving Services

Improvement	Count		Proportion		χ^2-statistic	p-value
	Willing	Unwilling	Willing	Unwilling		
Allow me to see the name, gender, and age of the other passengers in the app	243	66	0.239	0.214	0.699	0.403
Allow me to see a picture of the other passengers in the app	263	62	0.259	0.201	3.956	0.047
Allow me to set a preference for the gender of the other passengers I would be paired with in the app	235	71	0.232	0.231	0	1
Allow me to rate the other passengers and see other passengers' ratings in the app	267	70	0.263	0.227	1.411	0.235
Provide company vetting of other passengers through background and criminal history checks	241	63	0.237	0.205	1.265	0.261
Add the ability to match with other passengers from a trusted network like school, workplace, or social group to the app	310	81	0.305	0.263	1.845	0.174
Broadcast my current location during my trip to a family member or trusted friend (for safety)	330	85	0.325	0.276	2.428	0.119
Provide an on-call concierge number or helpline in case there are safety issues	309	73	0.304	0.237	4.907	0.027
Introduce and enforce a formal code of conduct for passengers to follow	339	80	0.334	0.26	5.682	0.017
Introduce video surveillance on board vehicles	369	104	0.364	0.338	0.581	0.446
Something else	6	5	0.005	0.016	1.93	0.165
None of these looks appealing to me	53	61	0.052	0.198	61.983	<0.001

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Chapter 5. Summary and Conclusions

This study involved an online survey conducted with residents in large metropolitan and small urban areas in Texas to learn more about their preferences for sharing rides while using on-demand transportation services. The shared mobility survey asked respondents about their use of different transportation modes, use of modes for different trip purposes and time of day, and use of on-demand services in general as well as while sharing trips. The survey also asked respondents to indicate their highest perceived benefits and barriers to sharing trips on on-demand services, and responses were analyzed based on the use of the services previously. The survey also presented options for solutions to encourage more shared rides through operational improvements, government policies, and employer programs that could be implemented. Finally, questions on using AVs with shared rides along with potential solutions to barriers were presented to respondents.

In terms of transportation modes, respondents showed a higher tendency to use TNCs compared to public transportation; this finding could be due to the service levels and quality of transit service in a respondent's particular area, along with the availability of TNCs and personal household income level. Figure 5 shows that a majority of the respondents who said they currently do not use public transit trains or light rail do not have access to them. Contrary to public transportation users, respondents reported using TNCs more for occasional trips, such as attending social activities on weekend nights or going to/from the airport rather than for regular travel needs. Figure 3 indicates that the most common trip purpose for ride-hailing services was attending social events, and the most popular mode of transportation for traveling to and from the airport was TNCs. These findings are consistent with previous studies that identified going to bars, parties, and other social activities as the top reason for TNC use (Clewlow & Mishra, 2017; Rayle et al., 2016; Tirachini, 2020). Consistent with the results presented in Figure 2, these same studies found that TNC use was higher on the weekends and at nighttime when such social activities typically take place. Previous research has also identified ride-hailing services as one of the top three preferred choices of travel for those making airport trips (Koudounas et al., 2020), likely owing to the convenience and flexibility they provide when making travel plans.

Survey responses found that TNCs and public transportation alike were slightly more popular among non-White populations and significantly more popular among respondents with higher household incomes. This first finding conflicts with previous research that found that White, Black, and Latino riders used ride-hailing services at similar rates (Smith, 2016). The second finding—respondents with higher incomes had higher opinions of on-demand transportation—is consistent with previous studies that showed high-income users used these services at higher levels (Circella et al., 2018; Vinayak et al., 2018); these services may still be viewed as a luxury that is beyond the means of many low-income families. Conversely, female and nonbinary or third-gender respondents indicated using non-driving modes less frequently than males, mostly due to safety concerns about riding with unknown drivers; these results on safety concerns were even higher for shared rides on on-demand services. These findings agree with previous research that found that the risks of physical and sexual assault often deter women from using TNCs (Ma, Zhang, et al., 2019; Panjwani, 2018). The top three issues for on-demand services were feeling unsafe with drivers, trip cost, and cleanliness/sanitation. The latter issue—cleanliness/sanitation—may have been elevated by respondents due to the ongoing COVID-19 pandemic; as pandemic concerns decrease, the expressed concern for these issues may also decrease, although it is also possible that the pandemic has permanently heightened people's awareness of contagious diseases.

Perceived availability of on-demand services could be an issue for policymakers aiming to encourage ridesharing. The findings indicated the need to do a better job of increasing awareness of available service options in communities. Non-White and lower-income population groups more frequently indicated lacking

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access to emerging mobility services like micromobility and microtransit. Respondents who indicated living in rural areas had more neutral opinions about on-demand services, likely due to service operations being less available in their area.

Forty-two percent of survey respondents indicated ever using a shared-ride service, but half of these individuals had only shared rides a couple of times. Not surprisingly, younger respondents were more likely to share rides than older respondents, and male respondents were much more likely to share rides than respondents of other genders. This latter finding is consistent with previous discussions around gender; non-males are more likely to feel uncomfortable using services with unknown riders, and adding more strangers to the vehicle (in the form of random passengers) only adds to this anxiety. Tang et al. (2021) confirmed that female discomfort increased as the number of strangers in the vehicle increased. Younger respondents were consistently shown to be more likely to share rides than older respondents (Gehrke et al., 2021; Moody & Zhao, 2020). This study found that younger participants had higher opinions of these emerging technologies and were generally early adopters of new technology, likely explaining the gap in pooled rides between younger and older riders.

