ANL/ESD-22/9

Shared Mobility Data Availability and Usage Trends

Energy Systems Division

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LIST OF ACRONYMS

ADA	Americans with Disabilities Act
ANL	Argonne National Laboratory
API	application programming interface
BTS	Bureau of Transportation Statistics
CPUC	California Public Utilities Commission
CTA	Chicago Transit Authority
EE/EJ	energy equity and environmental justice
EPA	U.S. Environmental Protection Agency
EV	electric vehicle
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GBFS	General Bikeshare Feed Specification
GHG	greenhouse gas
MaaS	mobility as a service
MDS	Mobility Data Specification
NABSA	North American Bikeshare & Scootershare Association
NACTO	National Association of City Transportation Officials
NASEM	National Academies of Science, Engineering, and Medicine
NYC	New York City
OMF	Open Mobility Foundation
PPP	public-private partnership
SFCTA	San Francisco County Transportation Authority
SFMTA	San Francisco Municipal Transportation Agency
TLC	Taxi & Limousine Commission
TNC	transportation network company
VMT	vehicle miles traveled

SHARED MOBILITY DATA AVAILABILITY AND USAGE TRENDS

ABSTRACT

In this report, we summarize data availability of new shared mobility technologies by mobility type and region and analyze how shared mobility usage varies by time and by demographic factors in the United States. The shared mobility technologies include ridehailing from transportation network companies (TNC), bikeshare, and scooter share. There is a wide range in shared mobility usage per capita across the country, even within urban areas. We observe that there was steady growth of new shared mobility usage from 2015 to early 2020, before COVID-19 reduced overall ridership. An analysis focused on Chicago shows that despite the availability of good public transportation, high usage of new shared mobility modes is centered in high income communities, especially by households who own less vehicles. However, we find that TNC is used for first-mile and last-mile in lower income communities. Analysis on the bikeshare usage also shows that household income is shown to not be a statistically significant factor when accounting for other factors including employment density, population density, percentage of college graduates, and bike-lane proximity.

1 INTRODUCTION

Cities around the U.S. have been very welcoming to changes in shared mobility technology. Their leadership has encouraged these new mobility technologies as potential solutions towards tackling traffic congestion, pollution, transportation equity, and resident health. As populations have grown, the use of roadways has grown as well, with total vehicle miles traveled (VMT) on American roadways more than doubling since 1980 (FHWA 2020). A majority of commuters in 14 out of 15 of the largest U.S. urbanized areas use single-passenger private vehicles to travel to work (Freemark 2020). Nationwide 80% of commuters drove to work alone in 2019, spending an average of 26 minutes each way on their commute (Burd et al 2021). By contrast, taxicabs, motorcycles, biking, and walking modes each had shorter average commute times than driving alone. Traffic congestion also enhances vehicle air pollutant emissions by up to 75% at the road level, which has noted health consequences for communities near major road networks as well as on the health of the commuters due to both emissions and stress (Gately et al. 2017). With a renewed interest in finding transportation alternatives to personal automobiles, new mobility technologies have garnered attention across the United States.

Shared mobility technology is seen as a large disrupter of traditional travel patterns. Having access to accurate data is an extremely powerful tool in understanding general and local travel trends as well as by providing the ability to forecast future travel patterns. In this report, shared mobility technologies include privately-run transportation network companies (TNC), also known as ridehailing or ridesourcing companies, as well as public bikeshare and scooter share systems, and to a lesser extent publicly-run TNCs and carshare programs. Traditional

public transportation modes are lightly discussed in this report, mostly as a point of comparison in ridership. This report specifically covers those transportation services in which the usage, in terms of both services and, in many cases, the infrastructure is shared across multiple users. A recent trend in new mobility technologies is the massive growth of micromobility systems, specifically bikeshare and scooter share, in American cities, which presents new challenges and possibilities for transportation and city planning professionals. Properly implemented, these shared mobility technologies can be a powerful tool in combating congestion, emissions, and also by improving transportation equity.

The purpose of this report is to 1) summarize shared mobility technology data availability in the United States, 2) track the usage trend nationwide, and 3) analyze how usage varies by demographic characteristics such as household income and the number of vehicles per household at the census tract level. In the remainder of Section 1, this report defines some necessary terminology related to new shared mobility modes and summarizes the recent literature. Section 2 explores data sources that we have identified that are publicly available for researchers. Section 3 describes general trends in the usage of shared mobility nationwide. Finally, section 4 explores its impacts on Chicago, Illinois, examining the interplay between TNC, micromobility, and transit, comparing the usage of these services to the demographic characteristics of different neighborhoods in the city.

1.1 TERMINOLOGY

This report considers new mobility technologies that are available today, many of which fall under the umbrella of shared mobility. To emphasize the change in ownership paradigm, this is also sometimes called Mobility as a Service (MaaS) (Kamargianni et al. 2016). Cohen and Shaheen (2016) note that shared mobility comprises both traditional, incumbent technologies such as public transit, car rentals, and taxicabs, as well as new modes of sharing transportation services that did not exist twenty years, including TNCs, bikeshare, and peer-to-peer vehicle sharing. These emerging mobility technologies are the focus of this report. They exhibit a wide variety of operational structures and, therefore, the data available to researchers for each varies widely. Data that is publicly shared ranges from very fine-grained data, which gives detailed information about individual trips, to highly aggregated data that has been processed by the company or system operating the mobility service and is of use in understanding overall trends, but less so for detailed geographic or demographic analysis. In this report, we define “trip” data as data that reflects a single individual trip from a single origin to destination, whereas “aggregated” data often reports sums of trips in small sections of a city or for the entire city or even region.

Given their recent, rapid growth, there are frequently multiple possible definitions for different new mobility technologies. TNC in this report are specifically companies that focus on ridehailing (also known as ridesourcing), in which a vehicle is driven to pick up a passenger (or multiple passengers) and then drops the passenger (or passengers) off at a designated destination. These rides are typically requested via a smartphone app and drivers are dispatched via algorithm. Although taxi services are also a type of ridehailing, and some taxi services have begun to modernize by incorporating cellphone apps, TNCs have made themselves distinct in their use of algorithms and one-app-access to multi-modal forms of transportation. TNCs are working to offer a transport ecosystem that connects seamlessly across mobility technologies,

including ridehailing, micromobility, and public transportation, all within a single application. Likewise, transit agencies increasingly aim to form partnerships with TNCs in order to improve their own service and to encourage collaboration rather than competition (APTA 2020).

Ridepooling is the grouping of multiple passenger who are willing to ride with strangers for part or all of their journey (in return for a lower fare). By using one vehicle for multiple people, this can minimize VMT and congestion. In TNCs, the passenger assignment and routing is done dynamically. Microtransit is the extension of this, with flexible schedules that shift based on rider demand (Via 2021). The vehicles are generally larger than other TNC vehicles, with vans and shuttles used instead of sedans.

While they are types of shared mobility, public transit and paratransit are not within the scope of new mobility; however, public transit ridership is occasionally examined in tandem with new mobility technologies in order to compare trends and assess interactions. The Federal Transit Administration (FTA) of the U.S. Department of Transportation publishes data on the operations of each transit system in the country (FTA 2020). The Americans with Disabilities Act (ADA) mandates that public services give accommodations for accessibility to disabled individuals. Paratransit is defined in the Code of Federal Regulations (1991) as "comparable transportation service required by the ADA for individuals with disabilities who are unable to use fixed route transportation systems" (49 C.F.R. § 37.3). Legally, "each public entity operating a fixed route system" (excluding commuter bus, commuter rail, and intercity rail systems) must provide "comparable" paratransit service for individuals with disabilities (49 C.F.R. § 37.121(a)). Riders of paratransit are often required to apply to qualify for the service, and historically have needed to make reservations in advance of the day when the ride is needed.

Micromobility is the set of lightweight and easily maneuvered transportation modes designed for the use of a single person. This definition of micromobility includes vehicles such as bikes and scooters, which travel at low speeds for short distances. This report considers vehicles within a publicly available system; bicycles and scooters can be personally owned, but those are outside of the scope of this report. The International Transport Forum (ITF) defines micromobility as vehicles less than 350 kg and slower than 45 km/hr (Santacreu et al. 2019). Micromobility devices can be entirely human-powered, motor assisted, or entirely motorized, as per the Pedestrian and Bicycle Information Center (Sandt 2019). The term "active transportation" is also often used when discussing micromobility, as it refers specifically to transportation modes that require physical activity to provide power.

This report considers both docked and dockless bikeshare and scooter share systems. Docked systems use fixed, permanent stations to begin and end the ride while dockless vehicles may be parked in a corral, bike rack, or on sidewalks, depending on the preferences of the city in terms of parking management. For micromobility services, the individual city has almost complete jurisdiction over the policies regarding its regulation within the city's boundary. This includes data sharing, geographic boundaries, maximum number of allowable vehicles, and, in severe cases, revocation of their permit to operate. Often cities do not have control over the day-to-day operations of these transportation services but work closely or in public-private partnerships (PPP) to coordinate safer, more equitable and efficient systems (NACTO 2018).

For TNCs, vehicles generally need to relocate to pick up the next rider, though optimized trip-chaining can minimize this distance. The mileage driven without a passenger is colloquially known as deadheading (Wenzel et al. 2019). The analogue to this for micromobility is

rebalancing, where bikes or scooters are moved from locations with an abundance of vehicles to neighborhoods with fewer vehicles (Chiariotti et al. 2018). This is a common practice in locations with a clear directional flow for commuting, such as morning commuters traveling to the central business district. Rebalancing is frequently handled by trucks or vans working for the mobility company, though micromobility systems will also incentivize their members to contribute towards these efforts in their daily use (Capital Bikeshare 2021), e.g. through offering credits towards future rides. For electric bikes and scooters, system management also includes charging of the vehicles. While some docks can serve as charging stations, dockless system vehicles need to be moved to charging locations. Some micromobility services pay users to charge overnight at their homes, while others manage the charging in-house (Osorio et al. 2021).

Carsharing is the temporary use of a vehicle that is not owned by the driver. Historically this has been most commonly accomplished through car rental agencies. To accommodate travelers, many car rental sites are located at heavily traveled destinations such as airports. Carsharing now includes systems with vehicles distributed throughout the city where the vehicle is returned to the same location where the trip started as well as one-way carsharing systems with vehicles that do not need to be returned to the same location. For each of these, the parked vehicle is not typically monitored by a company employee. Peer-to-peer carsharing involves a single vehicle owner renting out his or her personal vehicle; this is facilitated by companies such as Turo or Getaround.

1.2 LITERATURE REVIEW

Since their rise in popularity, approximately a decade ago, TNCs such as Uber and Lyft have been the subject of much research to understand their usage, growth, and effects (both intended and unintended) on the transportation system. In particular, TNCs have a significant impact on traffic congestion, energy usage, and emissions, which make any data available regarding TNCs extremely useful. Clewlow and Mishra (2017) published a brief history of the growth of shared mobility along with survey results on its public perceptions. Cramer and Krueger (2016) assessed how TNCs compete with taxicabs, emphasizing how their efficient technology yields higher capacity utilization. TNCs can have large impacts on larger urban mobility trends. Diao et al. (2021) found that the introduction of TNCs to a city leads to increased road congestion with a 0.9% increase in intensity and a 4.5% increase in duration, along with an 8.9% decline in transit ridership with little impact to vehicle ownership of residents. Balding et al. (2019) compared the vehicle miles traveled by TNC and privately owned vehicles within different cities, finding that TNCs comprised up to 3% of total ridership in certain metropolitan areas in September 2018, and over 10% of ridership within the central city of San Francisco. Henao (2017) surveyed riders to understand mode choice, finding that approximately half of TNC rides offset use of a privately owned vehicle, but the remaining rides replaced public transportation or active modes of transportation, or represent trips that would not have been taken at all (a phenomenon referred to as “induced demand”). Rodier (2018) reviewed other literature on TNC, summarizing that TNCs can reduce private auto ownership, but that displacement of both private vehicle trips and public transportation trips leads to uncertainty in the cumulative impacts of TNCs on VMT and total GHG emissions. The Union of Concerned Scientists found that a typical ridehailing trip is about 70% more polluting than a replaced trip, largely due to travel of these vehicles without passengers, known as deadheading (Anair et al.

2020). However, by considering ridepooling, where multiple travelers ride together, and the use of electric vehicles (EVs), the emissions can be halved from the original value. Henao and Marshall (2019) found an increase of 40% in total VMT solely from deadheading of TNC drivers. Similarly, examining data from Austin, Texas, Wenzel et al. (2019) found a total energy consumption increase of between 40% and 90%, compared to "baseline, pre-TNC, personal travel," from the growth in TNCs. Ward et al. (2021) found that replacing a private vehicle trip with a TNC ride increases average external costs by 32–37¢ due to increased crashes, congestion, noise, and climate change impacts. While these effects may be less pertinent to the individual making the decision to travel using TNC, they have profound societal impacts and are thus of concern to researchers. Ward et al. (2021) also found, however, that TNCs, in general, use newer and lower-emission vehicles compared to the general population, which may translate to reduced pollutant impacts in urban areas.

Feigon and Murphy (2018) were able to acquire data for the month of May 2016 for trips initiated in 5 major metropolitan areas: Chicago, Los Angeles, Nashville, Seattle, and Washington, DC. From their work, they found that zip codes with higher TNC usage owned fewer personal vehicles and were younger, higher-income, more densely populated, and had fewer single occupancy vehicle commuters. Brown and Williams (2021) found a higher share of Uber trips to essential locations from low-income and minority communities. This led to smaller changes during the COVID-19 pandemic, as essential travel was less impacted by the pandemic. McNeil et al. (2021) studied the equity impacts of a pilot program in Portland, OR offering fare credit for public transit, TNCs, carshare, and bikeshare services. Overall, the program was beneficial to disadvantaged residents, with many of them trying new transportation modes and reaching previously inaccessible areas. This reinforces the idea that the possible consumer base of new mobility technology can be expanded with education and incentive programs.

Micromobility is an essential part of this growing transportation sector. Sun et al. (2021) found that shared micromobility can reduce energy consumption from passenger travel by 2.6%. The most complete source on trends in shared micromobility is the annual "Shared Micromobility in the U.S." published by the National Association for City Transportation Officials (NACTO), with reports summarizing trends since 2010. The most recent version of the report is the 2019 edition, which explores micromobility, specifically bikes and scooters, prior to the effects of COVID-19 on travel patterns (NACTO 2020). Besides aggregate ridership data from across the US, the report also explores the demographic data of riders and the travel characteristics of micromobility. The average micromobility trip taken on a shared scooter or bicycle falls in the range of 12 minutes and 1 to 1.5 miles. In a survey of six cities, micromobility riders stated that 45% of the trips they took replaced a trip that would have been taken by personal or ride-hail vehicle and 28% of their trips replaced walking. The NACTO report found a large preference by riders for using protected bike lanes rather than sharing road space with vehicles or pedestrians. Riders of micromobility vehicles are, in general, more male and younger than the surrounding community and the median income of riders was found to be equivalent or higher than the surrounding area. Racial and ethnic characteristics of riders varies between cities. Many cities have purposefully chosen to provide additional resources, such as fee waivers, to low-income and historically marginalized resident populations to encourage ridership in those communities.

The North American Bikeshare & Scootershare Association (NABSA) has also published annual reports on the state of the industry, highlighting monthly trends in ridership and

presenting aggregate demographic assessments of the users (NABSA 2022). The latest NABSA report includes information for 2020, and thus covers ridership changes due to the COVID-19 pandemic. The COVID-19 pandemic hit many of these micromobility companies and networks extremely hard, as ridership plummeted. As the pandemic continued, many cities embraced micromobility as a COVID-19 safe way to travel for essential workers, and chose to expand service despite the loss in revenue. However, other cities shut down micromobility options, as explored by the Bureau of Transportation Statistics (BTS) in an interactive infographic (BTS 2021d). In particular, 28% of docked bikeshare stations and 10% of dockless bikeshare systems permanently closed from January to December 2020.

Many cities stipulate access to low-income individuals as a condition for entry of micromobility companies. Sometimes this takes the form of a requirement for docking stations or vehicles to be distributed in low-income communities (Samsonova 20211), and sometimes it is through reduced fares or membership fees (Wiltz 2018). Researchers from Portland State University found barriers for potential bikeshare riders in underserved communities to be safety, cost, and general knowledge about how the programs operate (McNeil et al. 2017). The Governor's Highway Safety Association identified key challenges and obstacles that cities will face coinciding with the growth of micromobility, including safety, micromobility as an alternative to private vehicle travel ownership, oversight, funding, infrastructure, data collection and reporting (Fischer 2020). A literature review of micromobility by Oeschger et al. (2020) found that micromobility that is integrated into public transportation systems can work in tandem to solve the problem of first-mile/last-mile access for existing public transit systems. Increased integrated ticketing systems as well as an abundance of dedicated micromobility infrastructure were found to be key components in encouraging multi-modal travel.

Carshare is also a relatively recent shared mobility technology that may be of interest to professionals in the field of transportation. Analysis by researchers from the University of California, Berkeley found that carsharing members reduced their ownership of household vehicles (Martin and Shaheen 2011). A deeper analysis using surveys of riders as well as a year of anonymized trip data directly from car2go found that carsharing reduced the net GHG output of residents through the reduction of car ownership (Martin and Shaheen 2016). It also found that access to carsharing service does allow some members of the service to completely forgo car ownership, lowering the overall VMT of the members. One motivation for carsharing is that highly efficient EVs can be used to replace inefficient personally owned vehicles, though supplying the necessary infrastructure for EV charging is an ongoing challenge (Nicholas and Bernard 2021).

2 DATA AVAILABILITY

Shared mobility has been deployed across multiple cities in the United States. TNC service is available in most U.S. cities, with Lyft available in over 600 cities and Uber available in over 250 metropolitan areas (Lyft 2021; Uber 2021a). The decentralized nature of TNC allows for rapid expansion, as the only major prerequisite is a sufficient pool of drivers, as opposed to a deployment of hardware as required for a micromobility system. The U.S. Department of Transportation has reported that there are 66 U.S. docked bikeshare systems in 51 cities open to the public as of June 2021 and a total of 92 U.S. cities with scooter share systems (BTS 2021a). Some cities and states report detailed trip-level information for TNCs while others have only published aggregate statistics for specific time periods, summarized in Table 1. Likewise, some cities publish data on bikeshare and scooter share usage, with those sharing trip-level data also listed in Table 1.

Table 1: Data Availability for Shared Mobility Systems in the U.S.

Location	TNC		Bikeshare		Scooter
	Trip	Aggregate	Docked	Dockless	Dockless
Austin, TX	✓		✓	✓	✓
Chicago, IL	✓		✓	✓	✓
New York, NY	✓		✓		
California (all)	✓				
San Francisco, CA		✓	✓		
Seattle, WA		✓	✓		
Washington, DC		✓	✓		
Massachusetts (all)		✓			
Boston, MA			✓		
Chattanooga, TN			✓		
Columbus, OH			✓		
Denver, CO			✓		
Fargo, ND			✓		
Jersey City, NJ			✓		
Kansas City, MO					✓
Los Angeles, CA			✓		
Louisville, KY			✓		✓
Minneapolis, MN			✓		✓
Philadelphia, PA			✓		
Pittsburgh, PA			✓	✓	
Portland, OR			✓		✓
Rochester, NY			✓		
Tampa Bay area, FL			✓	✓	

Data exists for shared mobility systems at different geographic and temporal scales that may be useful for researchers. At the national level, reports such as those highlighted in the literature review estimate the total ridership of different new mobility modes, including TNC, bikeshare, and scooter share. These are often aggregated from estimates from individual cities. From an analytical perspective, we are particularly interested in systems which share data on individual rides or which displays high geographic fidelity. This allows analysts to estimate more accurately how ridership may evolve as a function of deployment, demographics, and technology development.

