The New Automobility: Lyft, Uber and the Future of American Cities

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This report was prepared by Bruce Schaller, Principal of Schaller Consulting. An expert on issues surrounding the rise of new mobility services in major U.S. cities, Mr. Schaller served as Deputy Commissioner for Traffic and Planning at the New York City Department of Transportation and Policy Director at the NYC Taxi and Limousine Commission, and has consulted on transportation policy across the United States. He is the author of the February 2017 report, "Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City," and co-author of a 2015 National Academy of Sciences report on emerging mobility providers. He also served as an Advisor for the City of New York's study of for-hire vehicle issues. He has been called "a prominent transportation expert" (*New York Times),* "a widely acknowledged expert" on issues related to taxis, Uber and Lyft *(Politico)* and a "nationally recognized expert" on for-hire transportation issues (*Washington Post).* Mr. Schaller has published extensively in peer-reviewed academic journals including *Transport Policy*, *Transportation* and the *Journal of Public Transportation*.

This report was researched and written by Mr. Schaller to further public understanding and discussion of the role that app-based ride services and other vehicle-for-hire services can and should play in furthering urban mobility, safety and environmental goals.

Contents

WHO'S WHO – FOR-HIRE GROUND TRANSPORTATION SERVICES

Taxicabs

- Until TNCs arrived, predominant provider of for-hire services in the United States.
- Door-to-door service (not shared between strangers)
- Fare based on initial charge, mileage and time
- Trips arranged via street hail, taxi stands, telephone orders and sometimes on-line or using smartphone app.
- Drivers treated as independent contractors, not employees
- Vehicle may be responsibility of driver or provided by company
- Drivers pay a daily, weekly or monthly lease fee.

Microtransit

- Shared-ride service in which passengers walk to a pick-up location.
- Via and Chariot are the largest companies in the U.S.
- Flat fares, typically around $5.
- Drivers usually paid an hourly wage
- Drivers are treated as independent contractors (Via) or employees (Chariot)
- Vehicle may be responsibility of driver or provided by company

Transportation Network Companies (TNCs)

- Sometimes called ride-hail or rideshare
- Uber and Lyft are largest companies; other companies are in specific markets
- Fare based on time and distance
- Primarily provide door-to-door private ride service (not shared between strangers), e.g., UberX and Lyft.
- Also provide shared trips which pick up additional passenger(s) after the first passenger(s) board, (e.g., UberPOOL and Lyft Line)
- Recently introduced variations on shared rides that involve passengers walking to a pick-up location (e.g., Uber Express POOL and Lyft Shared Rides)
- Trips arranged using smartphone app
- Drivers treated as independent contractors, not employees
- Companies charge a commission on fares
- Drivers responsible for providing their vehicle

OTHER DEFINITIONS

Trips, riders and ridership

- For bus, rail, walk and bike trips, these terms refer to one person traveling between two points except that, for bus and rail each boarding is counted separately. A trip involving a transfer from bus to Metro is thus counted as two riders and two trips.
- For personal auto, TNC and taxi, "riders" and "ridership" means one person making one trip between two points. "Trips" refers to vehicle trips. Two people traveling together in an auto, TNC or taxi count as two riders but as one trip.

Personal vehicle (or personal auto)

- Motor vehicle owned or leased by individuals or households, e.g., "the family car." Does not include taxis or TNCs.

ADA Paratransit

- Transportation for people with disabilities who are unable to use the regular, fixed route rail and bus service.
- Usually a door-to-door service using vans and/or sedans.
- Trips are generally arranged in advance.
- Transit agencies are mandated to provide ADA paratransit service by the federal Americans With Disabilities Act (ADA).
- The service is typically provided by private companies under contract with the local transit agency.

Executive Summary

Municipal and civic officials in cities across the country are grappling with how to respond to the unexpected arrival and rapid growth of new mobility services. These include ride services such as Uber and Lyft (also called Transportation Network Companies, or TNCs), "microtransit" companies such as Via and Chariot and more recently dockless bikeshare and electric scooter offerings.

Are these new mobility options friendly to city goals for mobility, safety, equity and environmental sustainability? What risks do they pose for clogging traffic or poaching riders from transit? What will happen when self-driving vehicles are added to ride-hail fleets?

While these questions are widely discussed, the information available to inform policy making is limited and often fragmentary. This report is designed to fill the gap, focusing on ride services (TNC and microtransit), which currently produce the most far-reaching issues among new mobility offerings.

This report combines recently published research and newly available data from a national travel survey and other sources to create the first detailed profile of TNC ridership, users and usage. The report then discusses how TNC and microtransit services can benefit urban transportation, how policy makers can respond to traffic and transit impacts, and the implications of current experience for planning and implementation of shared autonomous vehicles in major American cities.

Key results, conclusions, methodology and sources are summarized below. (Additional details on methods and sources are provided in section 2 of this report.)

TRIPS, USERS AND USAGE

1) TNCs have more than doubled the overall size of the for-hire ride services sector since 2012, making the for-hire sector a major provider of urban transportation services that is projected to surpass local bus ridership by the end of 2018.

- TNCs transported 2.61 billion passengers in 2017, a 37 percent increase from 1.90 billion in 2016.
- Together with taxicabs, the for-hire sector is projected to grow to 4.74 billion trips (annual rate) by the end of 2018, a 241 percent increase over the last six years, surpassing projected ridership on local bus services in the United States (4.66 billion).

Sources/methodology: TNC trips and ridership based on published data on Lyft ridership and market share for 2017. Taxi ridership based on published data for 2012 and city-specific reports of declines since 2012. Bus ridership based on American Public Transportation Association data.

2) TNC ridership is highly concentrated in large, densely-populated metro areas. Riders are relatively young and mostly affluent and well-educated.

- 70 percent of Uber and Lyft trips are in nine large, densely-populated metropolitan areas (Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Francisco, Seattle and Washington DC.)
- People with a bachelor's degree, over $50,000 in household income, and age 25 to 34 use TNCs at least twice or even three times as often as less affluent, less educated and older persons.

Sources/methodology: National Household Travel Survey; published TNC trip totals in Massachusetts municipalities; industry sources.

3) TNCs dominate for-hire operations in large urban areas. But residents of suburban and rural areas, people with disabilities and those without smartphones continue to be reliant on traditional taxi services.

- TNCs account for 90 percent of TNC/taxi trips in eight of the nine large, densely-populated metro areas (New York is the exception) and in other census tracts with urban population densities.
- In suburban and rural areas, however, taxis serve slightly more riders than TNCs. The same is true in New York City (counting car services in the taxi category).
- People with disabilities make twice as many TNC/taxi trips as non-disabled persons, but taxis account for two-thirds of their TNC/taxi trips.
- TNCs account for only 13 percent of TNC/taxi trips taken by those without a smartphone.

Sources/methodology: National Household Travel Survey.

ROLE IN URBAN MOBILITY

1) TNCs added billions of miles of driving in the nation's largest metro areas at the same time that car ownership grew more rapidly than the population.

- TNCs have added 5.7 billion miles of driving annually in the Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Francisco, Seattle and Washington DC metro areas.
- Household car ownership increased across all large U.S. cities from 2012 to 2016, in all but a few cities exceeding the rate of population growth.

Sources/methodology: Mileage based on trip volumes (see above) and analysis of mileage increases from TNC growth from later in the report. "Additional mileage" includes both miles with passengers and mileage between trips and nets out reductions due to TNC passengers switching from their personal vehicle. Household car ownership is from American Community Survey.