Respondents who were Hispanic were 30.5 percent more likely to share rides, while no other racial/ethnic group preferences on ridesharing were statistically significant. This finding is consistent with previous investigations that found non-Hispanic Whites less likely to share rides on TNCs than their Hispanic counterparts (Kang et al., 2021; Lavieri & Bhat, 2018). The relationship between income and willingness to share rides remains disputed; the findings of this study implied that incentives may need to be increased to make sharing rides more attractive and attainable for those in the lowest income brackets. Hearing difficulties stood out as a disability type that would cause respondents to be more likely to share a ride, which may mean that this disability type presents fewer challenges and less discomfort for ridesharing than others. Respondents having a hybrid workplace (both at home and outside of the home) were 46.5 percent more likely to share a ride than those with exclusive work locations, and frequent use of on-demand as well as transit services also showed a higher willingness to share rides; these results could indicate that persons with less rigid routines and fewer driving-alone trips are more open to having a positive attitude on ridesharing.

The biggest factors for negative perceptions of shared rides were unreliable/increased travel times, unpleasant passengers, and discomfort talking to strangers; these factors were ranked near the top regardless of the level of satisfaction with taking a shared ride trip previously. Sarriera et al. (2017) also found that potentially being paired with unpleasant passengers (62 percent) and added uncertainty in travel times (61 percent) were the top reasons why people chose not to pool rides. Positive factors were also consistent between both groups, with cost savings being the biggest benefit, followed by convenience and comfort (compared to other modes of travel) and helping the environment; respondents that were satisfied with shared-ride trips also indicated enjoying meeting new people. Respondents were also asked about the types of trips for which they were more likely to share rides; the highest results were trips to/from the airport or for trips during the daytime (as opposed to nighttime), while respondents were less likely to share rides to school or medical appointments. For respondents that had not shared a trip on an on-demand service, the fear of getting paired with an unpleasant passenger was the biggest negative factor; this was especially true for female survey respondents, who were shown in previous studies to be more intimidated in shared rides than their male counterparts (Sarriera et al., 2017).

On the topic of operational improvements, the three top ideas from those proposed to respondents to make ridesharing more attractive were having a guaranteed drop-off window, offering financial compensation for late trips, and limiting the number of stops that could be added to the respondent's trip (as a result of taking on

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additional passengers). Respondents also indicated that designated boarding zones, priority preference options, and sequential drop-offs (in order of boarding) would increase the appeal of sharing rides, though this was more the case for respondents in denser urban areas than others. Most of these recommendations are related to preventing the traveling time of the rider from being excessively lengthened beyond what is expected going into the trip, which may indicate that the travel time of sharing rides may be a more important factor than those factors previously discussed and more important than the lower cost/cheaper fares for agreeing to split a trip on a taxi or TNC as well as using microtransit service.

Respondents also agreed with ideas to improve the safety of on-demand services through video surveillance within the vehicle and broadcasting their vehicle location to trusted family and friends during the trip. Female respondents indicated wanting to set a preference for the gender of other passengers in the shared-ride service, consistent with findings from Tang et al. (2021), even though this and other policy measures would not make them more likely to share a ride. Further policy and operational improvements that can better guarantee safe as well as comfortable ride experiences will likely need to be developed to influence the behavior of these travelers.

From a policy perspective, creating secure designated boarding zones and requiring private providers to report any safety incidents to local governments were indicated as factors that would improve perceptions of safety. Financial incentives were also important for some respondents; the related proposed ideas that respondents indicated as most useful were fare regulations, subsidies for trips, and reduced fares for trips that connect to public transit hubs. Respondents indicated top ideas for employers to encourage ride pooling to be rewards programs, flexible and/or work-from-home schedules, and guaranteed ride-home programs. Male respondents more frequently indicated incentives such as pretax benefits, direct subsidies, and subsidizing certain trips as options that would increase their willingness to share rides; this was also true for employer-related programs such as parking cash-out programs and flexible working hours. Conversely, female respondents were not as interested in ideas related to financial incentives (especially compared to those related to safety). For females, safety concerns may be too significant for them to ignore, despite financial incentives.

Overall, around 40 percent of respondents indicated low-fare costs and higher gasoline costs as being the most important factors driving shared-ride decisions; respondents with higher incomes additionally indicated unreliable parking availability as particularly important. On the other hand, the findings also indicated that travelers who find shared-ride services inconvenient due to longer travel times or unreliable service delivery, especially for time-sensitive trips, will not be significantly motivated by financial incentives to opt for shared rides unless other transportation options become excessively costly.

Regarding self-driving AVs being used in on-demand services, attitudes from respondents on the services in general and sharing rides in AVs were closely linked with the willingness to adopt newer technologies and feelings of safety and security. For instance, persons with disabilities indicated a lower preference toward AVs, which is likely due to a heightened need for assistance with accessing the vehicle and in the event of an emergency during the trip. Overall, around 40 percent of respondents indicated they would be willing to share a trip on an AV on-demand service; significant factors for choosing a shared-ride option were related to travel time, again reinforcing the same travel needs for current on-demand services. The top ideas selected for encouraging shared rides in AVs were having pictures of other passengers in the service app, providing an on-call concierge number, and enforcing a code of conduct. Regardless, willingness to share a ride on an AV did not increase for respondents who currently did not take shared-ride trips, suggesting that great improvements need to be made to service quality to change travel behavior in the future.

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