Data can be acquired directly from the company operating the system, or through the jurisdiction authorizing usage of the vehicles. To assess the data availability of the different shared mobility types, we collected usage data from various sources. We began by examining reports, papers, newsletters, and data sites presenting aggregate micromobility statistics that have been published by various sources, such as those presented in the literature review in Section 1.2. These sources helped us identify which companies and cities provide usage data for micromobility types, and where it is publicly published. If we found that data for one mobility type was available from a city, we performed web searches for data for other mobility types from the same city, considering that cities may provide data for multiple mobility types. Finally, we performed a series of simple, yet extensive web searches for mobility data from a wide range of large cities across the U.S.

We have examined and documented the variables provided in each publicly-available trip-level dataset. For each dataset, we provide information about the city/company of the mobility system as well as the important variables that are provided by each. We hope that this information can be useful to others in identifying what potential analyses can be done using various datasets; this information is included in Appendix A of this report. There are other methods for generating trip-level datasets for analysis. For example, Zou et al. (2020) pulled data from a public application programming interface (API) at 30-second intervals for five weeks to detail scooter share trip trajectories in Washington, DC.

In addition to the trip-level data, there are many aggregate statistics and datasets available from an even wider range of sources. For example, the Commonwealth of Massachusetts (2021) publishes an annual report on rideshare within the state, accompanied by a dataset with several aggregate statistics by town. This data may be of use to researchers, though conducting a fine-grained analysis would be more challenging using this data. Nonetheless, an interested party may be able to request specific data, possibly being able to obtain anonymized or aggregated trip data (Golde 2019).

Most cities and local transit authorities collect and maintain data from micromobility trips where the services are available. The main obstacle for researchers is that not all micromobility systems share their data to the public. There are many concerns regarding rider privacy when providing trip level data. Although much of the trip level data collected is not shared with the public, it is possible that researchers or interested parties could contact these cities to ask for access to an anonymized form of the data. It is unclear if there is a standardized anonymization technique for cities to share with researchers, although many dockless systems choose to remove some decimal places of accuracy from their coordinate start and end locations. Some systems will also only share data on trips created by multiple different users, e.g., bike station-to-bike station trip count only shared if three or more people have taken the same trip.

Many cities record this data in MDS format, or Mobility Data Specification, which keeps trip data in a standardized format in order to allow for easier collection and comparison between organizations. MDS was created by the Los Angeles Department of Transportation in 2017 for use in their mobility systems. The format is now managed by the Open Mobility Foundation (OMF) and, since then, has been adopted by over 130 cities and public agencies (OMF 2021). Los Angeles is in the process of requiring MDS and anonymized real-time tracking of taxicabs and TNCs (Henry 2021). MDS does not require inclusion of collision or safety incident data to adhere to the standard, although cities will often collect this data separately. Safety data is often among the most important data that city residents seek. Some of the main data gathered is data on collisions and injuries as well as location of parked, undocked vehicles (particularly when they block pedestrian right of ways on sidewalks). This is dependent on a per-jurisdiction basis, based on the needs of the residents and the city. Additionally, NABSA has emphasized the General Bikeshare Feed Specification (GBFS) for use in trip planning apps, and over two-thirds of agencies require GBFS feeds (NABSA 2021). GBFS is a near real-time specification for public data primarily intended to provide status information through consumer-facing applications, used in over 600 shared mobility systems worldwide (NABSA 2022). In order to better coordinate trip data sharing for all mobility technologies, NACTO has suggested a three-category method of data reporting: data for transportation planning (speed, location data, time, vehicle occupancy); data for equity (unfulfilled ride requests, vehicle availability); and data for safety (collisions) (NASEM 2021).

2.1 TRANSPORTATION NETWORK COMPANY DATA

Only two major cities currently publicly share TNC trip level data: Chicago and New York City. We collected monthly usage data for NYC from the city, which makes this data available on its Open Data website (NYC 2022). From 2016 until 2019, TNC data was included with other taxicab data; starting in February 2019, TNCs were defined as high-volume for-hire vehicles by the Taxi & Limousine Commission (NYC TLC 2021). For Chicago, we also collected monthly usage data from the city, provided on its Open Data website (Chicago Data Portal 2022c). For Austin, we downloaded rideshare data provided by the company RideAustin on data.world (RideAustin 2017). TNC data from California is available upon request from the CPUC.

TNCs are typically privately-run companies on public roadways. In general, these TNCs do not share data directly with the public. The use of public roadways is often the justification that municipalities use to justify data requests from these companies. In some locations, such as Massachusetts and Washington, TNCs have been compelled to share data with local or state governments, but this data is not publicly available at the highest resolution (Commonwealth of Massachusetts 2020; 2021; Grossman 2018). The San Francisco County Transportation Authority published a detailed report profiling ridehailing trips in the city in 2017 (SFCTA 2017). Washington, DC has released an interactive dashboard of for-hire TNC vehicle usage for June 2019 (DC 2019). Leisy (2019) summarized the growth of Uber and Lyft in Seattle from 2014 to 2018 with aggregate information about the number of rides and the number of licensed drivers. The state of California has required that TNCs register with the California Public Utilities Commission (CPUC) and share data with the public, starting in 2020, and are considering potentially unredacting prior reports back to 2014 (CPUC 2020a, CPUC 2020b).

Data on TNCs is simultaneously extremely useful for researchers but also extremely difficult to acquire due to privacy concerns. Its usefulness, however, goes beyond just researchers. TNC data can also be used to aid transportation planning; for example, Massachusetts uses TNC trip lengths to estimate travel speed and congestion across the state (Commonwealth of Massachusetts 2020).

While Chicago and New York City regularly publish TNC data, neither reports vehicle information by trip. This makes it challenging to form trip chains and to quantify deadheading, and, more generally, to quantify the potential energy and emission benefits of electrification of TNCs.

TNC companies have actively resisted open data sharing, in general. Their reluctance to share data can be attributed to both privacy concerns as well as the fact that such exclusive data on trip ridership represents a lucrative data source that could increase their profits in the future. It is unclear if TNCs currently sell user data on their trips. As an alternative, Uber has chosen to release a large amount of data through their Uber Movement platform, which releases anonymized, aggregated trip data for average travel times, street speeds, and micromobility usage in select cities, rather than share data in the MDS format (Uber 2021b). Lyft also does not share national TNC trip data. Feigon and Murphy (2018) accessed data from an anonymous major TNC. This dataset, which was comprised of a month of data for five major metropolitan areas, affirms the notion that data is collected and stored, but is often only shared on a case-by-case basis between researchers and TNC companies.

The two largest ridehailing companies in the United States are Uber and Lyft. In California, for instance, these two companies have a combined 99.9% market share for TNC ridership (CPUC 2020b). Likewise, in New York City, Uber has served 63% of the dispatched rides since 2017, followed by Lyft at 20%, Via at 4%, the now-defunct Juno at 3%, and 10% for all other providers of dispatched rides, typically taxicab or livery services (NYC 2022). With the COVID-19 pandemic, the for-hire market in New York further consolidated in 2020 and 2021. Via emphasizes shared ridership, focusing on microtransit as an alternative to conventional transit. RideAustin was a non-profit TNC based in Austin TX that operated from 2016 to 2020, beginning service when Uber and Lyft stopped service in the city (Garcia 2020). Data from the first year of operation for RideAustin is available online (RideAustin 2017).

Other shared mobility services currently operate either in specific markets or specific use cases. In California, there are 12 companies with operating permits from the CPUC and a total of 30 companies have submitted applications (CPUC 2021). Multiple cities are also operating publicly-run TNCs, either through a PPP or entirely through a local transit authority. This approach has been increasingly common in recent years, with more than a dozen appearing all around the country since 2018, in both suburban (less dense) and urban (more dense) cities. No data from these systems is readily available online, but may be available upon request. A list of public TNCs is shown in Appendix A.

2.2 MICROMOBILITY DATA

2.2.1 Ridership Data

Bikeshare data includes data for both docked and dockless stations. Most often, docked trip bikeshare data is more readily shared as open data. Docked stations can provide non-personally identifying data, whereas dockless system bring privacy concerns if users park their bikes near their homes or jobs. Bikeshare data may be on an individual basis, or provided as aggregated data on rides between a given station pair (i.e., there were a certain number of rides between two specific stations on a given day). For dockless systems (bike and scooter), some cities create a grid of anonymized locations around the city, and match the start and end locations with the closest anonymized location. Station-based bike share was the most common mode of micromobility through 2017, but scooter share and dockless bikeshare each exhibited large growth in 2018 and 2019 (NACTO 2020).

For nearly all of the bikeshare systems (whether dockless, docked, or combined), we accessed trip-level data on each bikeshare company's website, which we then aggregated into annual ridership and equipment use data. Bikeshare data typically includes trip time and location but lacks distance; it is also difficult to estimate the actual number of bikes in operation. Both of these factors make it difficult to quantify the energy/emissions impact. The Bureau of Transportation Statistics (BTS) maintains an up-to-date database of active and inactive bikeshare and scooter share systems around the U.S. (BTS 2021b). BTS has made available an interactive map using this data, including how the ridership and number of systems has changed over time (BTS 2021a). It keeps track of the amount of in-service docking stations of each system as well as the companies/services available in the city. The data also contains information on whether the system is only usable in a designated area as well as if the system is inter-city. As of January 2019 (BTS 2021c), BTS also publishes monthly data on the number of docked bikeshare system rides at a station level.

According to NACTO, 87% of all U.S. bikeshare trips happen in just six cities: San Francisco, Boston, Chicago, Honolulu, New York, and Washington, DC (NACTO 2020). This subset of cities may be enough of a sample size to accurately predict future city patterns as it contains a good mix of U.S. city types. Data from these cities could be extrapolated and applied to other cities nationwide. There are some use cases in which a particular city's data may be necessary to obtain, at which point a researcher may have to contact the city directly.

With regard to scooter ridership data, the majority of scooter share providers use MDS, and the scooter companies, Bird and Spin, are members of the Open Mobility Foundation (OMF 2021). Lyft shares more scooter data than TNC data and has fully adopted the MDS format. On the other hand, Uber sued the city of Los Angeles to prevent the mandate of the MDS format in 2018 (Ng 2019).

For the scooter usage data, many of the datasets were provided directly by the city on their websites. It is important to note that many of the scooter datasets come from pilot programs that occurred for only a short amount of time (perhaps less than a year) and/or for only a portion of each city, and so may not be representative of a full-scale deployment. In general, scooter data is available in limited cities and lacks information on user/device characteristics – as such, it is difficult to track the battery capacity and energy efficiency of the scooters. It is also challenging

to quantify the exact number of scooters available for use at any point in time, which can make quantifying the energy impact even more of a challenge.

Figure 1 shows the twenty-one U.S. cities where we have identified available trip-level data for bikeshare and scooter share. All 21 cities have bikeshare data available; scooter share data is available for Austin TX, Chicago IL, Kansas City MO, Louisville KY, Minneapolis MN, and Portland OR, and so these cities are shaded in purple. The size of each bubble represents the total number of trips with data across these two modes. Details about these micromobility services and the available data are shown in Appendix A.

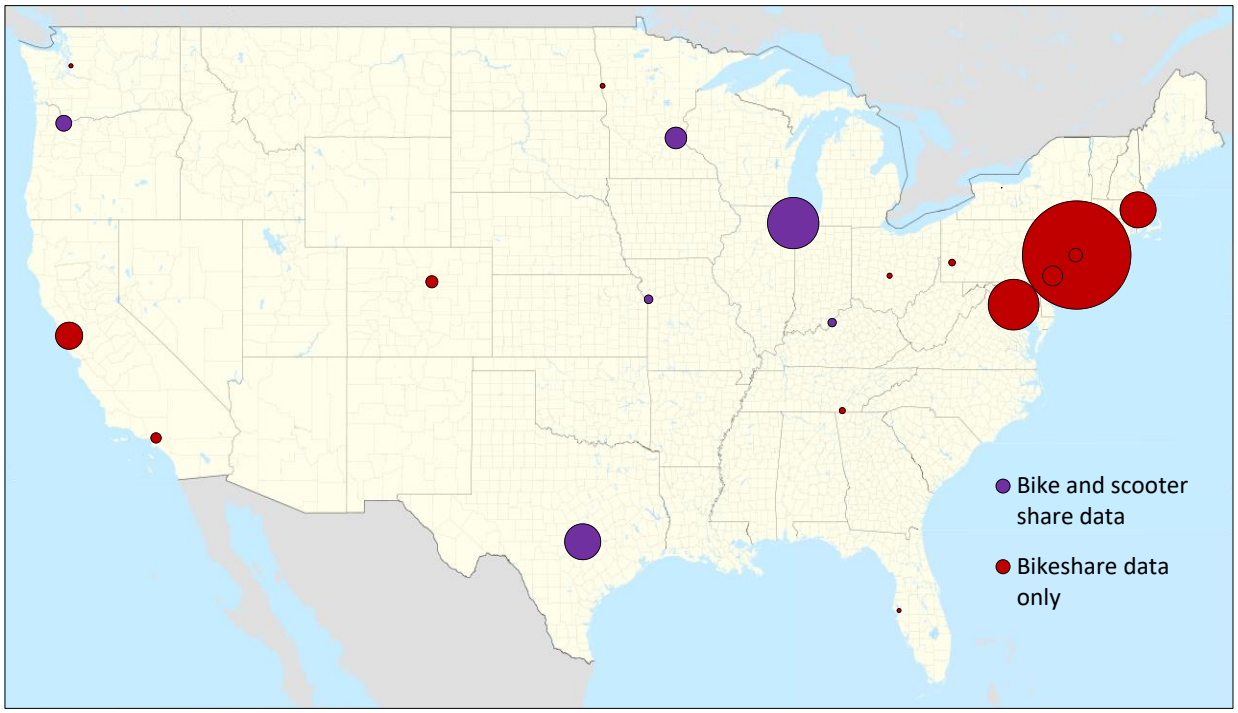

Figure 1: Data availability for micromobility services in 21 U.S. cities

2.2.2 Vehicle Characteristics

Bikeshare systems are diverse in the specification of their vehicles, with multiple service providers and bicycle models. The number of different manufacturers, variants, and bikeshare companies make it very hard to find common characteristics between system. Early bikeshare systems began with pedal-only bikes, but in recent years many cities have added pedal-assisted e-bikes to their systems. This can create confusion for riders in systems that contain both types of bikes due to different fare amounts and riding rules, including with regard to where a rider is allowed to dock the bike at the end of a ride.

According to NABSA, 44% of bikeshare systems offer e-bikes to riders, with 10 million e-rides served in 2020 (NABSA 2021). In New York City, NACTO found that e-bikes are used up to three times as frequently as pedal-only bikeshare bikes (NACTO 2019). Similarly, NABSA found that e-bikes are ridden 60% farther than pedal bikes (NABSA 2021). Federal law defines a low-speed electric bicycle as having an electric motor of less than 750 watts and maximum

electric-only speed of 20 miles per hour (Shinkle 2021). The e-bikes for the largest bikeshare systems in the country all have similar characteristics: they have pedal-assist to aid acceleration up to 15 to 20 miles per hour, and a battery and electric motor which, together, add approximately 20–25 pounds of weight. E-bikes typically have batteries on the order of 0.5–0.8 kilowatt-hours for a range of 20–50 miles (Cynergy E-Bikes 2021).

Table 2 lists publicly available specifications for the scooters that are available in major scooter share systems nationwide. In general, these vehicles have a maximum speed of approximately 15–20 miles per hour, and motor power ranging between 250 and 500 Watts. The all-electric range is more variable than for e-bikes, ranging from under 20 miles to up to 60 miles on a single charge. Typical battery capacities are on the order of 0.5 kilowatt-hours. No scooter share companies provide information on the quantity of each variant that is present in a city's system nor do they provide information on which variant was used in a given trip. The table does capture a majority of the scooters on the streets at present day. Table 2 presents the number of U.S. deployments, as published by each company, either on their website or in official regulatory applications with specific cities, including both municipalities and on university campuses. Cities may separately count scooter share programs with multiple scooter companies, and so the sum number of deployments will somewhat overestimate the number of locations with scooter share programs. Beyond the information in Table 2, Anderson-Hall et al. (2019) and Dias et al. (2021) have published information about which specific companies operate in specific cities.

Table 2: Scooters Used in Scooter Share Programs Nationwide

Scooter Company	Model Name	Battery Capacity	Max Range (Miles)	Max Speed (mph)	Motor Power (W)	Seat	# U.S. deployments
Bird	One	12800 mAh, 473.6 Wh	30	18	300	No	81
Bolt	One		25	15		No	33
	Two		37			No	
	Chariot		25	15		No	
	Gotcha		18	15	250	No	8
	OjO Cruiser		50	20	500	Yes	3
Hopr	HOPR-S		15	15	450	No	2
Lime	Lime-S		37	14.8	250	No	72
Link	E-Scooter V2.0	986 Wh	60	15	500	No	18
Segway-Ninebot	Lyft MAX	551 Wh	37.5	15	350	No	8
Skip	S3	615 Wh	35	18	350	No	4
Spin	S-100T		37		500	No	61
Razor	Share	8.25 Ah, 301 Wh	20	15	350	No	8
	EcoSmart	12 Ah, 432 Wh	20	15	350	Yes	4
Veo	Astro Vs3 / Vs4	14 Ah, 672 Wh	43	15	350	No	26
	Cosmo VE1		55	15	500	Yes	
Wheels	Atlas		25	18	350	Yes	15

Bird and Lime are the two most commonly deployed scooter brands in the United States, offering vehicles having a conventional scooter form factor with a vertical handlebar extending from a flat skateboard-like base. Bolt, Link, and Segway-Ninebot also have models with this style. Bolt has the One and Chariot models, and also manages the Gotcha scooter and the seated OjO cruiser after acquiring these companies. To increase accessibility, several companies offer both standing- and seated-versions of their scooters, including Razor and Veo. Unlike the other vehicles listed in Table 2, the Wheels Atlas has a form factor more similar to a bicycle, with stationary pedals rather than the flat base of the other scooters.

2.2.3 Company and Community Connections

Many companies have connections across the TNC and micromobility sectors, and the overall market is trending toward consolidation. Lyft owns Motivate, which owns or operates the five largest bikeshare systems in the United States, while Uber previously owned Jump (Walker 2019; NACTO 2019). Lime purchased Jump from Uber, and these two companies now collaborate in micromobility (Wilson 2020). Lime and Bird are the two largest scooter share companies in the U.S. (Wilson 2020). Gotcha and OjO merged in 2020 and were subsequently acquired by Bolt in 2021 (Korosec 2021). Bird purchased Scoot in 2019 (Dickey 2019a) and Helbiz acquired Skip in 2020 (Teale 2020). Lyft uses scooters supplied by Segway in its scooter share programs (Dickey 2019b). Spin was previously a subsidiary of Ford Motor Company, but was purchased in March 2022 by TIER Mobility, the largest micromobility provider in Europe (Spin 2022). Since then, Lyft made plans to partner with TIER to make Spin scooters accessible on the Lyft app, and to acquire PBSC Urban Solutions to bring its footprint to 50 cities worldwide (Bellan 2022).

In general, bike share systems are either run entirely by a city/county transportation authority or in a PPP with an established company or institution such as a college campus. For docked bikeshare systems, sidewalk or street space must be specifically allocated for the extra bike racks and computerized vending systems are needed for bike rental. Dockless bikeshare and scooter share systems require less infrastructure. Some prominent scooter using cities like San Diego also assign city street space to scooters, usually in the form of painted “scooter pens” to keep scooters which are not in use away from blocking the sidewalk. If trip data is available for a scooter share system, start and stop locations are almost always anonymized due to the potential for linking an exact trip location to a specific person.

2.3 CAR SHARE SYSTEMS

Compared to TNCs and micromobility, there is far less data about carsharing available. Cohen and Shaheen (2016) noted 22 operators of round-trip carsharing programs in 51 metropolitan areas in the United States in 2015. They also noted the presence of one-way carsharing programs in 13 cities; however, in 2020, the companies operating these services shut down their North American operations (Murray 2021). Zipcar (2021) noted that the average trip distance and length of trips in its system is 50 miles over 8 hours; this relatively long distance is attributed to use of walking, biking, or transit for short trips. Seattle publishes aggregate data of monthly usage of the GIG carshare system, showing over 300,000 trips from June 2020 through 2021, with an average length of 12.3 miles and 133 minutes (City of Seattle 2022). BlueLA is a fully-EV carsharing program based in Los Angeles, California (Blink Mobility 2021).