2) TNCs compete mainly with public transportation, walking and biking, drawing customers from these non-auto modes based on speed of travel, convenience and comfort.

- About 60 percent of TNC users in large, dense cities would have taken public transportation, walked, biked or not made the trip if TNCs had not been available for the trip.
- About 40 percent would have used a personal vehicle or a taxicab had TNCs not been available for the trip.

Sources/methodology: Published data based on surveys of TNC users in the cities of Boston, Chicago, Denver, Los Angeles, New York, San Francisco, Seattle and Washington DC and a statewide survey in California.

3) TNCs are not generally competitive with personal autos on the core mode-choice drivers of speed, convenience or comfort. TNCs are used instead of personal autos mainly when parking is expensive or difficult to find and to avoid drinking and driving.

- The most-often cited reasons to use TNCs instead of personal autos involve expense or hassle with parking and to avoid drinking and driving. Speed, comfort and convenience are cited rarely or never.

Sources/methodology: Published results of surveys of TNC users in the cities of Boston, Chicago, Denver, Los Angeles, New York, San Francisco, Seattle and Washington DC.

SHARED RIDES AND TRAFFIC

1) Shared ride services such as UberPOOL, Uber Express POOL and Lyft Shared Rides, while touted as reducing traffic, in fact add mileage to city streets. They do not offset the traffic-clogging impacts of private ride TNC services like UberX and Lyft.

- Private ride TNC services (UberX, Lyft) put 2.8 new TNC vehicle miles on the road for each mile of personal driving removed, for an overall 180 percent increase in driving on city streets.
- Inclusion of shared services (UberPOOL, Lyft Line) results in marginally lower mileage increases – 2.6 new TNC miles for each mile in personal autos taken off the road. (This is based on the current rate of about 20 percent of TNC trips being shared.)
- Lyft's recently announced goal of 50 percent of rides being shared by 2022 would produce 2.2 TNC miles being added to city streets for each personal auto mile taken off the road.
- Shared rides add to traffic because most users switch from non-auto modes. In addition, there is added mileage between trips as drivers wait for the next dispatch and then drive to a pick-up location. Finally, in even a shared ride, some of the trip involves just one passenger (e.g., between the first and second pick-up).

Sources/methodology: Analysis based on published mileage for passenger trips and mileage between passenger trips and published data on rates of pooled rides.

PUBLIC POLICY

1) TNCs and microtransit can be valuable extensions of – but not replacements for – fixed route public transit.

- Pilot programs around the country demonstrate that TNCs and other private transportation companies can help provide subsidized services to seniors, low-income persons and some people with disabilities.
- TNCs and other private transportation companies also show promise in providing subsidized connections to public transit services, e.g., taking commuters to rail and bus stations and park-and-ride lots.
- TNCs and microtransit companies like Via can also be helpful in providing subsidized transportation for trips that are geographically dispersed. Trip volumes tend to be quite low, however, and unless there are common origins or

destinations like a transit hub, relatively few trips are shared between passengers.

Sources/methodology: Published reports, news articles and personal interviews.

2) Trip fees, congestion pricing, bus lanes and traffic signal timing can help cities manage current congestion generated by increasing TNC trip volumes combined with other demands on limited street space.

- States and cities are generating valuable revenues for public transportation and other purposes from fees and taxes on TNC trips.
- Other measures to alleviate congestion can be valuable where there is public support and where competing needs for street space can also be accommodated.

Sources/methodology: Analysis of recent policies implemented by city and state governments based on published reports and news articles and personal interviews.

3) If additional steps are needed to reduce traffic congestion, policy makers should look toward a more far-reaching goal: less traffic. Key steps involve limiting low-occupancy vehicles, increasing passenger occupancy of TNCs and taxis, changing commercial vehicle operations, and ensuring frequent and reliable bus and rail service.

- Working toward a goal of less traffic means making space-efficient modes such as buses and bikes more attractive than personal autos and TNCs on key attributes of speed, reliability, comfort and cost.
- Policies can include limiting parking supply and limiting or banning low-occupancy vehicles from certain streets (possibly based on time of day). These serve to discourage personal vehicle use in congested areas.
- Policies can also increase utilization rates of TNCs and taxis so they spend less time without passengers and carry more passengers per mile of overall operation.
- An essential additional element is providing frequent and reliable bus and rail service. Less traffic will make bus service more attractive and build ridership, creating a virtuous cycle of faster trips, shorter waits, easier transfers and thus broader accessibility.

Sources/methodology: Analysis of recent policies being discussed or implemented by city governments based on published reports, news articles and personal interviews.

AUTONOMOUS VEHICLES

1) Without public policy intervention, the likelihood is that the autonomous future mirrors today's reality: more automobility, more traffic, less transit, and less equity and environmental sustainability.

- Tech companies, automakers and others are currently racing toward an autonomous future that envisions shared, door-to-door ride services weaning people from personal autos and combining the convenience of TNCs with the space-efficiency of shared trips.
- Today's TNC experience, however, calls into question the viability of the door-to-door shared service model. Most Uber and Lyft rides are still private rides (each traveling party riding by themselves) and the addition of pooled options fails to offset TNC traffic-clogging effects.
- Uber and Lyft are investing heavily in options like Uber Express POOL and Lyft Shared Rides that minimize turns to straighten out the zig-zag routing that limits the popularity of door-to-door pooled rides. Even if successful, these services are unlikely to draw people from their personal autos and will thus serve to add to traffic congestion.

Sources/methodology: Analysis of TNC service models and traffic impacts.

2) Policy-makers should steer AV development away from this future starting today with steps to manage TNCs and personal autos and emphasize frequent, reliable and comfortable high-capacity transit service.

- Key steps are limiting personal auto use in congested city centers; requiring that TNCs and other fleet-operated vehicles use street space efficiently; and providing high-frequency transit service.

CONCLUSION

New mobility has much to offer cities: convenience, flexibility, on-demand technology and a nimbleness to search for the fit between new services and inadequately served markets. But development of ride services must take place within a public policy framework that harnesses their potential to serve the goals of mobility, safety, equity and environmental sustainability. Without public policy intervention, big American cities are likely to be overwhelmed with more automobility, more traffic and less transit and drained of the density and diversity which are indispensable to their economic and social well-being.

1. Introduction

Uber and Lyft have become household names, ever-present in the news and on millions of smartphones and credit card bills. Yet accompanying their familiarity are many gaps. The business pages report the multi-billion-dollar valuations of Uber and Lyft, but not how many passengers they transport. Patrons experience them as providing a welcome new mobility option, but to whom exactly? Everyone knows they are growing rapidly, but what is their role in urban transport systems? News articles point to connections between TNC growth, traffic congestion and falling public transportation ridership, but what do these trends mean for public policy?

This report seeks to add facts and analysis to the increasingly important public discussion of these "new mobility" services. The report focuses mainly on "Transportation Network Companies," or TNCs, also called ride-hail or sometimes rideshare companies. Uber and Lyft are the main two companies in the United States, available to almost the entire American population, and the focus of this discussion. This report also looks at "microtransit" companies that pick up passengers along a route that may be predetermined or assembled on the fly by sophisticated computer algorithms. Chariot, which started in San Francisco, and Via, which first operated in New York City, are the main two microtransit companies and now operate in about a dozen U.S. cities.