Summarized data from the Los Angeles Department of Transportation indicated 1.3 million miles across 63,000 trips from September 2020 to July 2021, with more than half of trips made by low-income users with subsidized membership costs (Estrada 2021).

Electric mopeds are often marketed as "scooters", but they require a driver's license and use of a (supplied) helmet in most jurisdictions and are more akin to a carshare program than the scooters described in Section 2.2. Typical electric mopeds in use worldwide have a range of 40 to 80 miles, battery capacity between 1 and 3 kWh, and a power output from 2 to 4 kW (Invers 2021). Revel uses the Niu electric moped with a 2.4 kWh battery and a 60-mile range in four cities (Randall 2019). Lime also uses the Niu electric moped with a range of 87 miles for use in Washington, DC (Hawkins 2021; Lime 2021). The GenZe 2.0 electric scooter with a 1.6 kWh battery with a range of 30 miles is used by Scoobi for operations in Pittsburgh and Austin (Partain 2021), and was previously used by Postmates for delivery service and in San Francisco by Scoot (Zart 2017). Revel originally used the Torrot Muvi with a 2.4 kWh battery and a range of 45 miles (Toll 2018); this model was also used by Muving in Atlanta (Simon 2018). The only known trip-level data comes from the City of Austin (2022), which notes that 91,000 trips on Revel mopeds were taken from 2019 to 2020 and several hundred trips on Scoobi mopeds occurred in late 2021. The San Francisco Municipal Transportation Agency also tracks ridership on a monthly level, reporting 228,000 rides taken in 2021 (SFMTA 2022).

For peer-to-peer carsharing, there is little detailed information. Shaheen et al. (2018) published a report documenting consumer perceptions of peer-to-peer carsharing. Turo has noted a total of over 13 million days of rentals since its founding (Haddad 2020) and Getaround has noted 5 million trips (Getaround 2021), but neither of these companies share more specific details than the total number of rides.

3 GENERAL USAGE TRENDS IN NEW MOBILITY TECHNOLOGIES

Given the availability of ridership data, we were able to perform analyses to quantify how new mobility services are being used. Section 3 will present general usage trends nationwide, while Section 4 will focus specifically on ridership in Chicago, the largest city in the United States with TNC, bikeshare, scooter share, and transit data all publicly accessible.

To examine usage trends over time and in cities with various demographic and other characteristics, we compared TNC ridership for thirteen American cities for years for which the data is available: New York NY, Los Angeles CA, Chicago IL, San Diego CA, San Jose CA, Austin TX, San Francisco CA, Seattle WA, Boston MA, Fresno CA, Sacramento CA, Worchester MA, and Springfield MA. Cities were selected for this analysis on the basis of having a population over 500,000 people and at least one year of travel data or by having a population over 150,000 with at least three years of data available. Some results are shown in Figure 2. To calculate per capita ridership values, we used city population data from the U.S. Census Bureau (2021). As the figure demonstrates, there is wide variation in TNC usage across the country; some cities average less than ten rides per person per year, while others average nearly 100 annual rides per person. Some cities may have higher per-capita ridership due to tourist usage of TNC services. We use the per capita values instead of the total usage values in order to account for differences in usage due to large population differences between these cities. Data from California is for fiscal-year 2020 rather than calendar-year 2020, i.e. from October 2019 through September 2020. For all cities that have multiple years of data, the results demonstrate continued ridership growth through 2019. Due to COVID-19, however, ridership decreased in New York, Chicago, and San Francisco in 2020.

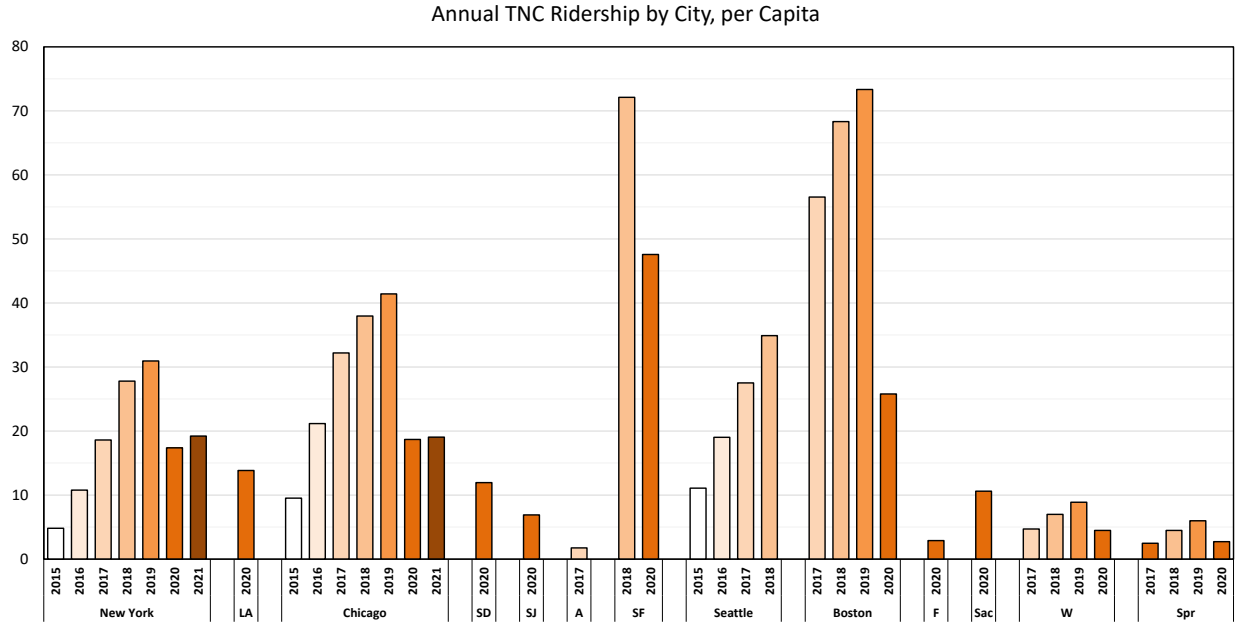

Figure 2: Per-capita TNC ridership for thirteen American cities

The total ridership in TNCs may be correlated with the availability of vehicles. This is explored in Figure 3, comparing the ridership and number of TNC drivers in six cities. The only cities found to openly share trip-level TNC data were Chicago IL, New York NY, and Austin TX; however, reports have been published with aggregate statistics for San Francisco CA, Seattle WA, and Washington DC with sufficient information to also plot here (DC 2019; Leisy 2019; SFCTA 2019). In Figure 3, each point represents one year of ridership data for each city, normalized by the city population. The vertical axis represents the total rides taken in that year within the city limits. Note that less than one year of data is available for Austin, San Francisco, and Washington; these three cities have had their total rides normalized to a full year. Because the data is from June for Washington, and ridership is generally higher in summer, this may lead to an overestimate of annual ridership. It is also worth noting that in all cases, Figure 2 and Figure 3 likely overestimate the rides taken by residents of the city, because visitors to the city and residents of nearby suburbs who use TNCs are both included in this data. The horizontal axis represents the number of rideshare drivers or vehicles registered with the city, though methodology is not identical across all cities: New York and Chicago show the average number of drivers who accepted a ride each month; Washington DC shows the day with the highest distinct number of drivers; Seattle includes those authorized to give rides even if they did not actually drive in that year, and includes those registered in all of King County (Leisy 2019); San Francisco shows SFCTA's estimate of registered drivers, but the San Francisco Treasurer's Office estimated more than twice as many total drivers including those who did not register with the city (SFCTA 2019). In Figure 3, the size of each bubble represents the city population, and 2020 and 2021 data are faded, highlighting anomalies resulting from COVID-19.

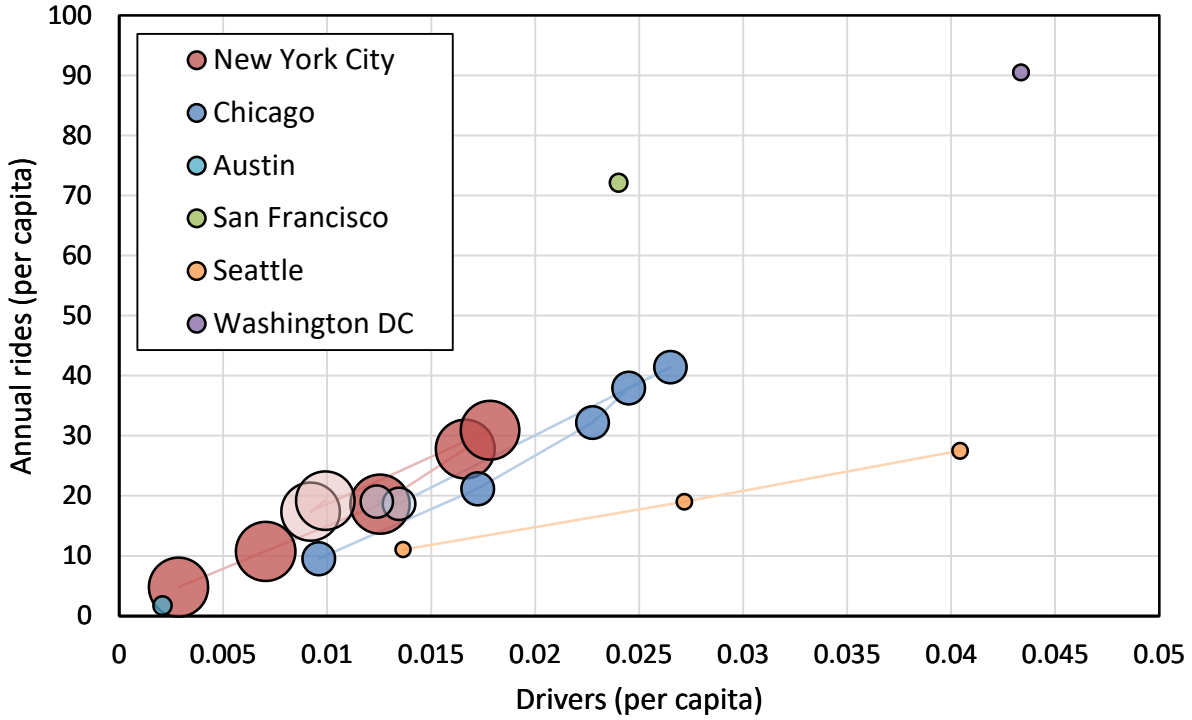

Figure 3: Per-capita TNC ridership compared with number of TNC drivers. Bubble size represents city population. 2020 and 2021 data are faded, highlighting COVID-19-induced anomalies.

Figure 3 shows that each of these cities show a generally similar trend, where the number of rides and number of drivers change in tandem. This shows both that more drivers will consider driving when the system is popular and that drivers will stop driving if overall ridership is reduced. For both Chicago and New York, there is a typical average of approximately 1,600 rides per driver per year. In Chicago and New York, both ridership and the number of available drivers regressed in 2020. Total ridership remained similar in 2021.

Using data from California, we examined spatial variation in per-capita ridership. Mapping usage across the state at the zip code level, shown in Figure 4, we find that ridership is higher in the major urban centers along the Pacific coast – the San Francisco Bay Area, Los Angeles, and San Diego – with over 10 rides per person in fiscal year 2020 throughout these urban areas. Ridership in smaller cities throughout the state is higher than in the surrounding suburbs and rural areas, with per capita ridership generally in the range of 4–10 for the year. Many rural zip codes recorded no ridership in that year, shown in dark purple. The most rural locations in the state (mostly in the mountains and in the desert) have no zip code associated with them, and are shown in gray.

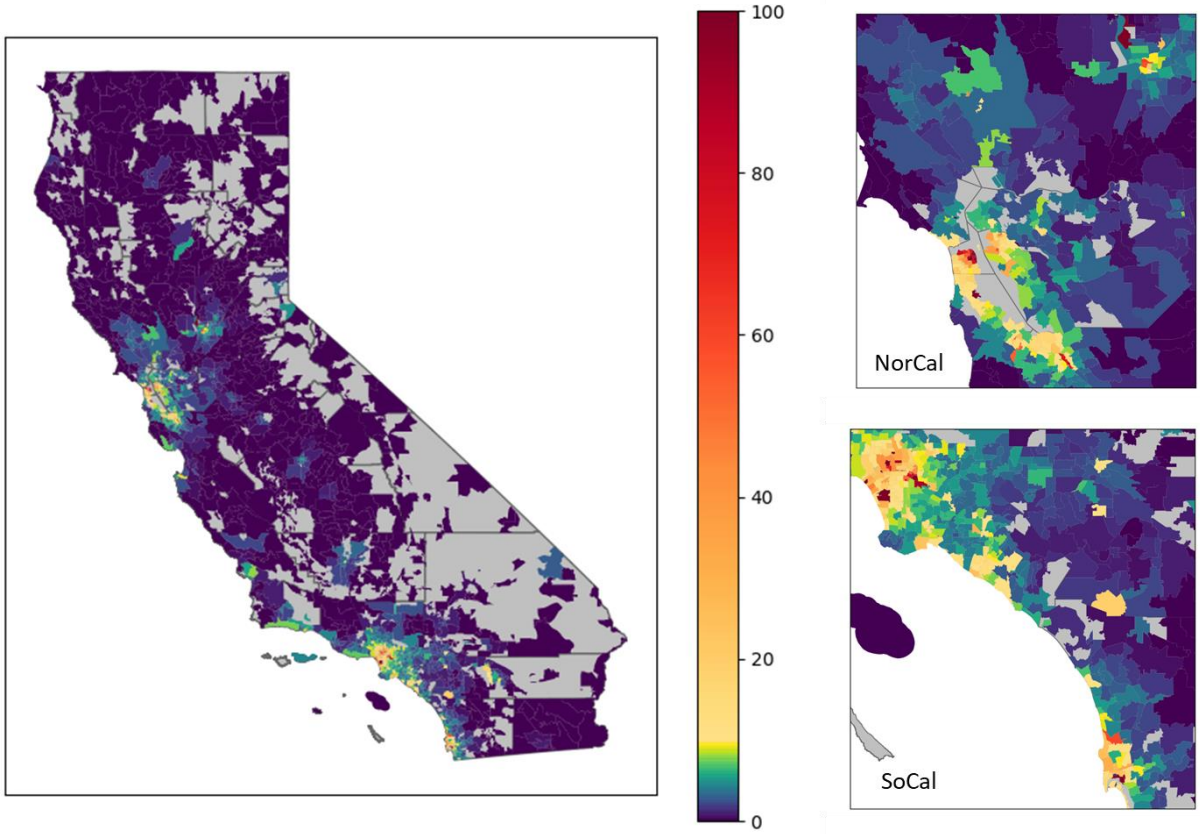

Figure 4: Per-capita ridership for TNCs in California, October 2019 to September 2020. Locations with no recorded ridership are shown in gray with county boundaries as black lines. Insets are for northern and southern California (labeled as NorCal and SoCal, respectively).

Examining the usage trends for bike and scooter share systems, NACTO (2020) found a large increase in travel from 2018 to 2019, with 60% more ridership, the majority of that increase coming from the growth in scooter share systems. This is reflective of upwards trends in national ridership from both scooter share and bikeshare systems. As of 2021, according to the Bureau of Transportation Statistics (2021a), there are nearly 8,000 bikeshare docks in the U.S., and the data for nearly 6,000 of those stations is publicly available. Fourteen cities out of the 66 total with active U.S. docked bikeshare systems as of 2021 have shared trip level data, along with six more cities with historical data that is no longer being updated. Six U.S. cities release scooter share system trip level data out of a total of 92 U.S. cities with scooter share systems available. These few cities that share data make up a large percentage of the ridership and usage.

Smaller micromobility systems saw a noted decrease in ridership. The number of micromobility systems increased by 45% in 2019; however, due to the COVID-19 pandemic, many bikeshare and scooter share systems were forced to downsize or outright close permanently due to financial strain and lower ridership. This has led to a significant decrease in the availability of micromobility options in many cities around the U.S. The NACTO report also found that the majority of micromobility ridership growth came from cities that already had large existing micromobility systems. The largest bikeshare systems by ridership are the systems based in Boston MA, Chicago IL, Honolulu HI, New York NY, the San Francisco Bay Area in CA, and Washington DC. The largest scooter share systems by ridership are found in Atlanta GA, Austin TX, Dallas TX, Los Angeles CA, San Diego CA, and Washington DC.

Figure 5 shows per capita ridership of bikeshare and scooter share for 25 cities in the United States. Lighter bars represent earlier years, dating back to 2010 for bikeshare and 2018 for scooter share. We used the trip-level data to calculate annual totals by city for bikeshare, again on a per capita basis to more directly compare across cities with very different populations. For scooter share, we included cities publishing trip-level data and also cities reporting multiple years of aggregated ridership data for comparison, specifically Atlanta, Baltimore, Milwaukee, Sacramento, San Francisco, and Washington. The set of cities offering bikeshare and scooter share data are shown in Appendix A. Bikeshare data for Austin, Chattanooga, and Louisville and scooter share data for Atlanta and Washington in 2021 are estimated in order to account for incomplete annual data. As with TNC usage, there is a wide range in per capita usage, ranging from systems with less than 0.1 rides/year to over 5 rides/year. Given the requirement for fixed infrastructure, a bikeshare system may not serve the entire city, and per capita normalization for the full city population may underestimate the utilization of the micromobility system. For example, in Los Angeles, Columbus, and Tampa Bay, the bikes service a relatively small area of the populated area of the city. Conversely, in Washington DC, Boston, and San Francisco, these bikes are used widely by commuters across these cities. Prior to 2020, most cities exhibited steady growth in the ridership of public micromobility systems. Most cities regressed in total ridership in 2020, but rebounded in 2021, with several cities setting new records for ridership.

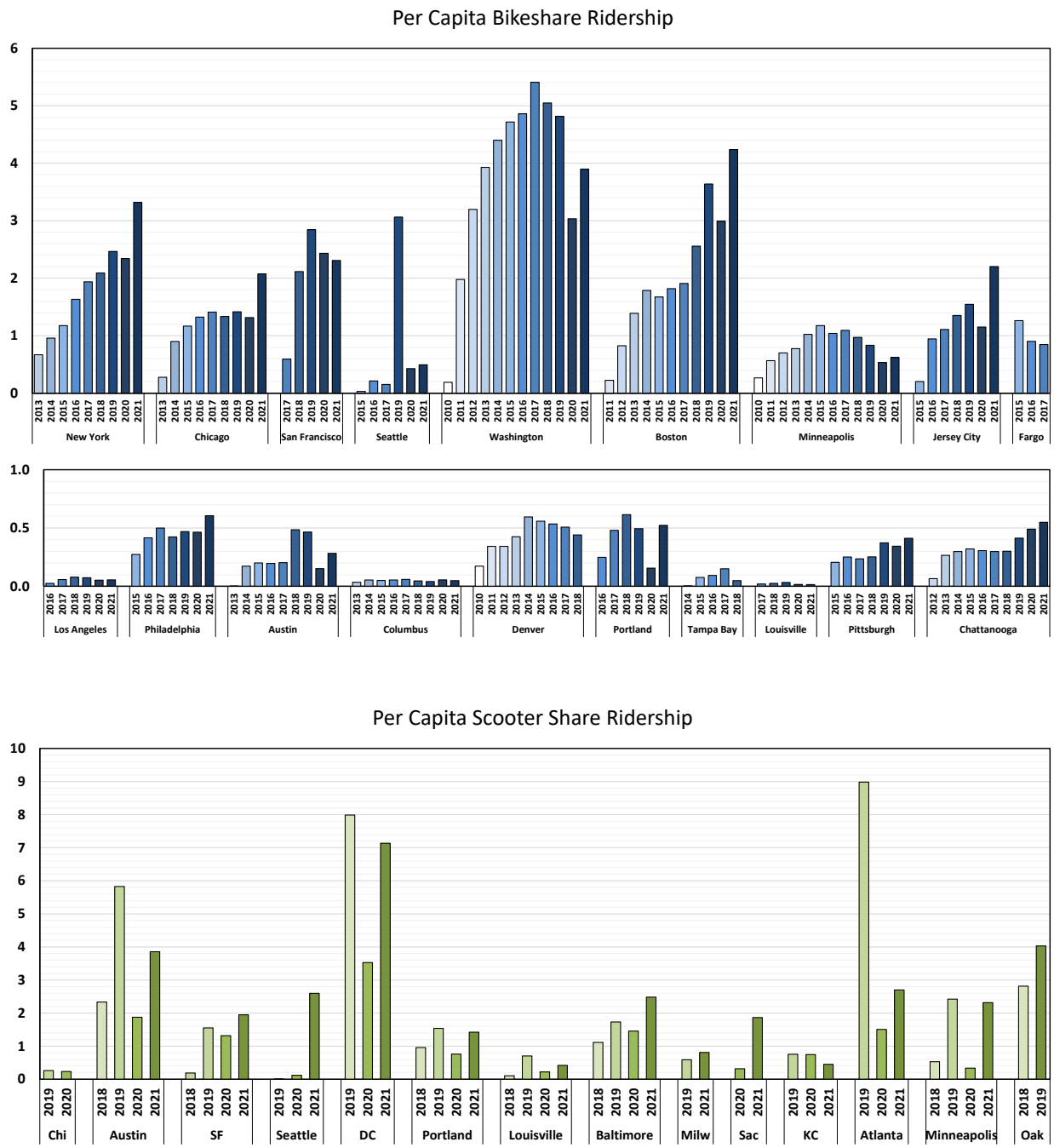

Figure 5: Trends in bikeshare and scooter share ridership over time for 25 U.S. cities. Lighter bars represent earlier years.

4 SHARED MOBILITY USAGE IN CHICAGO

In order to perform a more closely-focused analysis of new mobility technology use, we selected a single metro area, the Chicago area, examining usage trends by various demographic and other factors there. The aim of this approach is that, by examining by demographic factors and the like, we can then potentially expand some of our findings to other areas/cities with similar demographic or other characteristics. For our analysis, we selected the Chicago area primarily because it is the only U.S. city that has extensive trip-level usage data available for all three mobility types, and because its TNC and bikeshare data is updated regularly.

The data in the following section for the three mobility types come from three different sources. For the TNC data, we used the trip-level TNC data provided by the city of Chicago (Chicago Data Portal, 2022c). This dataset contains trip-level data for all TNC trips that started or ended within Chicago city limits between November 2018 and December 2021. Due to privacy issues, rather than giving a specific latitude and longitude, location data has been presented either by census tract (866 in Chicago) or by Chicago Community Area (77 in Chicago), with the level of resolution for a given trip being determined by the city out of privacy considerations. If there were two or fewer unique trips in the same census tract and 15-minute time window, the census tract was omitted for these trips (City of Chicago, 2019). Although the census tract data is more limited, it allows for analysis at a finer geographic size and the dataset is still sufficiently large for analysis. As such, we used all trips that have census tract information for our geospatial analysis, and used all trips for our temporal analysis (because all trips provide time/date information).

For the bikeshare data, we used the trip-level data provided by Divvy, the primary bikeshare company in Chicago. Divvy provides trip-level data from June 2013, when they first began service, through December 2021 (Divvy 2022). In July 2020, Divvy introduced electric assist bicycles (e-bikes) to their fleet; these are the only bikes that are able to be used in the dockless form. For the docked trips, which start and end at a Divvy docking station, Divvy provides the exact station for that trip, including latitude and longitude information (Divvy 2022). However, due to potential privacy concerns for the dockless trips, Divvy obscures the location data for these trips. For a trip start/end that does not occur at a docking station, Divvy provides the latitude and longitude to two decimals, or approximately 1 km, which is not sufficient to determine the census tract. For direct comparison with the other mobility types, which provide location information via census tract, we aggregated all trips by census tract rather than by individual station. Therefore, our quantitative analysis by census tract only includes docked trips.

For the scooter share data, we used trip-level data provided by the city of Chicago from their 2019 and 2020 pilot programs (City of Chicago 2021). Each pilot ran for 4 months, from June 15, 2019 to October 15, 2019 and from August 12, 2020 to December 12, 2020. In the 2019 pilot, scooters were only allowed to operate in a relatively small area west of downtown, while the 2020 pilot covered most of the city except for the downtown Loop. Again, due to privacy issues, location data has been obscured down to either the census tract or Community Area level; as with TNCs, we selected trips that have census tract information for our geospatial analysis, and used all trips for our temporal analysis (because all trips provide time/date information).

The city of Chicago provides trip-level TNC data going back to November 2018 (Chicago Data Portal 2022c); however, it also provides monthly estimated trips by driver (Chicago Data Portal 2022b) and by vehicle (Chicago Data Portal 2022d) in separate datasets, dating back to February and March 2015, respectively. The reporting is done on a monthly basis, and the totals are estimates, due to imperfections in the matching process. We found that the 'Drivers' dataset more closely aligns with the trip-level dataset than does the 'Vehicles' dataset, as shown in Figure 20 in Appendix B.

4.1 GENERAL USAGE ANALYSIS

When counting the number of trips in each census tract, we can either use the start or end location of each trip. (Adding both trip starts and ends could lead to double counting the total number of trips.) In this work we arbitrarily decided to use the trip start location, though the difference between aggregated trip start and end data is very minimal, as shown in Figure 21 in Appendix B. Henceforth in this paper, when we indicate calculations of the number of trips or trips per capita, geospatially, we are referring to the start location of each trip.

To get an initial sense of the usage trends for each of the mobility types, we have provided maps showing the distribution of usage across the city, on a per capita basis. These are shown in Figure 6, for TNC trips from November 2018 through December 2021, bikeshare trips from June 2013 through December 2021 and scooter share trips from August through December 2020. We consider aggregate usage of each mode on a per capita basis (dividing by the population of each census tract) to account for differences in population across the different census tracts. Note that because of different data timeframes, the scale is not directly comparable across all three modes. For all three mobility types, the highest usage areas are located near downtown. There is also high usage of all three modes in the Hyde Park/University of Chicago neighborhood. These areas tend to be higher income, as will be explored in greater detail in Section 4.2. For TNC, there is also very high usage at O'Hare Airport (in the northwestern corner of the city) and Midway Airport (in the southwestern corner of the city), though because these census tracts have zero population, they have undefined per-capita usage. We denote these tracts in gray with red hatching and do not include them in our demographic quantification.

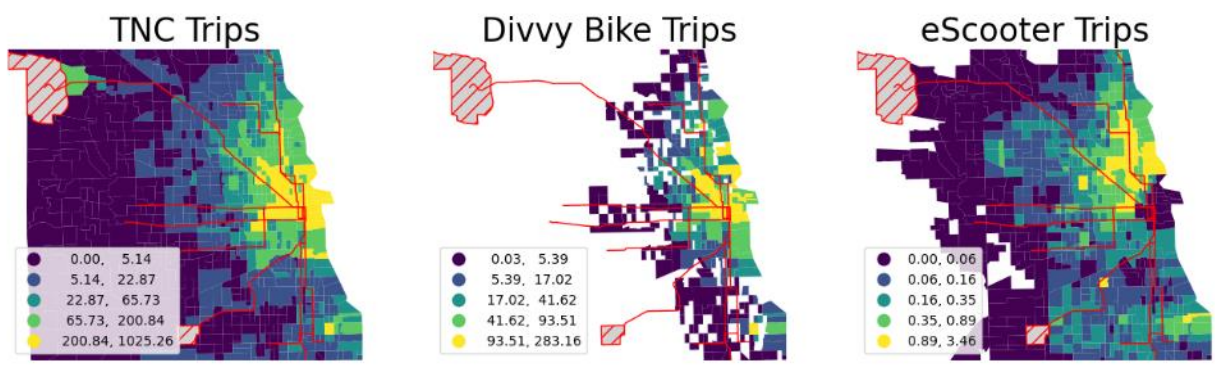

Figure 6: Number of trips per capita (range), by starting location, within Chicago for bikeshare, scooter share, and TNC. Tracts with no population at the airports are denoted in gray and red.

We begin with a high-level analysis, examining the high mobility usage areas in the city. The map in Figure 7 shows the census tracts that are above the 90th percentile in trips per capita

by TNCs, bikes, scooters, or some combination of the three. Here, the scooter pilot data only includes data for the 2020 pilot, as this covered the majority of the city; data for the 2019 scooter pilot is shown in Appendix B. When Figure 7 is compared with the income data displayed in Figure 9, below, we can see that high shared mobility usage is centered in high income areas, despite these areas also having good public transit accessibility. Areas north of downtown tend to have high usages of TNCs and at least one micromobility mode. The downtown Loop exhibits high usage of TNC and bikeshare. The 2020 scooter pilot excluded the downtown areas of Chicago, which explains the simultaneous low scooter share and high bikeshare ridership (shown in light blue).

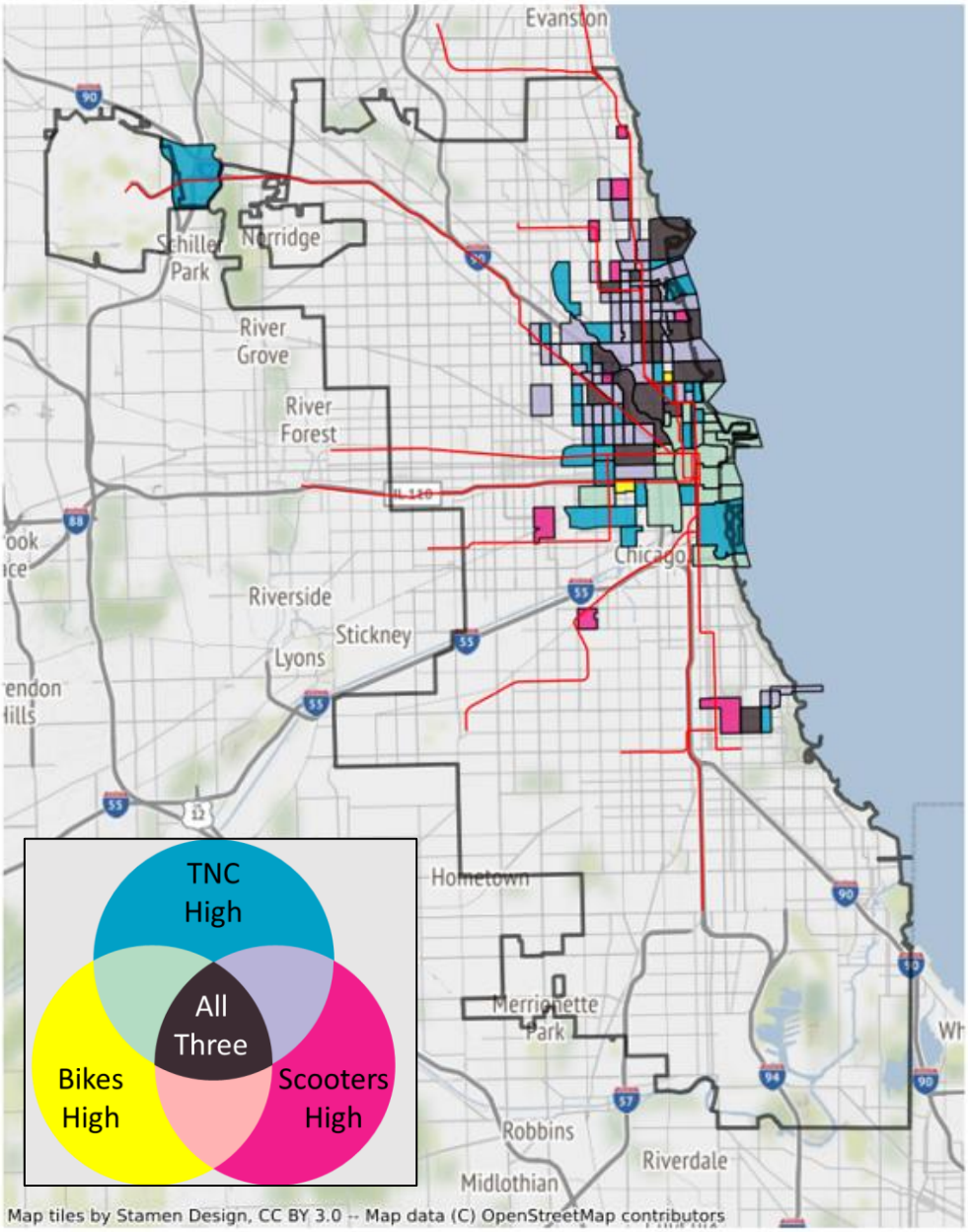

Figure 7: Locations of highest per-capita usage for TNC, bikeshare, and scooter share in Chicago

The city of Chicago shares information about the number and type of vehicles owned by residents. By far the most common vehicle owned is the Toyota Camry, with approximately twice as many trips as the second-ranked Toyota Corolla. The hybrid Toyota Prius is the third ranked vehicle. In general, the vehicles are smaller than the average vehicle in the United States; the top ten ranked vehicles are all cars and the Toyota RAV-4 is the most frequently used sport utility vehicle, ranked 11th in usage in Chicago. The vehicles in Chicago are also disproportionately newer than the average vehicle. Analysis of vehicles registrations from Experian Automotive (2021) shows that the average age of all vehicles registered in Cook County is ten years old, while the trip-weighted average age of registered ride-hailing vehicles is 1.5 years younger. This analysis aligns with information from Wenzel et al. (2019), who found TNC vehicles were on average more fuel efficient than comparable light-duty vehicles in Austin, Texas.

To examine the potential impact of TNC on transit ridership, we compared monthly TNC usage with monthly transit boardings (light rail and bus) through November 2021 provided by the Chicago Transit Authority (CTA) (Chicago Data Portal 2022a). In order to examine the relationship between TNC and transit over the longest time period possible, we used the 'drivers' TNC data rather than the trip-level dataset. We divided each month's usage by the city population in each year (Census Bureau, 2021) to account for diminishing population over time to obtain a per capita value. We used the average daily ridership rather than a total monthly number to account for differences in the number of days in each month.

Trends in ridership for both TNC and public transit are shown in Figure 8a. TNC usage increased in nearly every month from 2015 through mid-2018. In 2019, TNC exhibited smaller year-over-year increases. From 2015 to 2019, transit ridership decreased by about 10%, from around 0.54 trips per day to around 0.47 trips per day per person. Both TNC and transit had drastic decreases in March and April 2020 due to the COVID-19 pandemic, though both modes exhibited rapid growth in the following months.

For 2015 through 2019, TNC trips in Chicago were negatively correlated with public transit ridership on an annual basis. This is shown in Figure 8b, where the solid black line shows the regression curve for all years' data and has a negative slope. However, each transportation mode has its own unique seasonal trends within the year. Transit ridership in Chicago historically increases from January through late summer and decreases in the winter. TNC ridership trends in Chicago have been dominated by the rapid growth from 2015 to 2018 (and again after the COVID-19 pandemic). However, these data exhibited seasonal variations in 2018 and 2019 as growth tapered off. When looking at each year individually, we find a temporal component to the correlation between TNC and transit usage, where ridership was negatively correlated in 2015 and 2016, uncorrelated in 2017 (flat green line), and positively correlated in 2018 and 2019. There is a wide degree of uncertainty in these correlations; the 95% confidence interval for each intra-annual correlation (shown as shaded areas) spans positive and negative slopes. It is therefore important to consider how the choice of timescale can change the correlations between TNC and transit ridership. Sokolov (2021) has conducted spatial and temporal regression analysis between TNC and transit usage and found no significant change in transit ridership data over time for the observed period in Chicago.

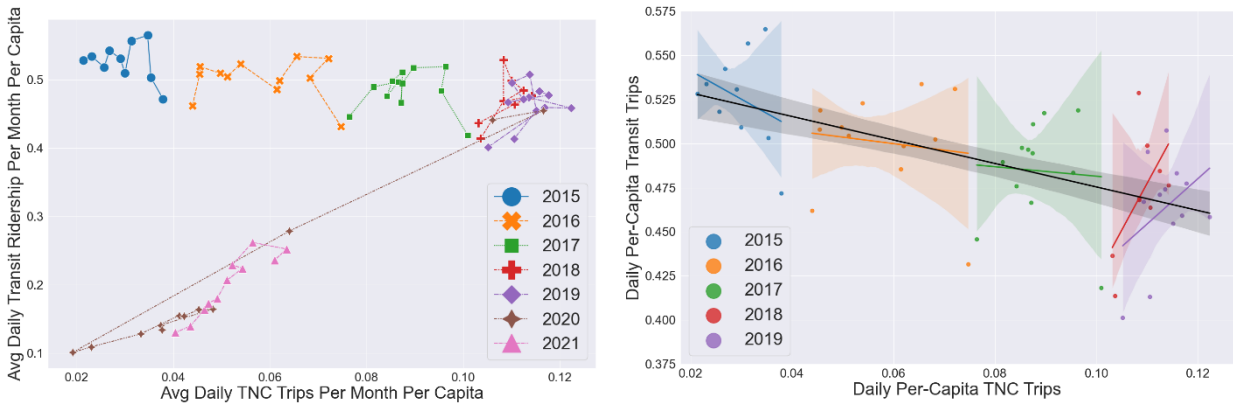

Figure 8: Comparison of TNC ridership and transit ridership per month in Chicago, 2015 to 2021. Left: Month-by-month trends in ridership. Right: Correlations between transportation mode (The shaded areas show the 95% confidence interval for each of the regression curves.)

4.2 DEMOGRAPHIC USAGE ANALYSIS

Chicago is the third largest city in the United States by total population and is the fifth densest city in the United States. Like many large cities, Chicago's city core anchors a large metropolitan area, while the population density within the city follows a pattern typical of many cities, with a higher population nearer the downtown area, and generally decreasing density as distance from the city center increases. This can be seen in Figure 9a. The demographics of Chicago are such that the wealthiest neighborhoods are downtown and in the North side and the lowest-income neighborhoods are on the South and West sides, as shown in Figure 9b. The low-income communities on the South and West sides are often considered at risk communities with regard to many metrics related to energy equity and environmental justice (EE/EJ), as can be seen, for example, using metrics from the EJSCREEN tool from the U.S. Environmental Protection Agency (EPA, 2021).

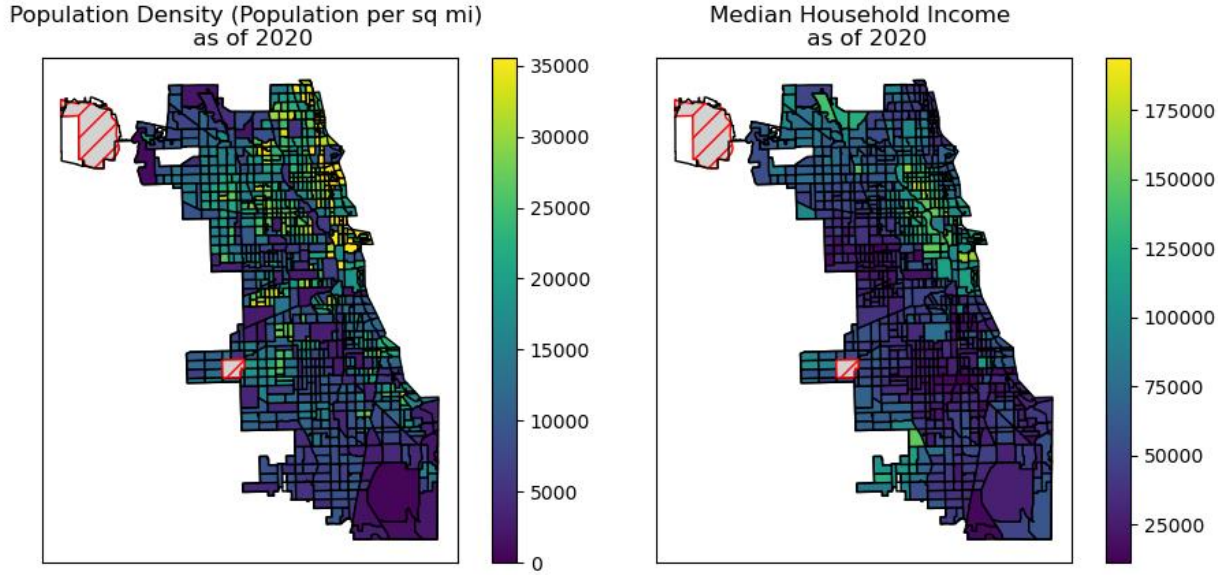

Figure 9: Left: Population density for Chicago. Right: Average income by census tract for Chicago.