After a review of sources and methodology in section 2, the report provides an overview of TNC ridership – how many trips, who uses, for what types of trips and where in sections 3 and 4. This profile uses a combination of data sources to provide the most detailed and comprehensive profile of TNC usage and users yet available. Its main conclusion – that TNC trips are concentrated in a relatively small number of large metro areas, and that users are predominantly affluent, educated and skew younger – will likely surprise few readers. However, putting numbers on intuition does provide a few twists in the storyline and creates an important factual basis for the more policy-focused discussion that follows.

TNCs have recently begun to push back against the narrative that developed in 2017 that they are contributing to big-city traffic congestion and falling transit ridership. They say they are a complement to public transit, not its competitor, and point to their heavily-promoted shared-trip options. The fifth section of the report assesses these claims.

There has been much interest across the country in "partnerships" between TNCs and microtransit companies on the one hand and cities and transit agencies on the other hand. Perhaps these private companies can truly complement transit services, or replace very inefficient bus routes, or reduce costs for services to seniors and people with disabilities. Pilot projects are beginning to show the potential for creating public benefits that merit public subsidy – and the limits as well. Section 6 looks at the experience with these pilots and what approaches have the most promise for public benefit.

The final two sections of the report examine some of the most-discussed aspects of TNCs and microtransit: what to do about traffic and transit impacts in big cities, and what they mean for a future in which self-driving vehicles are integrated into TNC operations.

The ride services and public policy issues discussed in this report are evolving rapidly and leave many uncertainties. But after six years of TNC growth, the picture is becoming more and more clear. In the process, policy implications and policy options are coming into focus. Thus, it is timely to be asking and putting forth at least preliminary answers to the three questions that are the focus of this report. What's happening? What does it mean? What should cities be doing?

2. Methodology

Findings in this report draw on published reports and news articles and newly available national travel survey and TNC trip data that have become available over the last 18 months. Information from this range of sources is brought together to form a detailed picture of TNC operations and discuss policy issues arising from their rapid growth. Results are presented nationally, with detail for cities and metro areas where available.

This section presents information on key data sources and methodology. Additional data sources used for specific tables and figures are referenced where results are presented.

TRIP AND RIDERSHIP VOLUMES

The report presents total TNC trips for the United States and for groups of metropolitan areas. Estimates of total trips are based on 2017 ridership reported by Lyft (365 million trips) and Lyft's market share based on credit card transactions compiled by the research firm Second Measure.[1]

Geographic breakdowns of trip volumes are estimated using a combination of sources. These include TNC trip counts in New York and several other major cities that TNCs provided to city or state agencies; results from the 2016-17 National Household Travel Survey (NHTS); and data from industry sources showing relative trip volumes for different size metro areas and urban and suburban/rural population densities. In addition, data released by the Massachusetts Department of Public Utilities showing TNC trip volumes for Massachusetts municipalities was used as a check against results from national estimates.

TNC ridership figures assumes 1.5 passengers per trip, based on a customer survey conducted in the Boston area and NHTS data showing average personal auto occupancy for urban trips of 1.5 passengers (including the driver).[2]

Taxicab ridership was based on a Transportation Research Board report for 2012,[3] combined with estimated declines in taxi ridership based on city-specific data where available, and news reports.

USER AND TRIP CHARACTERISTICS

The main data source for TNC user and trip characteristics is the 2016-17 National Household Travel Survey (NHTS). The 2016-17 NHTS was the first national travel survey conducted since 2009, and thus is quite timely for documenting information about TNC users.

The NHTS consists of an interview portion, in which each respondent answers a series of questions, and a travel diary, which captured details of each trip on a designated day. These include mode, start and end times of each trip, trip distance and trip duration. A total of 264,000 people completed the 2016-17 NHTS survey, reporting 924,000 trips (all modes) on the travel day. Data are weighted to reflect U.S. population characteristics.

There were 3,463 "Taxi/Limo (including Uber/Lyft)" trips in the sample. TNC trips within this group were identified based on responses to a question from the interview portion. This question asked how many TNC trips the respondent took in the past 30 days. For respondents who took one or more TNCs trips in the past 30 days, taxi/limo trips recorded in the travel diary were classified as TNC trips. All others were assumed to be taxi trips. (Limos account for only a tiny percentage of all taxi/limo trips.)

This methodology likely categorized some taxi trips as TNC trips, in the case of respondents who used both taxis and TNCs in the past month. However, the effect appears to be small, for two reasons. First, trip volumes estimated using the interview question (TNC trips in the past 30 days) align closely with results from the travel diary. Second, the market shares for TNC and taxi trips nationally, based on the survey results, aligns closely with national market shares from the estimates described earlier.

GEOGRAPHIC CATEGORIES

This report shows trip volumes and user and trip characteristics for the United States, groups of metro areas and a typology based on population density at the census tract level. The latter categorization is described here.

Generally speaking, TNC usage is strongly related to metro area size and density. On a per capita basis, big, densely-populated cities have higher trip volumes than more sprawling cities, which in turn have higher rates of TNC use than suburban or rural areas. These differences are generally due to differences in the number of households without a personal vehicle and the cost and convenience of parking, both of which reduce rates of auto travel.

The NHTS data files include the population density of each respondent's home address. To highlight the higher usage of TNCs in more urban, higher-density areas, results are reported separately for persons living in more urban census tracts (defined as at least 4,000 persons per square mile) and for those living in suburban or rural census tracts (fewer than 4,000 persons per square mile). This cutoff for urban versus suburban/rural is consistent with research showing that people living in neighborhoods with more than 4,000 persons per square mile tend to see themselves as living in urban neighborhoods; conversely, those living in areas with fewer than 4,000 persons per square mile tend to see their neighborhoods as suburban or rural.[4]

The urban category includes virtually the entire populations of large, dense cities such as New York, Chicago and Philadelphia, as well as the relatively dense portions of their suburbs. "Urban" census tracts also cover most of the population of large but less dense cities such as Baltimore, Detroit, Minneapolis and Milwaukee. In addition, there are numerous urban-density census tracts in smaller cities and towns, primarily in older, walkable residential neighborhoods. Maps of selected metro areas showing census tracts classified as urban is available at www.schallerconsult.com/rideservices/maps.

To show differences in TNC usage rates in section 3, a three-part typology was developed based on population density and size of metro area:

- Large, densely-populated metro areas (a group of 9 metros, listed below).
- Large but less-densely populated metro areas (a group of 11 metros)
- All other metro areas combined with non-metropolitan and rural areas.

The first group is composed of Boston, Chicago, Los Angeles, Miami, New York, Philadelphia, San Francisco, Seattle and Washington DC. These metro areas and their central cities have high population densities and large numbers of no-car households and public transportation commuters. This group is intuitive as encompassing the country's distinctively large, dense, urban centers with a host of leisure and entertainment activities and multi-modal transportation system.

The second group consists of eleven large metro areas that have at least 300,000 people living in urban census tracts but fewer no-car households and public transit commuters and a generally less multi-modal transportation system than the first group. These are Baltimore, Dallas, Detroit, Denver, Houston, Milwaukee, Minneapolis, Phoenix, San Antonio, San Diego and San Jose.

It should be noted that any list of metro areas aimed at capturing size, density and urban character is necessarily arbitrary. A larger list could easily include Portland (Oregon), Las Vegas, Riverside (California), Sacramento, Cleveland and Austin. However, the typology of these 20 metro areas works well in practice to portray patterns of TNC use across different types of urban and suburban land uses.

The Appendix contains detailed data on each of the 20 metro areas and their central cities.

3. How Big

Taxicabs for many decades served niche markets ranging from business travelers to low-income households without a personal auto. Cabs were usually readily available at airport taxi stands and downtown hotels and entertainment venues. But otherwise, service availability could be unreliable and wait times unpredictable, with wait times commonly running 10 to 15 minutes or longer. Using a cab was often further complicated by the small-scale and fragmented nature of the industry, with different companies in each local market, each with their own branding and business practices.

TNCs changed all that. Lyft and Uber are now available to nearly all Americans. The same smartphone app can be used throughout the country and internationally. Pick-up times are prominently shown counting down the minutes until the driver arrives. Uber and Lyft are well-known brands and deliver a much more consistent user experience than was possible for taxicabs.

RIDERSHIP GROWTH

TNCs' popularity has transformed the for-hire sector into a major provider of urban transportation service, rivaling other non-auto modes of travel. Figure 1 shows estimated TNC and taxi ridership over the past quarter century.

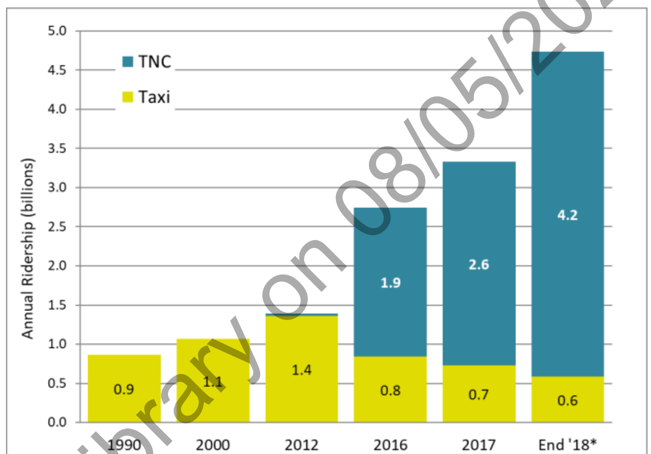
TNCs are popularly assumed to have revived a moribund taxi sector. In fact, taxi ridership had been increasing prior to 2012. As shown in Figure 1, taxi ridership grew substantially in the 1990s and 2000s, showing about a 30 percent increase from 2000 to 2012, reflecting growth in population, jobs and tourism in cities across the country.[5]

Not surprisingly, as TNCs started to spread across U.S. cities in 2012, growth in for-hire ridership accelerated, reaching 3.3 billion passengers (2.61 billon TNC and 730 million taxi) in 2017, an increase of 140 percent from 2012.

Uber and Lyft's growth came in part from traditional taxis. About 20 percent of the 2.61 billion TNC ridership in 2017 represents a loss of taxi ridership, which declined by about 50 percent from 2012 to 2017.

TNCs also attracted people from rental cars, buses, subways and personal motor vehicles, with the result that about 80 percent of TNC ridership represents net growth in the for-hire sector.

Figure 1. TNC and taxi ridership in the U.S., 1990-2017
(annual ridership, in billions)



Sources: See Methodology section

TNCs continue to grow very rapidly. By the end of 2018, ridership is projected to reach an annual rate of 4.2 billion passengers. At this rate of growth, for-hire ridership (combining TNCs and taxis) will surpass ridership on local buses in the United States by the end of 2018. If current trends continue, the gap will widen over time, given that bus ridership fell from 5.5 billion in 2012 to 4.8 billion in 2017.

GEOGRAPHIC CONCENTRATION OF TNC TRIPS

As shown in Figures 2 and 3, TNC usage is concentrated in the nation's largest and most densely populated urban centers.

- The nine largest and most densely-populated metropolitan areas in the United States accounted for 1.2 billion trips, or 70 percent of TNC trips nationally. This includes 215 million trips in the New York area and a total of 1.0 billion trips in the Boston, Chicago, Los Angeles, Miami, Philadelphia, San Francisco, Seattle and Washington DC metro areas.
- 11 large but less densely-populated metro areas accounted for 171 million trips in 2017. (These 11 metros are Baltimore, Dallas, Denver, Detroit, Houston, Milwaukee, Minneapolis, Phoenix, San Antonio, San Diego, and San Jose.)
- The remainder of the U.S. accounted for 344 million TNC trips.

Figure 2. TNC trips by metro area group, 2017
(annual trips, in millions)

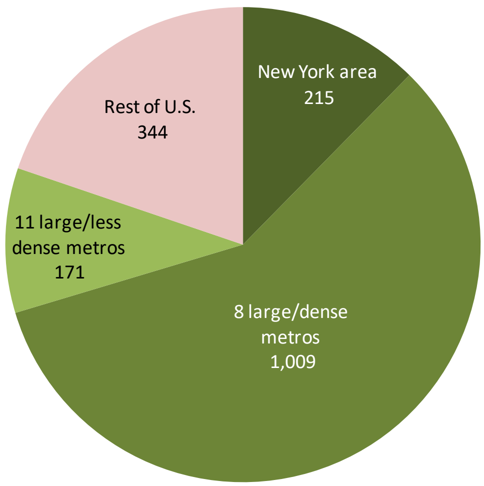
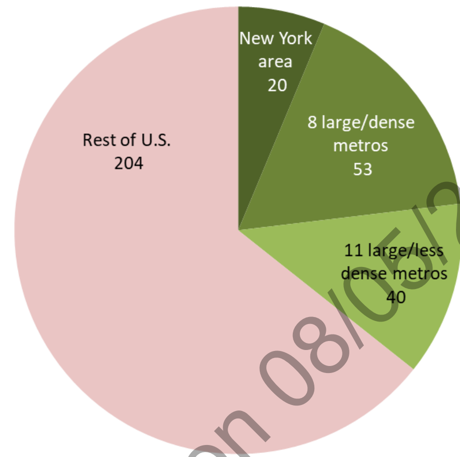


Figure 3. Population by metro area group
(population in millions)



The 8 large metro areas are Boston, Chicago, Los Angeles, Miami, Philadelphia, San Francisco, Seattle and Washington DC metro areas.
The 11 metro areas are Baltimore, Dallas, Denver, Detroit, Houston, Milwaukee, Minneapolis, Phoenix, San Antonio, San Diego, and San Jose.

Sources: See Methodology section.

The 9 large metro areas accounted for 70 percent of all TNC trips while having 23 percent of total U.S. population, indicating much higher usage rates than in the rest of the U.S. (See Figure 3.)

Furthermore, TNC trips are concentrated within the central cities and other census tracts with relatively urban population densities:

- 38 percent of all TNC trips were in the center city of the 9 large metro areas listed above.
- 26 percent were in urban-density census tracts (population densities over 4,000 persons per square mile) outside the central city in these 9 metro areas. Included in this group are cities that are separate from the central city such as Newark, Oakland and Long Beach, and higher-density suburban areas such as Orange County, California.
- 7 percent were in suburban or rural areas in these 9 large metro areas (census tracts with less than 4,000 persons per square mile).

The nine large metro areas have high densities of population and employment, large transit systems and a substantial number of households that do not have a motor vehicle. They also have very substantial levels of entertainment and social activity and draw large numbers of business and leisure travelers. The combination of density, transit usage, relatively low rates of car ownership, and social and entertainment activity contribute to much more frequent use of TNCs among their residents.