To examine mobility usage trends by various demographic characteristics, we utilize data at the census tract level from the U.S. Census Bureau. Median household income and number of household vehicles data comes from the 5-year 2019 American Community Survey (Census Bureau 2020). The Census Bureau provides the percentage of households in each tract with 0, 1, 2, and 3+ vehicles. To calculate an average number of household vehicles in each tract, we calculate a weighted average number of vehicles; for the 3+ vehicles bracket, we assume that all households have 3 vehicles.

4.2.1 TNC Usage in Chicago Communities

The boxplot in Figure 10 shows the variation in TNC trips per capita for a given income bracket, split into four quantiles for the number of household vehicles available. Each census tract in Chicago is included as one data point in the following boxplot. Each boxplot shows the median (horizontal line) and spread of the TNC trips per capita for all census tracts within the indicated income bracket along the horizontal axis and the mean household vehicles bracket, indicated by the four colors. Note that an inset is included for the lowest income brackets to better show the variation in the data. In general, census tracts with higher household income and fewer household vehicles tend to have higher TNC usage per capita. High-income households with fewer than one vehicle are the highest single group, averaging nearly 1.5 TNC rides per person per day. We also observe that the highest income group has the biggest variation in usage, and that in general, the higher the income group, the more the variation in TNC usage.

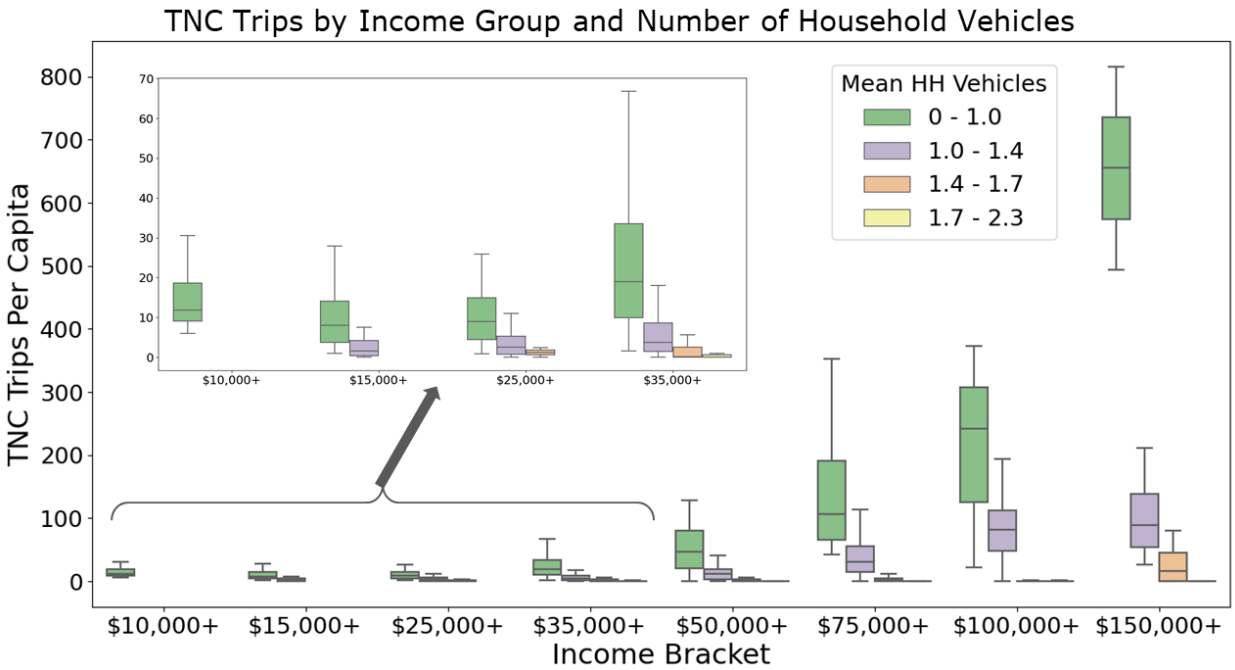

Figure 10: Distribution of TNC ridership by household income and vehicle ownership

Geographically, TNC ridership in the city of Chicago is shown in Figure 11, alongside the number of household vehicles. The dashed black lines indicate the city limit. Downtown and the North side generally have high ridership and high incomes, but a comparatively low number of vehicles. The South and West sides have a similarly low number of vehicles, but much lower average incomes and lower TNC ridership. The suburbs generally have low TNC ridership and a high average number of vehicles. A map that represents ridership and income together can be found in Appendix B.

Interestingly, there are isolated, comparatively high usage areas located on the South side and in near the Northwestern corner of the city in Rosemont. These two areas are at the end of the southernmost (Red) "L"/light rail line (note that purplish-blue and, respectively, red lines indicate rail transit lines in the maps), and the westernmost blue subway line. Figure 11 highlights these specific areas by solid black ovals. The location on the South side is especially interesting because this is located in a lower income community, as well as one with lower-than-average household vehicle ownership, as indicated by the second map. As such, we investigate all TNC trips beginning or ending in either of the two South side census tracts at the end of the light rail line (within the circle), henceforth referred to as South side interest area, in greater detail. The blue-line location in Rosemont is a designated park-and-ride station for commuters, and adjacent to O'Hare airport; due to these conflating factors, we do not focus analysis on this location.

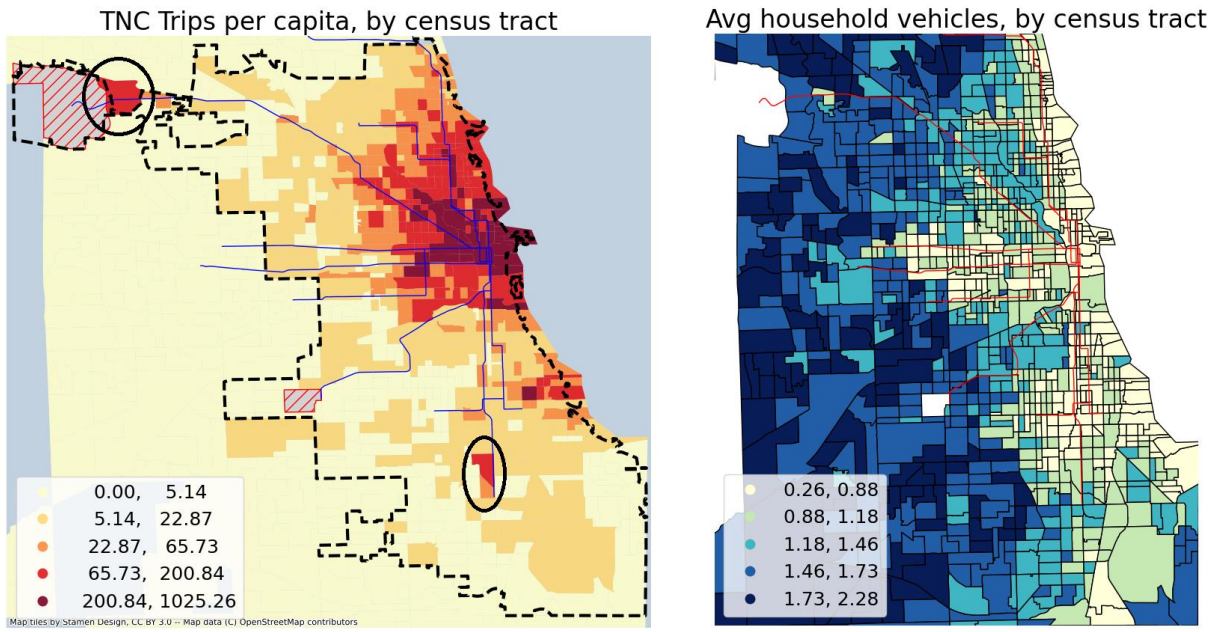

Figure 11: TNC ridership per capita and number of household vehicles in Chicago. (See text for discussion of the areas within the black ovals.)

We first examine the time of day when the trips originating and ending at the South side interest area are occurring. As shown in the histograms in Figure 12, in this lower income community, TNC is used most frequently in the morning to get to the rail station and used most in the evening to depart the rail station.

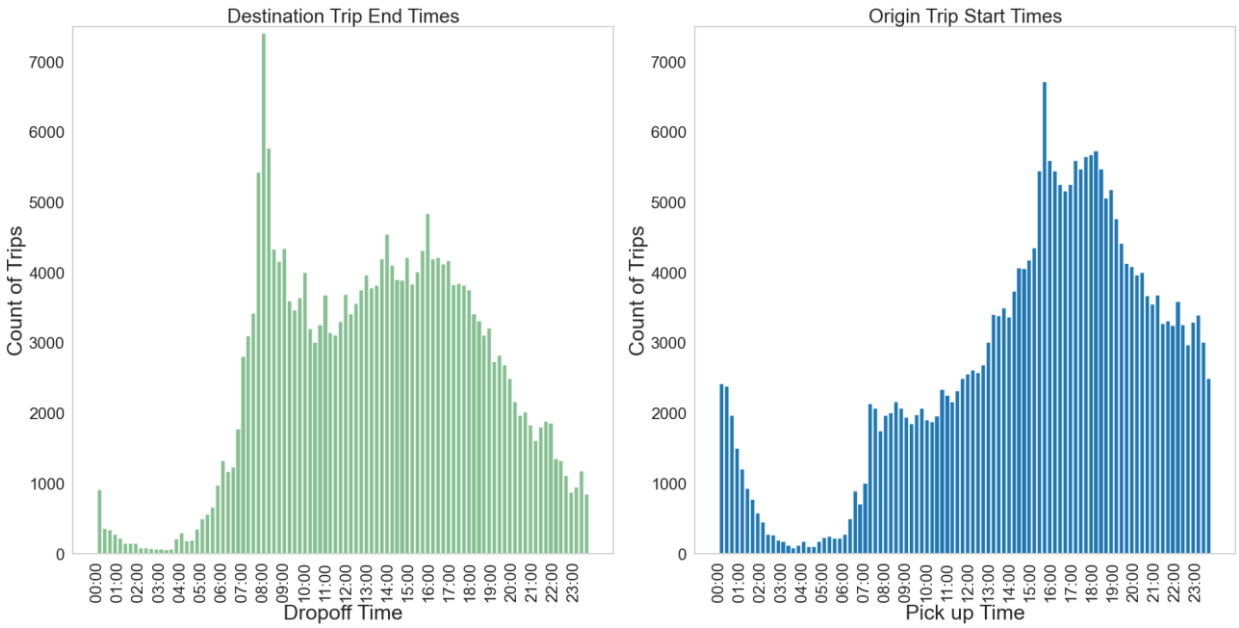

Figure 12: Time of day of TNC travel in Chicago South Side census tract near subway line

The presence of this high TNC usage area at the end of the southernmost CTA light rail station might suggest that people are using TNC as a first-mile, last-mile solution to connect to public transportation. It may be that the nearby lower-income community is using TNC, or potentially that longer-distance commuters are taking TNC into the city from the suburbs to reach public transit access. In order to investigate this further, we examine the mean TNC trip distance of all trips beginning in each census tract, shown in the map in Figure 13. Once again, the city limits are indicated by the dashed black lines; for census tracts outside of this, the average trip distance is not accurate since only trips originating or ending within the city limits are reported to the city, and thus suburb-to-suburb trips are excluded. As seen in the map below, there is indeed a pocket of shorter average TNC trip distance right near the Southernmost light rail stations, i.e. the mean distance of trips beginning in this tract is lower than that of the surrounding census tracts. Granted, it is important to keep in mind that not all TNC trips starting in these census tracts are starting/ending at the light rail station; however, those trips that do start/end at the light rail stations are counted in the average distance for these census tracts. The overall results seem to confirm the hypothesis that TNC trips are used for so-called first-mile, last-mile travel in lower income communities.

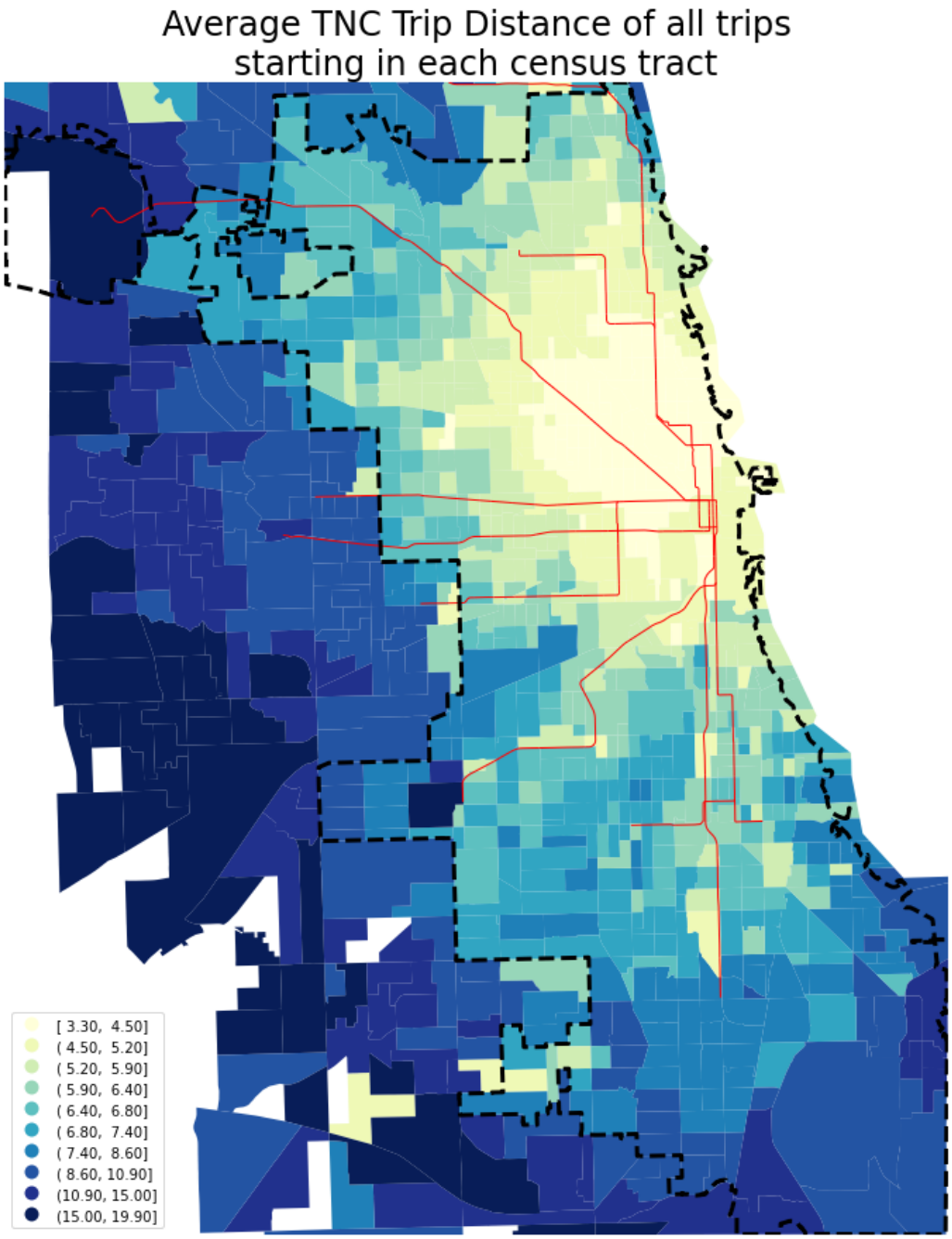

Figure 13: Average trip distance for TNC trips by census tract, in miles. Rail transit routes are indicated by red lines.

Interestingly, in Figure 13 we can also observe that along each of the light rail lines, the average TNC trip distance tends to be shorter than in surrounding tracts. We also observe a centroid of short TNC trips just northwest of downtown, with generally growing trip distance as you move away from this centroid. Therefore, we built a regression model to estimate the average trip distance of each census tract using two simple variables: distance to the nearest light rail station (stations from Chicago Data Portal 2021a), and distance to the ridership center (this

centroid of shortest average TNC trip distance). We used the centroid of each census tract when determining these distances and we only fit the model on those census tracts that fell completely within city limits. We also excluded both O'Hare and Midway airports from the model. When calculating both the distance to the nearest light rail station and the distance to the ridership center, we used the Manhattan (or taxicab) distance.

With just these two variables, our regression model has an R^2 of 0.84; our model results and the residuals map are shown in Figure 14. In Figure 14b, positive values shown in blue indicate places where the regression model underestimated the actual average TNC trip distance and negative values shown in red indicate where the regression model overestimated the actual distance. While the model performs quite well on average, it appears to perform the worst in the lower income communities, i.e. on the south and southwest sides of the city. While not explored in further detail here, this may be indicative of variations in TNC usage by lower-income communities, or may simply be due to non-linearities in travel behavior that are not captured by our simple linear regression. The model also does not serve to predict travel distance from the airports, which have many TNC travelers from across the city and beyond the city limits.

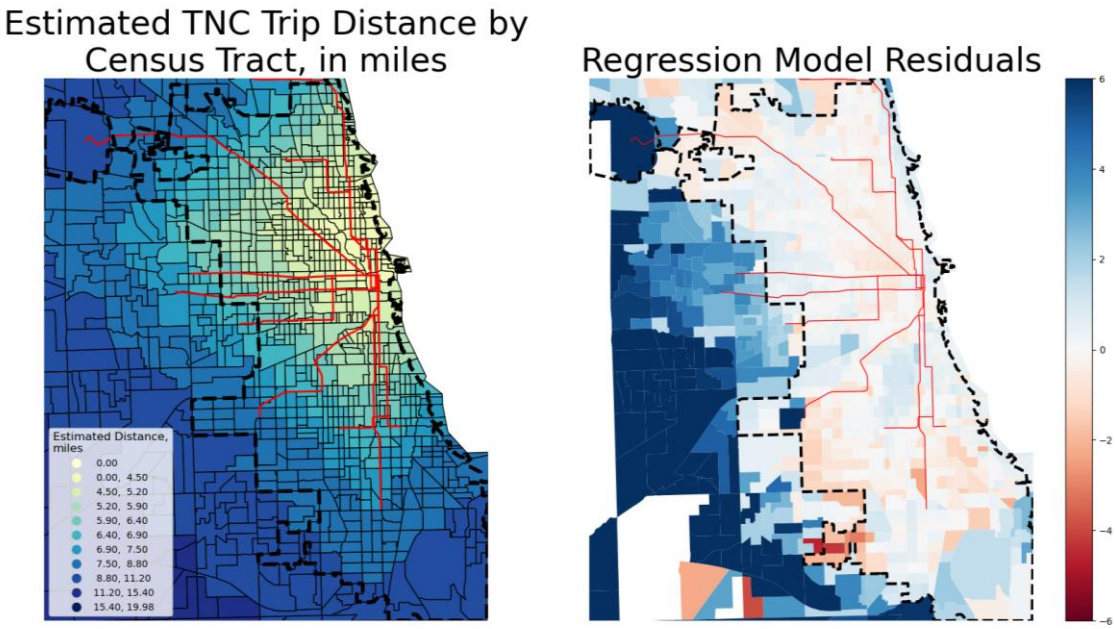

Figure 14: Left: Modeled estimation of TNC ridership by census tract. Right: Accuracy of TNC trip distance fitting algorithm (with blue colors indicating model underestimation and red colors indicating model overestimation).