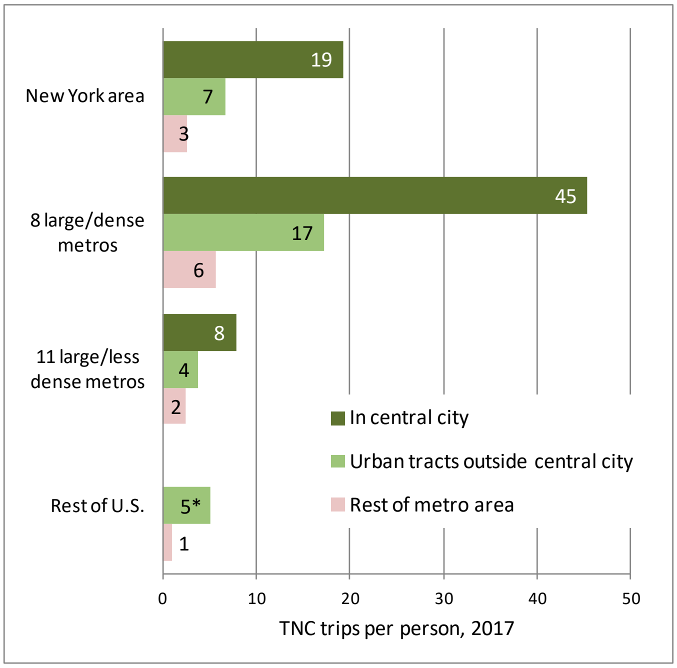
The group of 11 large but less dense metro areas accounted for 10 percent of all TNC trips. Trips were divided about evenly between the central city and the rest of these metro areas.

Outside these 20 large metro areas, TNC trips were split about evenly between urban-density census tracts and areas with suburban and rural population densities.

TRIP RATES

Figure 4 shows trip rates for central cities, urban census tracts outside the central city, and suburban/rural tracts. Annual TNC trips per resident are far higher in the central city and urban portions of large metros than elsewhere in the country. In the central cities of the eight largest, most densely-populated metros (excluding New York), there were 45 TNC trips per person in 2017. Trip rates were lower but still substantial in urban tracts outside the center city (17 trips annually per person) and much lower in suburban and rural tracts (6 per person).

Figure 4. TNC trips per person by metro area size and density, 2017 (TNC trips per person, annually)



* In Rest of U.S., the 5 trips per person is for all urban-density census tracts (over 4,000 persons per square mile) and the 1 trip per person figure is for all suburban/rural tracts.

Sources: See Methodology section.

Perhaps counter-intuitively, TNC trip rates in the New York metro area are lower than for the other 8 large metros. This is primarily because taxicabs account for an approximately equal number of trips as TNCs in the New York area. By contrast, taxi ridership in the other 8 large metros is approximately 15-20 percent of combined TNC/taxi ridership. Using combined New York taxi, TNC and other for-hire services' trip volumes, trip rates for all for-hire services are similar in the New York metro area as in the other 8 large metros.

In the next group of 11 large but less densely-populated metro areas, TNC trip rates are one-third to one-fifth those found in the 8 large metros.

The concentration of TNC trips in the core of just nine major metropolitan areas is quite striking. It underscores concerns discussed in section 7 about potential traffic and transit impacts of TNC growth. At the same time, it should be recognized that a substantial number of TNC trips in these large metro areas are outside the most congested downtown core neighborhoods. News reports have documented the value of Uber and Lyft service in some of these neighborhoods,[6] although studies have also shown mixed results about TNC service in minority areas with relatively less transit service.[7] Equity issues are

Table 1. TNC and taxi trips in selected cities, 2017
(annual trips in millions)

City	2017 trips (millions) TNC	Taxi	Total
San Francisco	75	6	81
Washington DC	45	12	57
Boston	35	6	41
Seattle	20	3	23
New York City*	159	167	326
Manhattan	66	106	172

Table 2. TNC and taxi trips per person in selected cities, 2017

City	Trips per person, annually: TNCs	TNC+taxi
San Francisco	86	93
Washington DC	66	84
Boston	54	64
Seattle	33	37
New York City*	19	39
Manhattan	42	108

Data are for central cities (not metro areas).
*New York City includes both Manhattan and the other 4 boroughs.

Sources: Faiz Siddiqui, "As ride hailing booms in DC, it's not just eating into the taxi market — it's increasing vehicle trips," Washington Post, April 23, 2018. Massachusetts Department of Public Utilities, "Rideshare in Massachusetts," available at https://tnc.sites.digital.mass.gov. Kelly Rula, Seattle Department of Transportation (personal correspondence), May 29, 2018. San Francisco estimated based on intra-Manhattan trips reported in San Francisco County Transportation Authority, "TNCs Today," June 2017. Author's analysis of NYC Taxi and Limousine Commission TNC and taxi trip data.

particularly important where TNCs growth comes at the expense of traditional taxi operations.

DATA FOR SELECTED CITIES

TNC and taxi trip volumes are available at the city level for a few large cities. In addition, the State of Massachusetts recently released TNC trip totals for all cities in Massachusetts.

Table 1 summarizes the TNC and taxi trip volumes data for San Francisco, Boston, Washington DC, Seattle and New York City overall, and for Manhattan only. (Like San Francisco, Boston and Washington DC, Manhattan comprises the relatively small core of a large metro area and is more comparable in population to the other three cities than is New York City as a whole.)

Table 3. Trip volumes and trip rates in Massachusetts

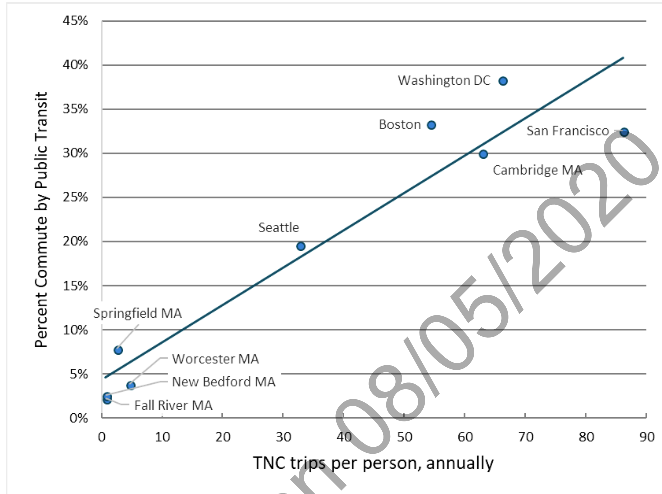
Municipality	TNC trips, 2017	TNC trips per person
Boston MA	34,911,476	54.1
Cambridge MA	6,782,366	62.8
Somerville MA	2,727,951	35.7
Brookline MA	2,074,425	28.3
Newton MA	1,051,030	13.3
Medford MA	966,710	16.3
Quincy MA	957,311	10.3
Malden MA	906,043	14.9
Worcester MA	848,943	4.6
Everett MA	775,773	17.7
Revere MA	722,136	13.6
Waltham MA	711,420	11.4
Chelsea MA	656,686	17.5
Lynn MA	549,822	6.0
Lowell MA	490,389	4.5
Brockton MA	433,885	4.6
Springfield MA	378,381	2.5
Lawrence MA	350,752	4.5
Salem MA	296,482	7.0
Arlington MA	258,133	5.8
Belmont MA	195,807	7.7
Melrose MA	129,355	4.7
New Bedford MA	64,621	0.7
Fall River MA	59,477	0.7
Swampscott MA	51,522	3.6
Marblehead MA	43,184	2.1

Sources: Massachusetts Department of Public Utilities, "Rideshare in Massachusetts," available at https://tnc.sites.digital.mass.gov, and U.S. Census Bureau, American Community Survey for city population.