4.2.2 Micromobility Usage in Chicago Communities

Figure 15 and Figure 16 show the spread of ridership for the other two new shared mobility types in Chicago: scooter share and bikeshare. As in Figure 10, trips per capita are grouped by income bracket and household vehicle ownership bracket. Note, again, that the scooter share data is from a four-month pilot program encompassing nearly the entire city with the notable exception of the loop/downtown area, and also that not all census tracts have a bikeshare station, or therefore bikeshare usage. Despite the more limited data, we see the same general trends as with the TNC data (i.e. greater usage variation in areas with higher incomes

and, generally speaking, highest usage in tracts with high incomes and lower mean vehicle ownership). For all three modes, it is possible that rides may be taken by those people who work in the city but do not live there.

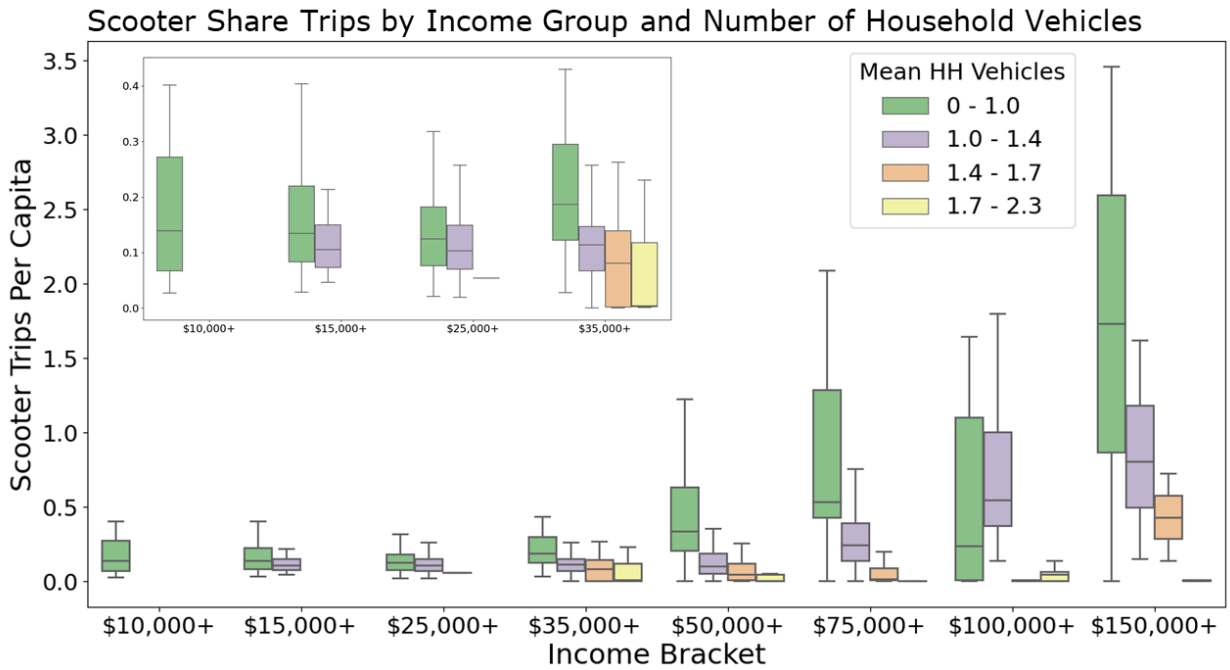

Figure 15: Distribution of scooter share ridership by income and number of household vehicles

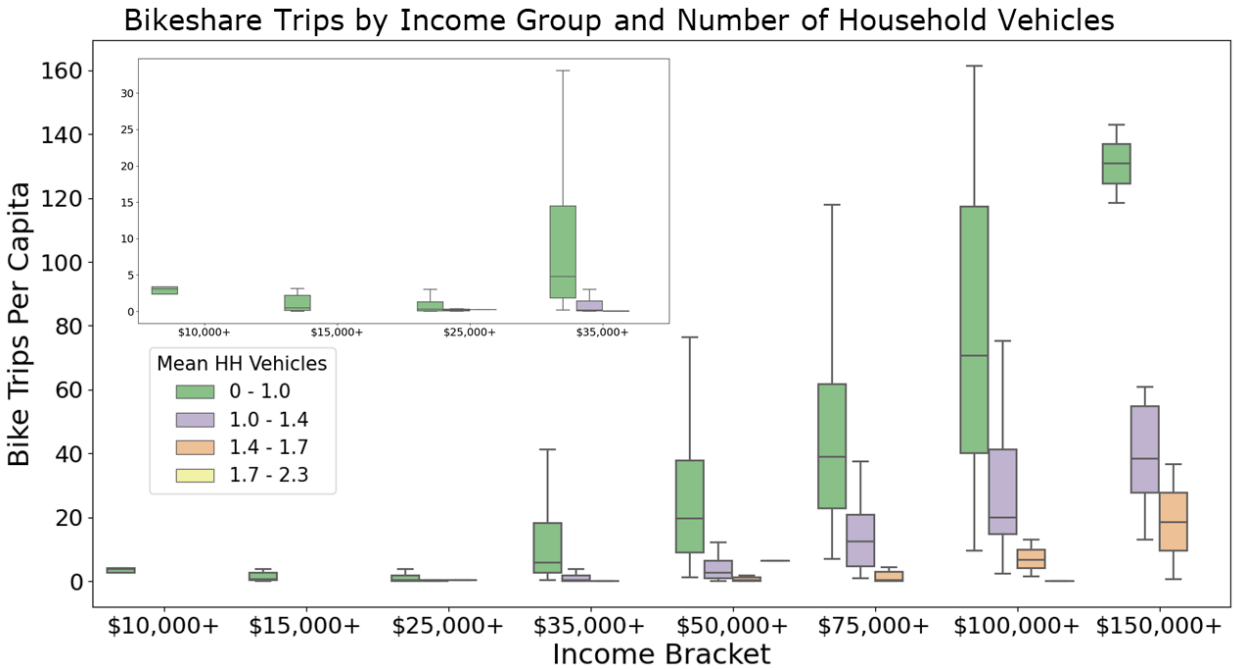

Figure 16: Distribution of bikeshare ridership by income and number of household vehicles

We performed a closer analysis of bikeshare usage trends within Chicago since we have more years of data than for the other two mobility types and in light of recent announcements for more equitable access (Divvy 2020). In Figure 17, which shows the results of the analysis, we show the Divvy stations in each year as small dots, black for a traditional station and red for a "lightweight" station, which does not have official docks, but rather simple racks to which to lock a bike (Greenfield 2020). The stations shown for a given year are the stations that were in operation on January 1 of that year; in general, this gives us a lower bound for the potential stations in a given year as stations installed later in the year will not be included (Chicago Data Portal, 2021b). The Divvy bikeshare system has expanded in nearly every year since its opening in 2013, and in recent years has begun to reach more of the West and South sides of Chicago. However, as can be seen in the figure, the highest-use areas have always been located downtown and in the Hyde Park area near the University of Chicago, which is also a higher income area. Generally speaking, there is a high correlation between income and Divvy bike usage. The most frequented Divvy station in the city is near Navy Pier, a tourist attraction on Lake Michigan. Other major stations (over 100 riders per day) are located outside of Chicago's Union Station and the Ogilvie Transportation Center, as well as at the entrances for other parks and tourist locations along Lake Michigan.

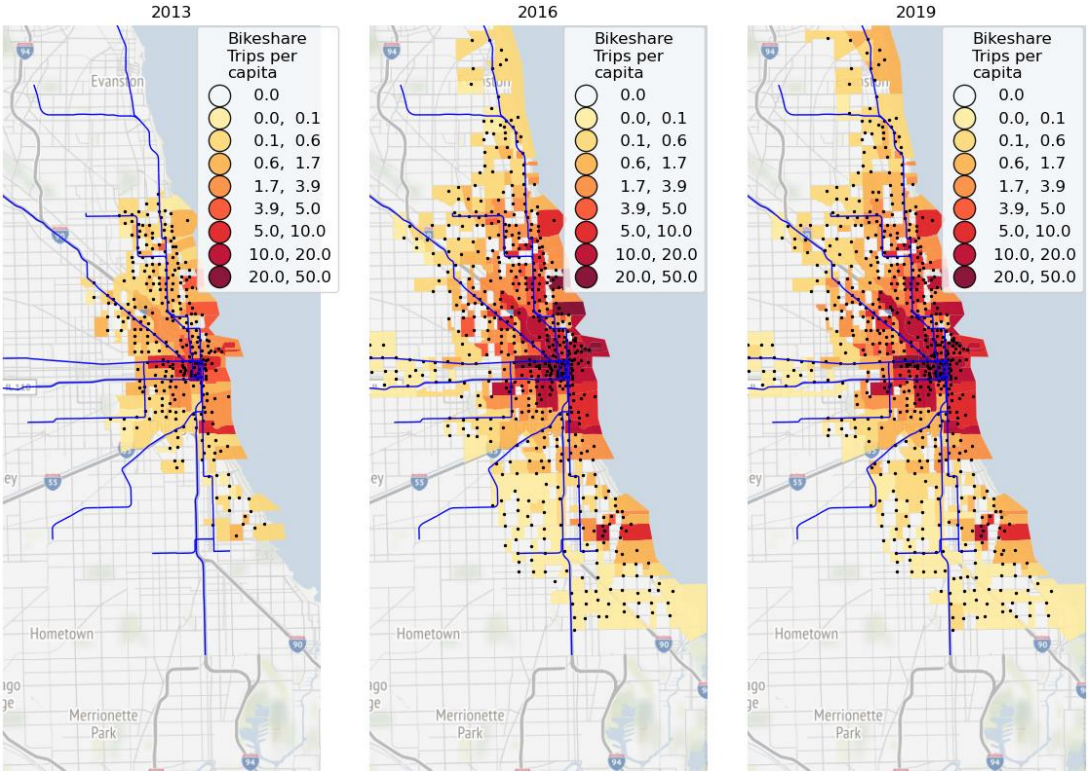

Figure 17: Divvy bike ridership in Chicago: 2013, 2016, and 2019. The dots denote Divvy stations.

Bikeshare availability has not been evenly distributed throughout the city. For each census tract, we consider the number of Divvy stations within 0.5 miles of the center of the tract in a linear regression model, finding a correlation of $R^2 = 0.62$ when considering seven demographic variables. The bikeshare stations are most strongly correlated with employment density, which makes sense as these are preferentially located near downtown and near

recreation destinations. Percentage of college graduates, population density, percentage of 18-65 year olds, and percentage of Black/African Americans are all positively correlated with bike station availability, statistically significant at the 0.01 level. Hispanic/Latino percentage is not statistically significant when considering these variables. Interestingly, after controlling for the above variables, median household income is also not a statistically significant predictor for bikeshare station location.

In August 2020, the city and Divvy began an effort to expand bikeshare availability to the South and West sides of Chicago, where lower income communities are located (Divvy 2020). Bikeshare has expanded to these areas, with the first Divvy usage in the far South side occurring in 2020. However, a major part of this initiative was to also introduce e-bikes, which can be used as dockless devices and need not be returned to a traditional Divvy docking station. As e-bikes do not need a docking station, these may be an effective way of spreading bikeshare availability beyond the central business district. The two maps in Figure 18 show 2020 usage and 2021 usage after this initiative was rolled out. Black and red dots, again, indicate the two types of stations in operation on January 1 of each year. In addition to showing the docked bicycle usage with the yellow-red color palette, this map also indicates the dockless e-bike usage with blue circles. The size of each blue circle indicates the number of dockless e-bike trips that began in or near that location. As shown in the figures below, the dockless bicycle usage is centered in the same places as the docked bicycle usage, which are also the high income areas. Again, we are unable to determine a census tract for the dockless trips since the latitude and longitude is rounded to two decimal places, so we examine docked and dockless trips separately. For comparison, a map showing median household income is also shown in Figure 18. Although bikeshare has indeed expanded to several lower income communities in 2020 and 2021, when compared with downtown, which generally aligns with the higher income areas, both the docked and dockless usage is still quite small.

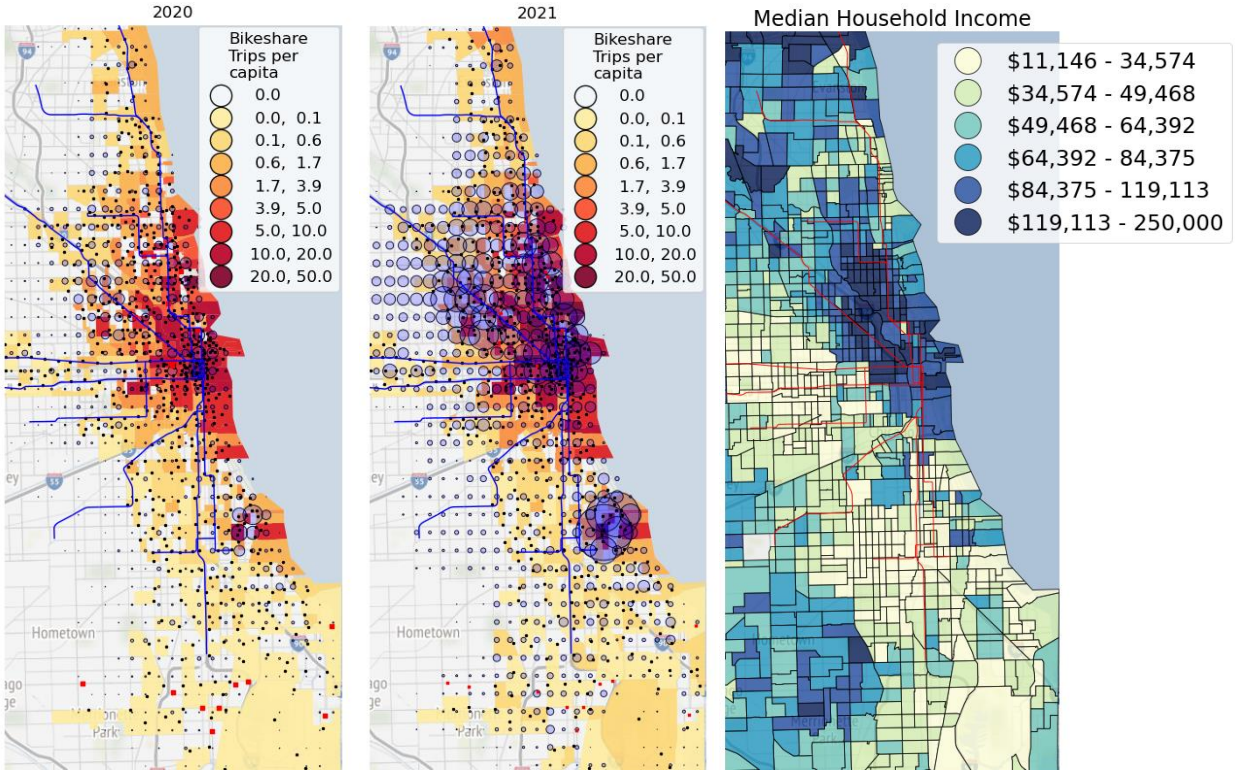

Figure 18: Docked and dockless bikeshare in Chicago (alongside median household income data), 2020 and 2021

Clearly, bikeshare usage is lower in these underserved, lower income communities; however, it is also true that access has only been more widely available for less than a year. To investigate this further, we examined the rate of growth in docked bikeshare usage at each Divvy docking station. For every station, we calculated the total cumulative rides departed from that station each day since its initial ride. We have then aggregated by income and show the mean cumulative trips each day of all of the stations that lie within each median household income bracket (based on the census tract that each station is in), demonstrated by Figure 19. The gradual slope for each line shows the increase in total trips at these stations; large dips or spikes represent opening or closing of docking stations. We see that, in general, bikeshare usage has grown more rapidly in higher-income areas than in lower-income ones. Therefore, although bikeshare is relatively new in several of the lower-income communities on the south side of the city, and understandably usage is far lower than in more established locations near downtown, ridership is growing at a slower rate than it first did in the higher income areas across the city. Divvy has announced that they will be expanding to more parts of the city, focusing on expanding the e-bike and e-station availability (Divvy 2021). As such, continuing to track Divvy usage and accessibility trends will be important future work.

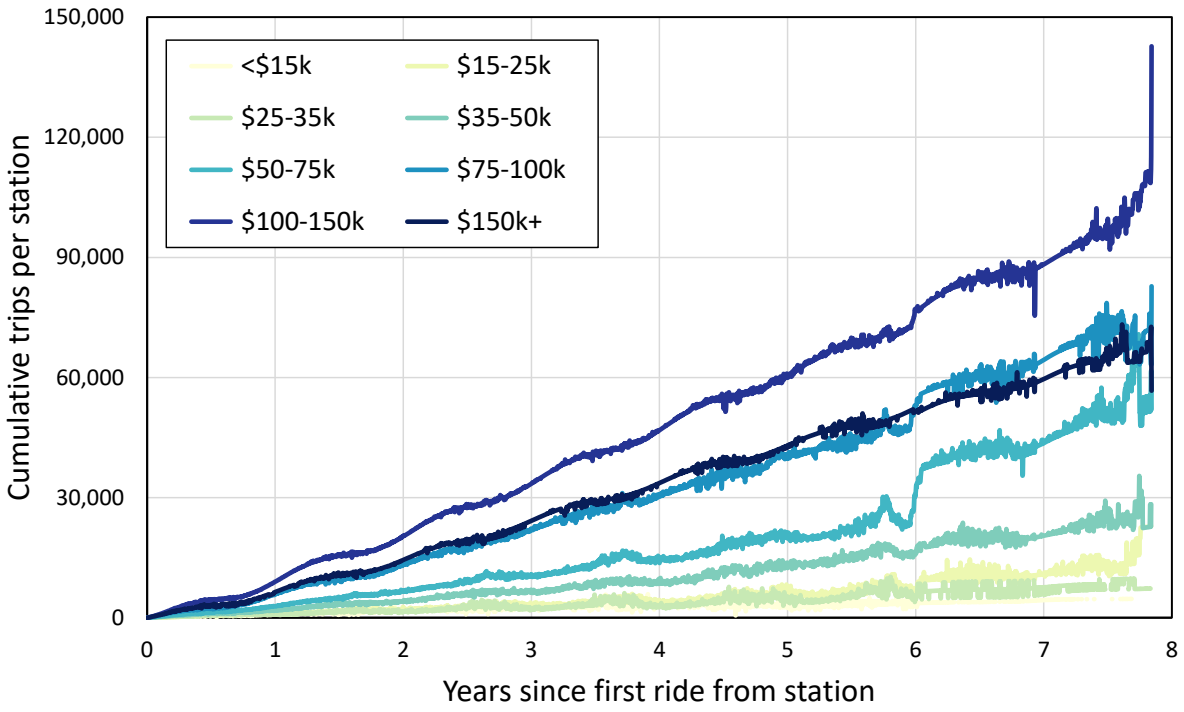

Figure 19: Average cumulative trips on Divvy bikeshare since station opening, grouped by income bracket of station census tract

5 DISCUSSION AND CONCLUSIONS

TNC and micromobility are both becoming more popular in cities across the United States. This report has aimed to 1) summarize shared mobility technology data availability in the United States, 2) track usage trends nationwide, and 3) analyze how usage varies by demographic characteristics such as household income and the number of vehicles per household at the census tract level.

We have shared general findings from the systems that share data on individual rides or with high geographic fidelity such as trip time, location, vehicle (or device), and user characteristics. The main obstacle for researchers is that not all shared mobility systems share their data with the public. Docked bikeshare data, still the large majority of publicly available bikeshare data, typically includes trip time and location but lacks distance and route data. Publicly available dockless bikeshare data also lacks distance and route information, though this data should be available to the bikeshare companies, as the dockless vehicles have GPS trackers. Scooter data is available in limited cities and lacks information on user and device characteristics – as such, it is difficult to track the battery capacity and energy efficiency of the scooters. The typical battery capacities of scooters are 0.5 kWh, E-bikes, on the other hand, typically have capacities of 0.5 to 0.8 kWh, but there are diverse specifications across shared bikes. Only Chicago and NYC regularly publish TNC data; however, neither reports vehicle information by trip. This creates challenges, for example, for estimating the potential energy and emissions benefits of electrifying TNC and for assessing charging infrastructure needs. In general, there are many concerns regarding rider privacy that underlie the provision of trip level data. The resulting limitations make it difficult to quantify the energy and emissions impact as well as to accurately estimate how ridership may evolve as a function of deployment, demographics, and technology development.

In general, scooter, bikeshare and TNC usage all declined during the first several months of COVID, in 2020. However, while still a relatively new technology, per capita ridership of scooter systems has surged in recent years. It has yet to be seen if this large ridership base will continue through the coming years. There is a wide range in TNC usage across the country, even within urban areas; some cities average less than ten rides per person per year, while others average nearly 100 annual rides per person. Some cities may have higher per-capita ridership due to riders who are visiting the city. From 2015 to 2021, we see transit ridership decreased and TNC ridership increased in Chicago on the annual base. However, when looking at each year individually, there is a positive correlation between the two. As both transportation methods tend to follow seasonal trends in Chicago, time-scale is important when trying to understand if the introduction of TNCs has caused lower transit ridership. Moreover, the TNC technologies are still new and the usage trends were very different than we have seen in recent years. With more collaboration emerging between transit and TNC services, continuing to track their usage trend and interaction will be important future work.

Despite the availability of good public transportation, this research finds that high usage of new shared mobility modes is centered in high income communities in the city of Chicago. Tracts with higher income and fewer household vehicles tend to have higher TNC usage per capita. We also observe that the highest income group has the biggest variation in usage and that, in general, the higher the income group, the more the variation in TNC usage. A similar trend is observed in shared bike and scooter usage.

Despite the city's efforts to expand bikeshare availability on the south side of Chicago, where many low-income communities are located, low bikeshare ridership in those areas has persisted. In general, bikeshare usage grows more rapidly in higher-income areas than in lower-income ones when the services were introduced at the same time. However, regression analysis shows that employment density, population density, percentage of college graduates, and bike-lane proximity are stronger predictive variables for ridership. When these terms are accounted for, household income is shown to not be a statistically significant factor.

Dockless e-bikes have grown rapidly in Chicago, and this growth is not strictly limited to high-income neighborhoods or areas which already had bikeshare. The largest growth appears to be in places that didn't have docks previously, especially moderate income neighborhoods on the Northwest side and lower income neighborhoods on the West Side. Therefore, new implementation of dockless electric bikes, as well as expansion of bike lanes and stations across Chicago could result in increased usage beyond traditional locations. Many cities are also pushing for the placement of docked stations or the reshuffling of dockless bikes and scooters in economically disadvantaged neighborhoods and majority non-white resident neighborhoods.

We find that TNC is used for first-mile and last-mile in lower income communities. In Chicago, TNC ridership peaks near ends of train lines, and there is an increase in short-distance TNC ridership in the vicinity of transit stops. Incentivizing TNC for first/last-mile usage could improve accessibility to key amenities and job opportunities for low income communities.

Micromobility is a rapidly growing field of transportation that has received little attention from federal legislation. While there is now federal legislation on the horizon to support and regulate the micromobility industry (Wilson 2021), most current legislation pertaining to micromobility exists at the local scale (along with at least some attention from state-level policy makers). The lack of concrete action at higher levels has allowed some micromobility companies to take advantage of the political inattention. There have been multiple cases of micromobility companies appearing in a city overnight without city approval (Irfan 2021). This lack of apparent rules or standardization leaves residents confused, frustrated, and resentful towards future micromobility systems. There is a considerable need for more standardization and nationwide implementation of, both, operation of micromobility systems and data sharing. Micromobility has the opportunity to revolutionize the mobility sector; however, without the proper policy infrastructure, the effects may not be fully understood.

Appendix A: DATA SOURCES AND DETAILS

This appendix presents public data sources for TNC and micromobility in the United States, summarized in five tables. In each of these tables, a checkmark designates that the dataset includes information about this topic. Where necessary, additional information is given as a note for each entry.

Table 3 shows information about the trip-level data available for TNCs. The columns in Table 3 show the geographic location for TNC ridership, the specific TNCs which are in the dataset, the dates of the rides, and the total number of entries included in the data. For each trip, the data notes if the vehicle and/or trip ID is given, the spatial and temporal resolution of the startpoints and endpoints, and the online source of the data. Table 4 shows additional data for TNCs, including a rider-specific ID, the fare amount and any potential extra costs including tip, if the rider was willing to consider pooling their trip, and ratings for the driver and passenger. The California data is notable in that it includes the distance traveled by the driver between accepting the fare and reaching the passenger for pick-up.

Table 5 gives a list of public TNCs. As none of these are known to share data publicly, this simply lists name and location and any known information about the types of vehicles. Two of these public TNCs (Anaheim, CA and Eugene, OR) offer electric vehicle shuttles.

Table 6 gives a list of recently operating electric-moped sharing systems, including those that are currently active or recently defunct. These have operated in eight cities, with aggregate data available in San Francisco and trip-level data available in Austin, TX.

Table 7 shows data for docked and dockless bikeshare programs. This presents largely the same information as for TNCs in Table 3. Note that, in general, trips shorter than one minute in length are removed from the datasets. Table 8 shows additional demographic information for bikeshare systems, including if the rider is a member or guest, if the type of bike is known, the gender of the user, and the birth year of the member.

Table 9 shows scooter share information, specifically the location, the dates of available data, the approximate number of trips for which data exists, any information about the specific scooter fleet or if there is a dedicated vehicle or trip ID, temporal and spatial resolution of the trip origin and destination, and the overall resolution for the trip. No rider demographics are available for any scooter share system.

Table 10 shows access information for six cities in Canada and Mexico which also make bikeshare trip data publicly available.

Table 3: Trip Level, TNC, Trip Information

Location	TNC companies included	Dates of Data	Number of Entries	Vehicle ID Given	Trip ID Given	Origin and Destination Information	Trip Duration	Trip Distance
Austin, TX	RideAustin (now defunct)	06/2016 - 04/2017	1.5M	✓	✓	Lat/Long; 1-second intervals	seconds	meters
California	Lyft, Uber	10/2019 - 9/2020	227M	✓		Zip code; 1-second intervals	seconds	miles (to nearest hundredth)
Chicago, IL	Uber, Lyft, Dryver, Scoop, Via	11/2018 - present	230M		✓	Community area; 15-minute intervals	seconds	miles (to nearest tenth)
New York, NY	Uber, Lyft, Via, Juno	01/2016 - present	1,040M			TLC taxi zone; 1-second intervals	seconds	N/A

Table 4: Trip Level, TNC, Ride Specific Data

Location	TNC company	Dates of Data	Rider ID	Base Fare	Total Fare	Pooling	Rating	Access
Austin, TX	✓	06/2016 - 04/2017	✓	✓	✓		✓	https://data.world/ride-austin
California	✓	10/2019 - 9/2020		✓	✓	✓		Access by request to CPUC
Chicago, IL		11/2018 - present		✓	✓	✓		https://data.cityofchicago.org/Transportation/Transportation-Network-Providers-Trips/m6dm-c72p
New York, NY	✓	01/2016 - present						All datasets available at https://data.cityofnewyork.us/browse?q=FHV Prior to February 2019, TNC is included with all for-hire vehicles, and can be distinguished by their dispatching base number. In 2016, data only includes origin; no destination information is given.

Table 5: Public TNCs in the United States

Location	Service Name	Vehicle Type	Notes
Albany, NY	FLEX	Shuttle	
Anaheim, CA	FRAN	Electric shuttle	
Antioch, CA	Tri MyRide	Shuttle	
Austin, TX	Pickup	Shuttle	Operates in a few suburban cities as well
Bellevue, WA	Crossroads Connect	Minivan or car	Pilot ended
Columbus, OH	COTA+	Shuttle	
Denton County, TX	GoZone	Van	
Eugene, OR	EmGo	Electric shuttle	
Grand Rapids, MI	GO!Bus	Bus	
Houston, TX	Community Connector	Minivan or bus	
Los Angeles, CA	Metro Micro	Van or minivan	
Marin County, CA	Connect	Van	
Montpelier, VT	MyRide	Shuttle	
Orange County, CA	OC Flex	Shuttle	
Sacramento, CA	SmaRT Ride	Shuttle	
Tucson, AZ	Sun On-Demand	Shuttle	
Westborough, MA	Via WRTA	Van	

Table 6: Shared Electric Moped Systems in the United States

Location	Operators	Notes
Atlanta, GA	Previously Muving	Currently defunct
Austin, TX	Scoobi; previously Revel	Data available online (City of Austin 2022)
Miami, FL	Revel	
New York, NY	Revel	
Oakland, CA	Revel	
Pittsburgh, PA	Scoobi	
San Francisco, CA	Revel; previously Scoot and Lime	Aggregate data available online (SFMTA 2022)
Washington, DC	Lime; Revel	Pilot through 2021 (DC 2021)

Table 7: Trip Level Data Availability, Docked and Dockless Bikes

Location	Dates of Data	Number of Entries	Docked	Dockless	Vehicle ID Given	Origin and Destination Information	Trip Duration	Trip Distance
Austin, TX	12/2013 - present	2.1M	✓	✓	✓	Docked: Start/End Station; 1-hour interval. Dockless: Council district / Census tract; 15-minute interval	Docked: minutes; Dockless: seconds	meters
Trips of distance greater than or equal to .1 miles and less than 500 miles and trip duration less than 24 hours are reported. https://data.austintexas.gov/Transportation-and-Mobility/Shared-Micromobility-Vehicle-Trips/7d8e-dm7r and https://data.austintexas.gov/Transportation-and-Mobility/Austin-MetroBike-Trips/tyfh-5r8s								
Boston, MA	07/2011 - present	15.8M	✓		✓	Start/End Station; 0.1-minute interval	seconds	station
Number of docks at each station are in a separate document. https://www.bluebikes.com/system-data								
Chattanooga, TN	07/2012 - present	527k	✓		✓	Start/End Station; 1-minute interval	seconds	station
https://internal.chattadata.org/Recreation/Bike-Chattanooga-Trip-Data/tdrg-39c4								
Chicago, IL	06/2013 - present	30.4M	✓	✓	✓	Docked: Start/End Station; 1-minute interval. Dockless: Lat/long; 1-minute interval	seconds	station
Vehicle ID only given for trips before mid-2020. https://divvy-tripdata.s3.amazonaws.com/index.html and https://data.cityofchicago.org/Transportation/Divvy-Trips/fg6s-gzvg								
Columbus, OH	07/2013 - present	386k	✓		✓	Start/End Station; 1-minute interval	minutes	station
https://www.cogobikeshare.com/system-data								
Denver, CO	04/2010 - 12/2015	1.9M	✓		✓	Start/End Station; 1-minute interval	minutes	station
https://web.archive.org/web/20170206232338/https://denver.bcycle.com/company								
Fargo, ND	03/2015 - 12/2017	348k	✓		✓	Start/End Station; 1-second interval	seconds	station
https://greatrides.bcycle.com/about/data								
Jersey City, NJ	09/2015 - present	2.3M	✓		✓	Start/End Station; 1-minute interval	seconds	station
Operated with Citi Bike in New York City. E-bike data available starting February 2021. https://ride.citibikenyc.com/system-data								
Los Angeles, CA	07/2016 - present	1.4M	✓		✓	Start/End Station; 1-minute interval	minutes	station
Trip lengths are capped at 24 hours. https://bikeshare.metro.net/about/data/								

Location	Dates of Data	Number of Entries	Docked	Dockless	Vehicle ID Given	Origin and Destination Information	Trip Duration	Trip Distance
Louisville, KY	01/2019 - 07/2021	35k	✓		✓	Lat/long (to 3 decimals); 1-minute interval	minutes	N/A
https://data.louisvilleky.gov/dataset/louvelo-bicycles								
Minneapolis, MN	06/2010 - present	4.6M	✓		✓	Start/End Station; 0.1-minute interval	seconds	station
Vehicle ID only given for trips before mid-2020. https://www.niceridemn.com/system-data								
New York, NY	06/2013 - present	139M	✓		✓	Start/End Station; 1-minute interval	seconds	station
Rideable type of bicycle to distinguish classic bikes from e-bikes available starting February 2021. https://ride.citibikenyc.com/system-data								
Philadelphia, PA	04/2015 - present	5.0M	✓		✓	Start/End Station; 1-minute interval	minutes	station
https://www.rideindego.com/about/data/								
Pittsburgh, PA	04/2015 - present	624k	✓	✓	✓	Start/End Station; 1-minute interval	seconds	station
No location data for dockless trips https://healthyridepgh.com/data/								
Portland, OR	07/2016 - 08/2020	1.3M	✓		✓	Start/End Station; 1-minute interval	seconds	miles (2 decimal)
https://www.biketownpdx.com/system-data								
Rochester, NY	03/2018 - 10/2018	19k	✓		✓	Latitude/longitude; 1-second interval	seconds	N/A
Data includes GPS coordinates between origin and destination. https://data.cityofrochester.gov/datasets/RochesterNY::masterbikedata2018csv/about								
San Francisco, CA	06/2017 - present	9.1M	✓		✓	Start/End Station; 1-minute interval	seconds	station
Vehicle ID only given for trips before mid-2020. https://www.lyft.com/bikes/bay-wheels/system-data								
Seattle, WA	10/2014 - 12/2016	263k	✓		✓	Start/End Station; 1-millisecond interval	seconds	station
https://s3.amazonaws.com/pronto-data/open_data_2016-12.zip and https://s3.amazonaws.com/pronto-data/open_data_year_one.zip								
St. Petersburg / Tampa, FL	10/2014 - 03/2018	240k	✓	✓	✓	Docked: Start/End Station; 1-minute interval. Dockless: Lat/long; 1-minute interval	seconds	miles (2 decimal)
https://web.archive.org/web/20190220220642/http://coastbikeshare.com/data/								
Washington, DC area	09/2010 - present	31.0M	✓		✓	Start/End Station; 1-minute interval	minutes	station
https://www.capitalbikeshare.com/system-data								

Table 8: Trip Level, Docked and Dockless Bikes, Rider Demographics

Location	Docked	Dockless	Dates of data	Passholder type	Bike type	Gender of user	Birth year of member
Austin, TX	✓	✓	12/2013 - present	✓			
Boston, MA	✓		07/2011 - present	✓		✓	✓
Chattanooga, TN	✓	✓	07/2011 - present				
Chicago, IL	✓	✓	06/2013 - present	✓	✓	✓	✓
Columbus, OH	✓		07/2013 - present	✓	✓		
Denver, CO	✓		04/2010 - 12/2015	✓			
Fargo, ND	✓		03/2015 - 12/2017	✓			
Jersey City, NJ	✓		09/2015 - present	✓		✓	✓
Los Angeles, CA	✓		07/2016 - present	✓	✓		
Louisville, KY	✓		01/2019 - present	✓			
Minneapolis, MN	✓		06/2010 - present	✓	✓		
New York, NY	✓		06/2013 - present	✓		✓	✓
Philadelphia, PA	✓		04/2015 - present	✓	✓		
Pittsburgh, PA	✓	✓	04/2015 - present	✓			
Portland, OR	✓		07/2016 - 08/2020	✓			
Rochester, NY	✓		03/2018 - 10/2018				
San Francisco, CA	✓		06/2017 - present	✓	✓		
Seattle, WA	✓		10/2014 - 12/2016	✓		✓	✓
St. Petersburg/Tampa, FL	✓	✓	10/2014 - 03/2018				
Washington, DC area	✓		09/2010 - present	✓	✓		

Notes: For Chicago, rider demographics are only available for rides before 2020. The Portland dataset includes information on RentalAccessPath and how many bikes are rented at once (e.g., for a group).

Table 9: Trip Level Data for Scooter Share

Location	Dates of Data	Number of Entries	Company Given	Vehicle ID Given	Trip ID Given	Origin and Destination Information	Trip Duration	Trip Distance
Austin, TX	04/2018 - present	13.7M		✓	✓	Council district / Census tract; 15-minute intervals	seconds	meters
Trips over 7 hours or trips <0 miles or >24 miles are removed. https://data.austintexas.gov/Transportation-and-Mobility/Shared-Micromobility-Vehicle-Trips/7d8e-dm7r								
Chicago, IL	06/2019 - 10/2019; 08/2020 - 12/2020	1.3M	✓		✓	Community area / Census tract; 60-minute intervals	seconds	meters
Census tracts only available for 2019 pilot. https://www.chicago.gov/city/en/depts/cdot/supp_info/escooter-share-pilot-project.html								
Kansas City, MO	06/2019 - present	1.0M			✓	Latitude and longitude; 1-second intervals	seconds	miles
Data resolution only to 3 decimals and 15-minute intervals prior to April 2020. Includes about 5,000 e-bike trips mixed with scooter data. https://data.kcmo.org/Transportation/Microtransit-Scooter-and-Ebike-Trips/dy5n-ewk5								
Louisville, KY	08/2018 - present	913k			✓	Latitude and longitude (to 3 decimals); 15-minute intervals	minutes	rounded to nearest mile
Start and end point fuzzed randomly to 0.5km resolution. https://data.louisvilleky.gov/dataset/dockless-vehicles								
Minneapolis, MN	05/2019 - 11/2019; 07/2020 - 12/2020	1.2M			✓	Neighborhood; 30-minute intervals	seconds	meters
Trips over 7 hours or trips <0 miles or >24 miles are removed. https://opendata.minneapolismn.gov/search?groupIds=9bc71a032e984a22a5e94312d9d9bf7f								
Portland, OR	07/2018 - 08/2020	1.9M			✓	Census block; 60-minute intervals	seconds	meters
Trips shorter than a minute; trips with distance <0 miles or >40 miles, or trips longer than 4 hours were removed, some location data removed for privacy. https://www.portland.gov/transportation/escooterpdx/trips-dashboard								

Table 10: Publicly Available Micromobility Trip Data in North America

Location	Dates of Data	Number of Entries	Trip ID Given	User ID Given	User Information	Origin and Destination Information	Trip Duration	Trip Distance
Calgary, AB, Canada	07/2019 - 09/2019	482k	✓			30,000 square meter hexagon; 1-hour intervals	seconds	meters
Pilot program, bikeshare and scooter share. https://data.calgary.ca/Transportation-Transit/Shared-Mobility-Pilot-Trips/jicz-mxiz								
Guadalajara, JA, Mexico	12/2014 - present	18.7M	✓	✓	✓	Start/end station; 60-minute intervals	minutes	station
Information about user birth year, and ride information is linked to a specific user. https://www.mibici.net/es/datos-abiertos/								
Mexico City, CDMX, Mexico	02/2010 - present	73.5M	✓		✓	Start/end station; 1-second intervals	seconds	station
Information about rider age and gender. https://www.ecobici.cdmx.gob.mx/es/informacion-del-servicio/open-data								
Montreal, QC, Canada	04/2014 - present	32.5M	✓		✓	Start/end station; 1-minute intervals	minutes	station
Information about membership status of rider. https://bixi.com/fr/donnees-ouvertes								
Toronto, ON, Canada	10/2014 - 09/2015; 07/2016 - present	12.9M	✓			Start/end station; 1-minute intervals	minutes	station
Data prior to 2016 aggregated by station-to-station pairs. https://open.toronto.ca/dataset/bike-share-toronto-ridership-data/								
Vancouver, BC, Canada	01/2017 - 07/2021	3.2M	✓		✓	Start/end station; 60-minute intervals	seconds	meters
Information about membership status of rider. Also includes information about battery voltage, trip temperature, any stopovers during the trip. https://www.mobibikes.ca/en/system-data								

Appendix B: DATA VALIDATION

This appendix validates some of the assumptions used for modeling shared mobility usage in Chicago in Section 4. Figure 20 shows a comparison of three different data sets for TNCs supplied by the city of Chicago, focusing on the individual driver, the specific trip, and the licensed vehicle, respectively. From 2015 through 2021, these three data sets each give excellent agreement, showing that the three of them can largely be used interchangeably for high-level analysis. The trip and driver datasets are consistently within 1% of each other. The vehicle dataset tends to be approximately 5% larger than the other two datasets, but the cause of this discrepancy is unknown. For aggregate analysis, we primarily focus on the driver data set, as it matches very closely with the individual trips while having a longer history. Note that we do not include February 2015 in our analysis since it may just be a partially-reported month, since that is the first month for which data is available. Also note that there was a known data reporting error in Q2 2018 (April-June).