The number of TNC trips varied from 20 million in Seattle to 75 million in San Francisco and 159 million in New York City in 2017. (See Table 2.) On a per capita basis, San Francisco, Boston, Washington DC and Manhattan have between 42 and 86 TNC trips per person per year. (See Table 3.) Manhattan is at the bottom end of this range, but that is largely because of much higher taxi usage in Manhattan. Combining TNC and taxi trips, Manhattan moves to the top of the list. (See Table 2.)

Among cities in Massachusetts, Cambridge, Somerville and Brookline (in addition to Boston) had at least 28 TNC trips per person in 2017. (See Table 3.) Seattle is also in this range, with 33 TNC trips per person.

Figure 5. TNC trips per person and percent commuting by public transit, selected cities



Sources: TNC trips per person from Tables 2 and 3. Public transit commuters from American Community Survey, average 2011-15. Data are for central cities (not metro areas).

TNC usage closely parallels public transportation ridership. Figure 5 shows TNC trips per person in selected cities where data is available together with the percentage of residents in these cities who commute by public transportation (based on Census data).

As can be seen, cities with higher transit commute shares also have relatively high rates of TNC use. This is further indication of an overlapping TNC and transit customer base. This relationship is not surprisingly since TNCs and transit draw from the same well of people who do not exclusively use their own vehicle to get around. (Note that the graph shows correlation between TNC and transit use. Whether this correlation translates into TNCs being competitive with or complementary to transit is addressed in section 5.)

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4. Who Uses

From their early days in San Francisco, Lyft and Uber have rapidly gained ridership by offering quick, convenient ride service in major U.S. cities. Closely associated with the popularity of urban lifestyles, their ridership skews urban, young, educated and affluent. Newly released data from the National Household Travel Survey (NHTS) paint a detailed picture of the demographic and trip characteristics of TNC users.

The data presented here are for adults age 18 and over, for TNC and taxi trips in their home area. The relatively small number (about 10 percent) of TNC trips undertaken while out of town all day are not included in these data.

Trip rates shown here are somewhat lower than in the previous section. This reflects in part differences in timing; most of the NHTS data was collected in 2016 whereas trip volumes in the previous section are for 2017. It also reflects underreporting of trips that is common for travel surveys that do not use GPS to track respondents on their travel day.

AGE, EDUCATION, INCOME AND OTHER CHARACTERISTICS

Figures 6 to 8 show rates of TNC use by age, education and income. This section shows results for the following three geographic areas:

- "Urban - 9 metros" is for urban census tracts (over 4,000 persons per square mile) in the nine large, densely-populated and multi-modal U.S. metro areas identified earlier. (Urban census tracts are both in and outside the central city of each metro area.)
- "Other urban" are census tracts with over 4,000 persons per square mile outside the nine large metros. This group combines the 11 large, less-dense metro areas discussed in section 3 with all other urban-density census tracts as the two groups show similar characteristics in the NTHS data.
- "Suburban and rural" are all census tracts with fewer than 4,000 persons per square mile. These include suburban and rural areas within metro areas and in non-metropolitan areas.

These three categories illustrate differences across key variables of city size and density, and urban versus suburban/rural.

Figures 6 to 8 show that TNC usage is generally higher among younger, more educated and higher income residents. In the "urban – 9 metros" census tracts, TNC usage is highest among:

- 25 to 34 year-olds, followed by those age 18-24 and 35-54;
- Residents with a college degree
- Residents living in households with incomes of $50,000 or more.

Older persons, those with less than a college degree and households with incomes under $50,000 show the lowest rates of TNC use in the nine large metros.

Overall trip rates are lower in other urban census tracts and suburban/rural areas as compared with urban residents in the 9 large/dense metros. However, the same patterns hold for age, education and income groups. TNC trip rates are highest among younger, more educated and more affluent residents.

In addition, residents of very low-income households (income under $15,000) use TNCs somewhat more frequently than middle-income residents in these areas. This reflects lower rates of car ownership in this group.

Figure 9 to 11 show TNC usage rates by gender, car ownership and access to smartphones:

- Across geographic groups, men are somewhat heavier users of TNCs than women, but the differences are modest.
- Not owning a car is highly related to TNC use in all geographic areas. Those without a car in their household use TNCs 2.5 times more often than car owners in the "urban – 9 metros" group; 3.6 times more often in the "other urban" census tracts; and 6.6 times more often in suburban and rural areas.
- Another major factor, not surprisingly, is access to a smartphone, which is generally necessary to use TNC services. Figure 11 shows that very few TNC trips are reported by households without a smartphone. (The small number shown may be situations in which a person rode with someone who has a smartphone.) People without a smartphone do, however, use taxicabs at a somewhat higher