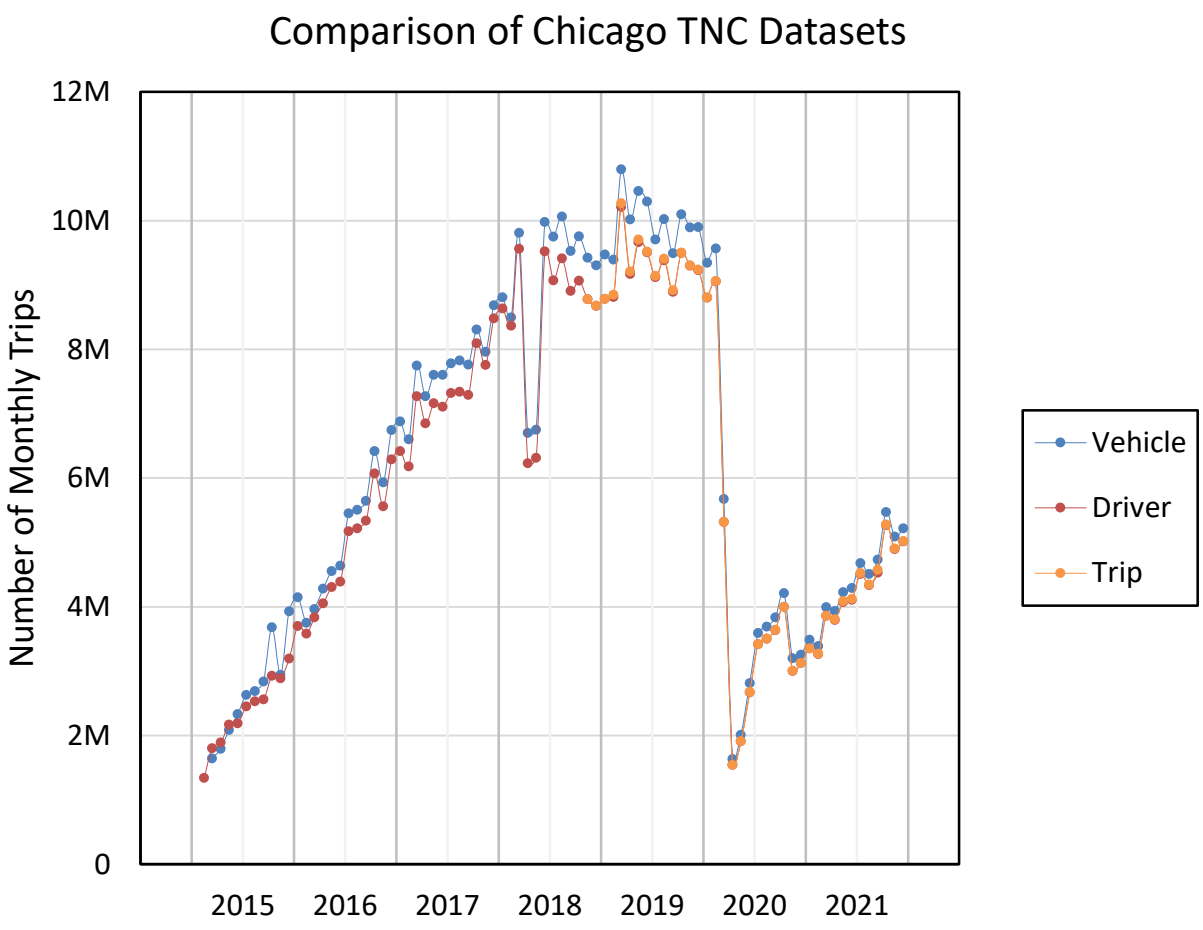

Figure 20: Comparison of 'Driver', 'Trip', and 'Vehicle' datasets for Chicago TNCs

Figure 21 shows a heat map of the trip start and end locations in the Chicago E-Scooter Pilot Program in 2019. These two heat maps are very similar, with nearly every tract remaining in the same quintile when ranked by either trip starts or trip ends. In this study we selected trip-start locations for geospatial analysis, though results would be similar if we had chosen to use trip-end locations. This graphic also shows the reduced area for permitted ridership in the 2019 pilot, as compared to the 2020 pilot (shown in Figure 6).

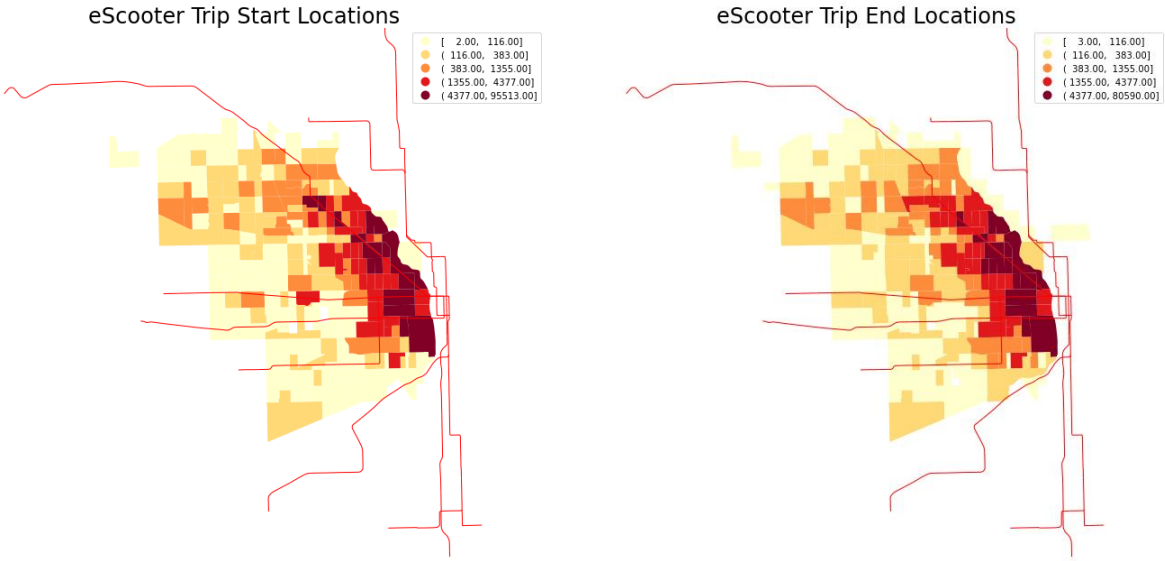

Figure 21: Trip start and end locations for electric scooters in 2019 Chicago E-Scooter Pilot Program

Figure 22 shows the locations of highest ridership for the 2019 scooter pilot. Note that the scooter pilot area does not span the entire city. The scooter pilot area is shown in the map by the dotted black lines. Within the scooter pilot area, there are four census tracts where all three shared mobility modes are in the top decile in the city (shown in dark gray), as well as 22 census tracts where TNC and scooter share usage are both in the top decile (shown in purple). Most census tracts where bikeshare usage is high are also frequently served by TNCs.

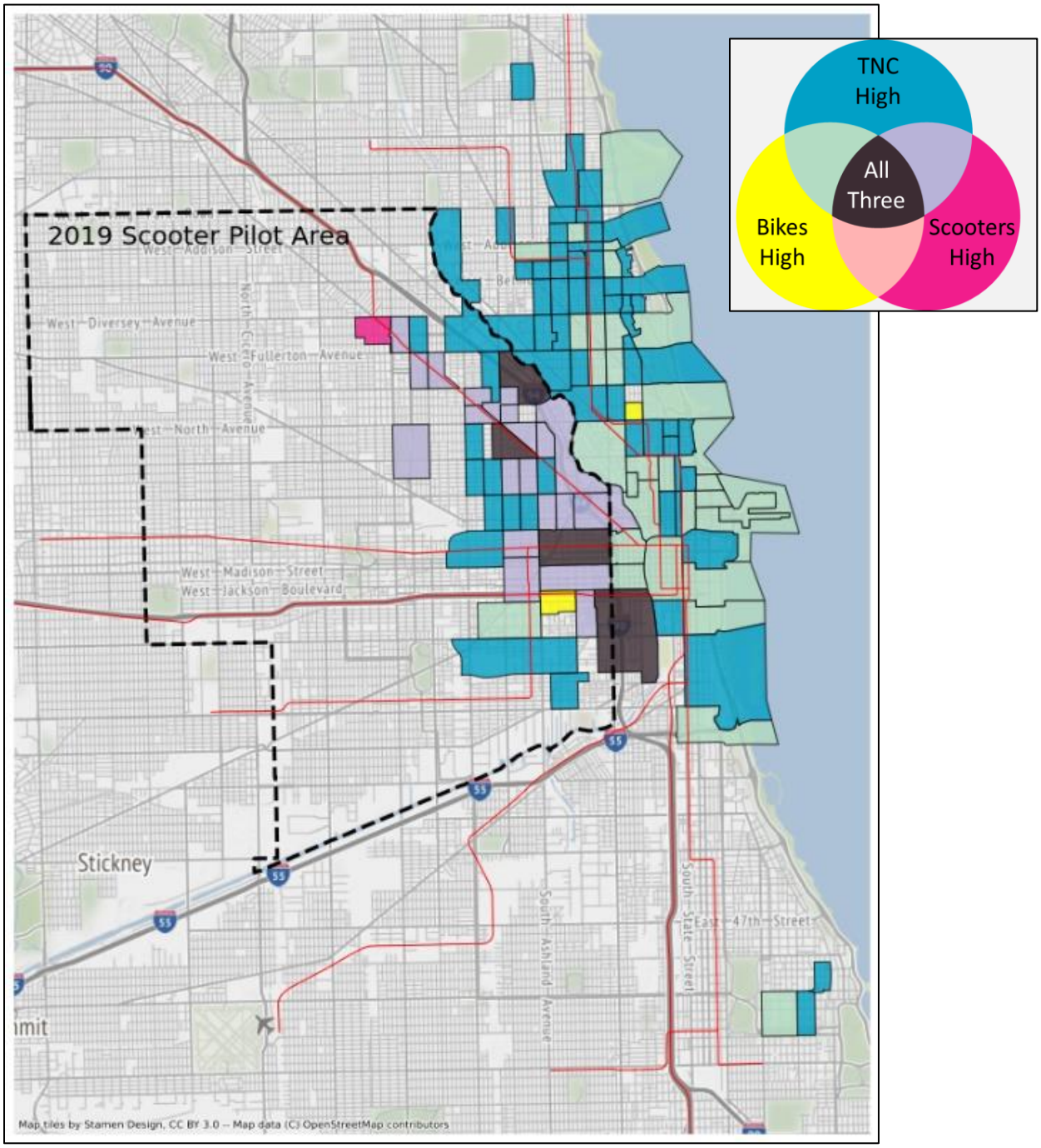

Figure 22: Locations of highest usage for TNC, bikeshare, and scooter share

Figure 23 shows ridership trends for transit and TNC within Chicago from both annual and monthly perspectives. From 2015 to 2019 transit ridership decreased while TNC ridership increased. In 2020 each mode decreased due to the COVID-19 pandemic, with each mode steady in 2021. On a monthly scale, transit in Chicago exhibits peak ridership from March through October. Average TNC ridership is higher later in the year, as the overall growth of TNC usage is the dominating factor in this graphic.

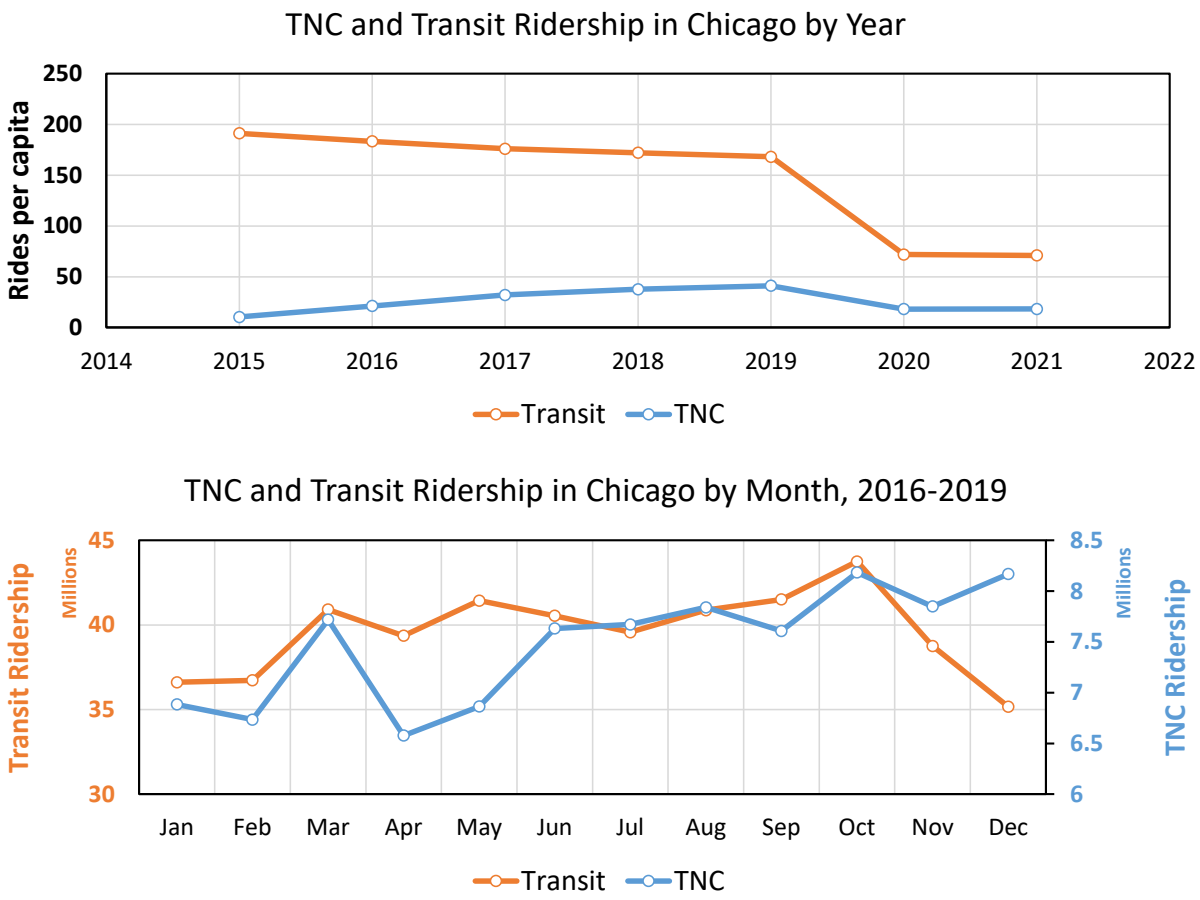

Figure 23: Comparison of ridership trends for TNCs and transit in Chicago

An alternative representation of TNC ride frequency and median household income is shown in the bivariate choropleth plot in Figure 24. Census tracts that have high TNC usage are colored in deeper shades of blue, while census tracts with higher median household income are colored in deeper shades of orange. The city boundaries of Chicago are shown by a dashed line, and light-rail (including subway and elevated rail) is shown by red lines. Downtown and the North side generally have high ridership and high incomes. Lower-income areas on the South and West side are visible as light-blue. The suburbs are characterized by low TNC ridership; this is true for both low-income and high-income neighborhoods.

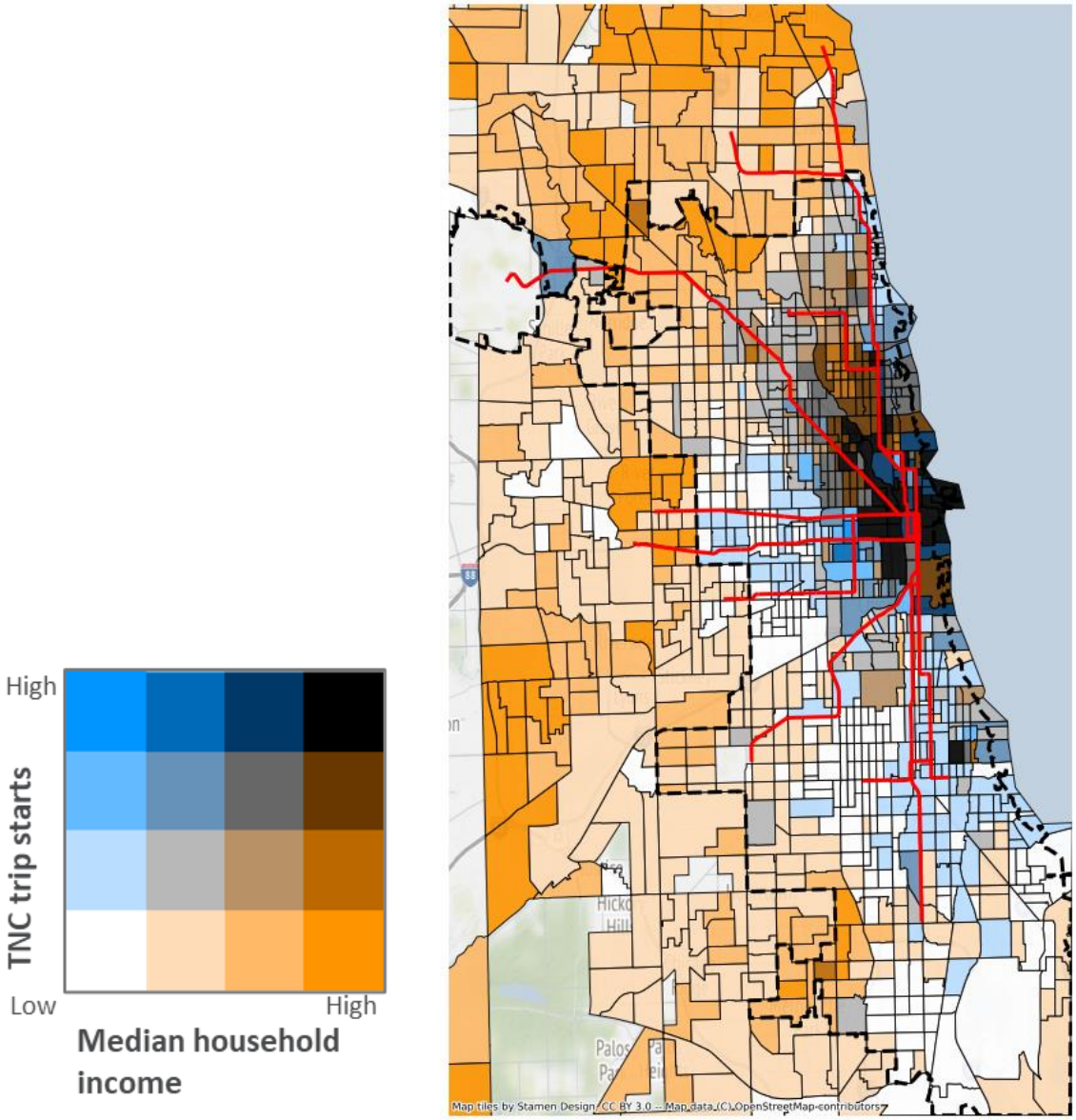

Figure 24: Comparison of TNC ride frequency and median household income in Chicago

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