Figure 6. TNC trip rates by age

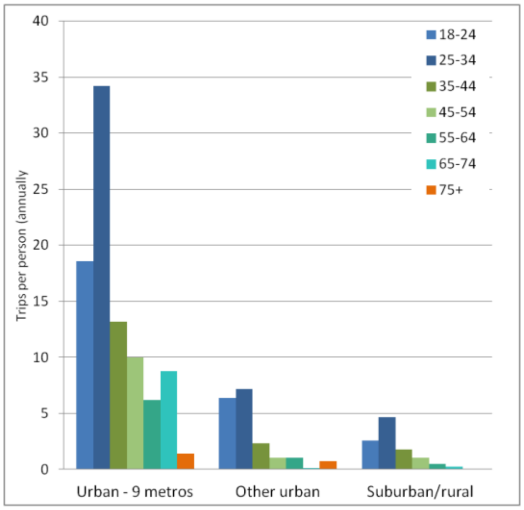


Figure 7. TNC trip rates by educational level

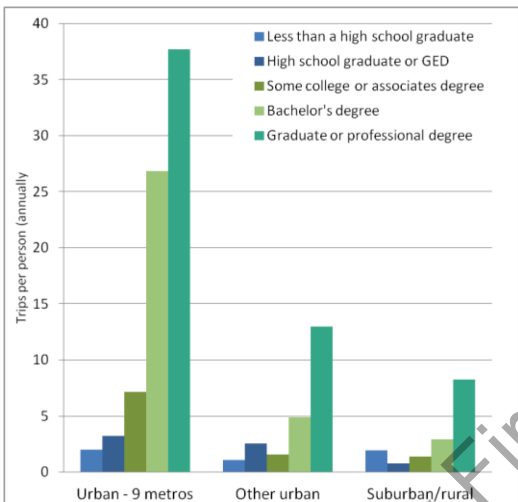


Figure 8. TNC trip rates by household income

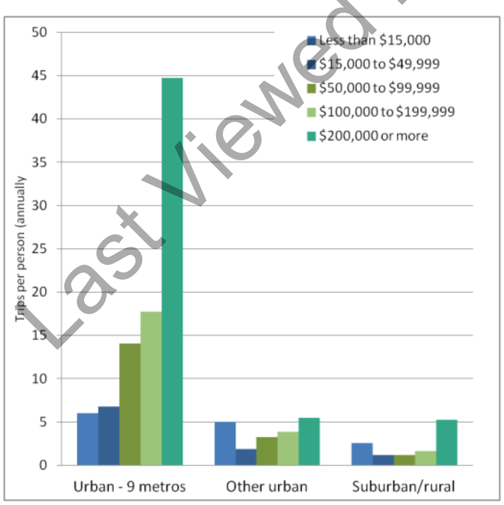


Figure 9. TNC trip rates by gender

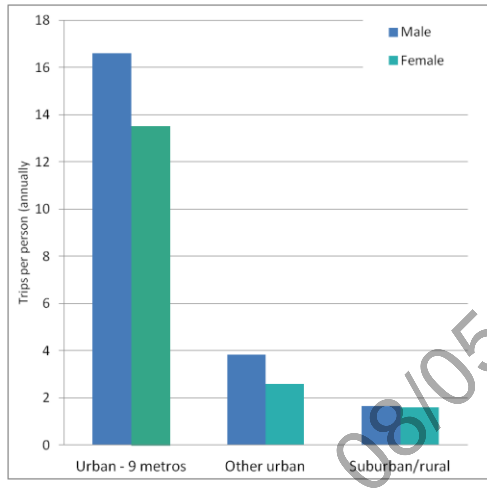


Figure 10. TNC trip rates by whether vehicle is available to the household

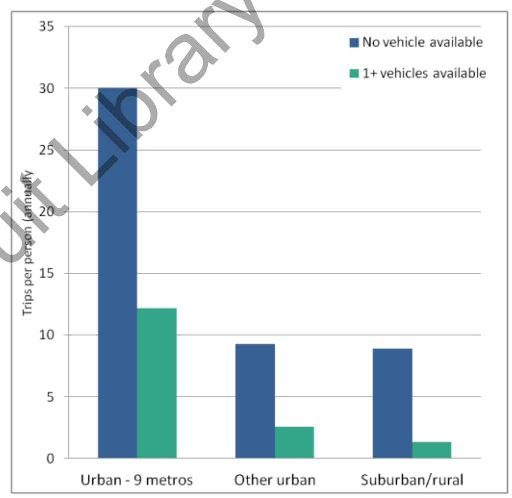
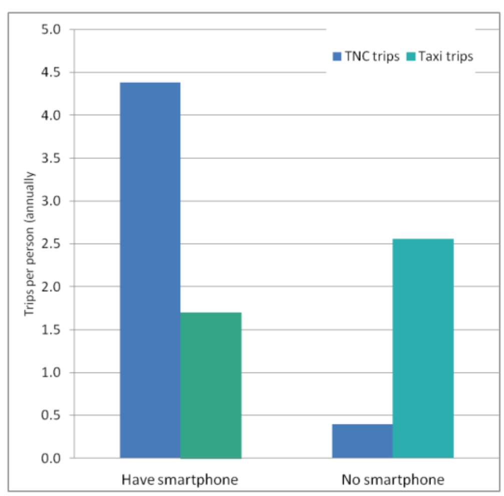


Figure 11. TNC and taxi trip rates by whether traveler has a smartphone available to household



Figures 6 to 12 show annual TNC trips per person, adults age 18 and over, for local travel (not out of town all day) rate than smartphone owners. The lack of a smartphone likely accounts for higher reliance on taxicabs among non-smartphone owners.

TNC AND TAXI RIDERSHIP

Although TNCs have largely displaced taxis as the main provider of for-hire service in the United States, some areas see more of an even split in ridership between TNCs and cabs.

Figure 12 shows that:

- TNCs account for 90 percent of for-hire (TNC and taxi) trips in the eight large metros outside the New York area;
- In other urban census tracts TNCs account for 80 percent of for-hire trips.
- In suburban and rural areas, trip volumes are about the same for taxicabs as for TNCs.
- There is also a nearly even split in urban census tracts in the New York area (most of which are in New York City).

PEOPLE WITH DISABILITIES

People with disabilities are more reliant on for-hire services, in particular taxicabs, than non-disabled persons. While non-disabled people make 4.1 for-hire trips annually, people with disabilities make twice as many trips (8.2 per year). (National data only; sample size too small for geographic detail.)

People with disabilities are also more reliant on taxicabs than the general population. People with disabilities take 5.9 taxi trips annually, twice their use of TNCs (2.3 trips per year).

TRIP CHARACTERISTICS

TNC trips include a mix of trip purposes that typify travel by other modes. Work trips are about 20 percent of all trips, typical of personal auto use. The other major trip purposes are social and recreational trips and going home. Social and recreational trips are somewhat more frequent in urban areas while work trips are somewhat more frequent in suburban/rural areas. See Table 4.

TNC trips typically travel 6.1 miles with a duration of 23 minutes, implying an average speed of 16 mph. Trips in large, densely-populated metro areas tend to be somewhat shorter (4.9 miles) and slower (13 mph). Trips in suburban and rural areas tend to be somewhat longer in distance (8.7 miles) and faster in speed (20 mph). Table 5 show average TNC trip distance, duration and speed.

Figure 12. TNC and taxi trip rates

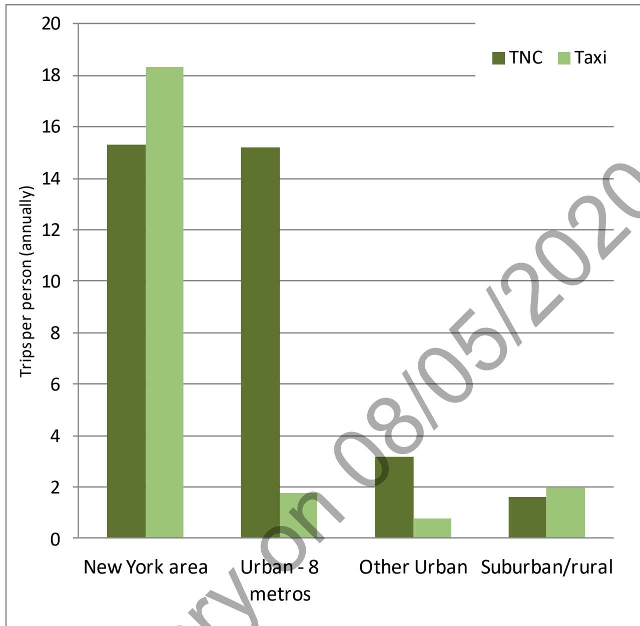


Table 4. Trip purpose for TNC trips

	Urban census tracts			
	Boston, Chicago, DC, LA, Miami, NY, Phil., SF, Seattle metros	Other urban tracts	Suburban and rural	Total
Home	41%	41%	37%	40%
Work	15%	20%	23%	18%
Social/recreational	20%	20%	12%	18%
Meals	7%	5%	6%	6%
Shopping/errands	4%	5%	4%	4%
School/daycare/ religious activity	3%	1%	2%	2%
Medical	2%	3%	4%	2%
Transport someone	1%	0%	3%	1%
Something else	8%	6%	9%	8%
Total	100%	100%	100%	100%

Table 5. Trip characteristics for TNC trips

	Distance (miles)	Duration (min.)	Speed (mph)
Urban - 9 metros	4.9	23	13
Other urban	6.1	20	18
Suburban/rural	8.7	26	20
Total	6.1	23	16

These results are consistent with trip data from several other cities and states. Statewide data for Massachusetts shows trips averaging 4.5 miles and lasting 15.4 minutes, for an average speed of 18 miles per hour. In New York City, the average TNC trip is about 5.5 miles in distance and 24 minutes in duration, reflecting relatively lower traffic speeds.

FOR-HIRE RIDERSHIP AMONG ALL MODES

Although at the national level the vast majority of trips are by personal motor vehicle, TNCs and taxis have an important role, particularly for non-car owning households.

Table 6 shows modal shares broken out for households with no car available, and with one or more cars available. In urban census tracts in the nine large, densely-populated metros, 5 percent of all trips are taken by for-hire modes (TNC and taxi). Notably, the percentage is the same in New York as the other 8 metro areas in this group. A similar mode share is also seen in other urban census tracts across the country.

These figures show that persons living in no-car households rely on a mix of travel modes. Although they do not own a car, about one-quarter of their travel involves an automobile, whether getting a ride from a friend, TNCs or taxis. Among no-car households, TNCs and taxis account for about one-half of auto travel in the urban New York area; one-third in urban census tracts in the other eight large, densely-populated metros, and one in eight auto trips elsewhere in the country.

As would be expected, the picture is quite different among people living in households with one or more motor vehicles available to them. In the urban New York area census tracts, the for-hire share is just 3 percent, dropping to 2 percent in other large metro areas (urban census tracts) and less than one percent in the rest of the United States. Walk and transit use also drop among these households, particularly in suburban and rural areas, where autos account for 88 percent of all trips.

Table 6. Modal shares by whether household has motor vehicle available

	Urban census tracts				
Mode	NY metro area	Boston, Chicago, DC, LA, Miami, Phil., SF, Seattle metros	Other urban tracts	Suburban and rural	Total
HOUSEHOLDS WITH NO VEHICLE AVAILABLE					
Auto	4.6%	12.0%	26.9%	35.5%	21.6%
Bus	7.7%	16.3%	18.2%	10.1%	11.8%
Rail	22.7%	9.4%	2.5%	0.3%	8.3%
Taxi/TNC	5.1%	5.2%	3.7%	5.4%	5.0%
Walk	54.4%	50.8%	38.0%	33.1%	42.8%
Other	5.5%	6.4%	10.6%	15.7%	10.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
HOUSEHOLDS WITH 1+ VEHICLES AVAILABLE					
Auto	62.1%	74.4%	83.6%	88.1%	85.3%
Bus	2.0%	1.5%	0.9%	0.3%	0.6%
Rail	7.4%	2.8%	0.4%	0.2%	0.8%
Taxi/TNC	3.3%	1.7%	0.6%	0.3%	0.6%
Walk	22.2%	15.8%	10.6%	6.9%	8.8%
Other	3.0%	3.9%	3.9%	4.2%	4.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Sources: National Household Transportation Survey, 2016-17. Ridership for bus, rail and taxi/TNC are adjusted to match administratively-derived ridership for each mode. Auto, rental car, walk and other are adjusted by factor of 1.16 from NHTS based on average adjustment for bus, rail and taxi/TNC.

Notes: "Urban" defined as census tracts with 4,000 persons/sq. mile or more.

Rail includes subway, light rail, streetcar, commuter rail and Amtrak.

Transit trips are unlinked trips (e.g., bus-to-Metro counts as two trips).

5. Better for Cities?

The previous two sections of this report profiled trip volumes and user and trip characteristics. This section and the next two sections address three questions about the role of TNCs in American cities. First, are TNCs good for cities in the ways that TNCs currently assert? Second, what benefits do they bring to cities that public policy should consider supporting financially or otherwise? Third, what public policies should be considered to address traffic and transit trends related to TNC growth?

The last section of this report then discusses implications for a future world of self-driving vehicles.

TNCS' GOOD-NEWS STORY

TNCs tell a good-news story about how TNCs benefit urban America. They declare that their competition is the personal auto, not public transit. They say their services will strengthen urban transportation systems and their mission is to make car ownership obsolete. They hope to help usher in a new era of multi-modality where most trips are taken in shared and environmentally sustainable modes including shared TNC trips, buses and subways.

However, prominent reports and news articles published over the last 18 months have led to concerns about the relationship between TNC growth, worsening traffic congestion (see box at right) and nearly across-the-board drops in transit ridership in major American cities.

TNCs have pushed back against the narrative that they promote automobility and unsustainably increase traffic congestion while also weakening public transportation. Each of the good-news claims thus deserve careful consideration.

COMPETING WITH THE PERSONAL AUTO?

TNC impacts on auto usage can be assessed through recent research that has focused on large, densely-populated metro areas where traffic and transit issues are most often raised.

First, as has been widely publicized, surveys of TNC users have consistently found greater impacts on public transit than personal vehicle use. The research summary on the next page shows results from studies conducted by academic and governmental researchers. Although the results vary somewhat by locality, the overall picture is clearly that most TNC users would have taken public transportation (15-50 percent), walked or biked (12-24 percent), or not made the trip (2-22 percent) had TNCs not been an option. Consistently across surveys, about 40 percent would have used a personal vehicle or taxi, with surveys generally showing about an even split between the two.

Thus, the overall results show about 60 percent would go by transit, walking, biking (or not make the trip) while about 20 percent would have used their own car and 20 percent a taxi.

These results clearly show that instead of "replacing the personal auto," TNCs in large cities are primarily supplanting more space-efficient modes such as bus, subway, biking and walking.

Survey results also detailed on the next page show the limited appeal of TNCs as compared with personal auto travel. The main reasons to choose TNCs over personal auto are to avoid the cost or hassle of parking and to avoid drinking and driving. These motivations are consistent with trip data showing that

RESEARCH SUMMARY

TRAFFIC IMPACTS

TNCs added 976 million miles of driving to New York City streets from 2013 to 2017. [Schaller Consulting 2018]

"Ride-hailing is likely adding vehicle miles traveled in [seven] major cities." [Clewlow 2018]

TNC usage increased vehicle miles traveled by 85% in the Denver area. [Henao 2017]

TNCs account for 20-26% of trips in the [S.F.] downtown and South of Market areas at peak, "likely exacerbating existing peak period congestion." [SFCTA 2017]

"Ride-hailing is adding new auto trips … [and] exacerbating congestion on the [Boston] region's roadways." [MAPC 2017]

Sources: see page 17.

RESEARCH SUMMARY

MODE TO USE IF NOT TNC

Results from asking what mode survey respondents would have used had ride-hailing service not been available.

UC Davis study of 7 large metros (4,094 residents of Boston, Chicago, Los Angeles, New York, San Francisco, Seattle and Washington DC areas)

- 39% drive alone, carpool, taxi
- 15% rail
- 17% walk
- 7% bike
- 22% not made the trip

[Clewlow 2017]

Boston area (survey of 919 Boston area residents)

- 18% personal vehicle
- 23% taxi
- 42% public transportation
- 12% walk or bike
- 5% would not have made the trip

[MAPC 2018]

New York City (616 NYC residents; multiple responses)

- 12% personal vehicle
- 43% taxi or car service
- 50% public transportation
- 13% walk
- 3% bike
- 2% would not make trip

[NYCDOT 2018]

Denver area (300 Denver-area Uber and Lyft users)

- 26% personal vehicle
- 10% taxi
- 5% other TNC
- 11% ride with someone else
- 22% public transportation
- 12% walk or bike
- 12% would not have made the trip

[Henao 2017]

California: (208 California residents age 18-50 who use Uber or Lyft at least once a month; multiple responses):

- 35% personal vehicle
- 22% ride with someone else
- 51% taxi
- 33% public transportation
- 19% walk or bike
- 4% van or shuttle
- 9% not made trip

[Circella 2018]

RESEARCH SUMMARY

REASONS TO USE

Results from asking why TNC patrons use ride-hailing services instead of other modes (personal vehicle or transit).

UC Davis study of 7 large metros (4,094 residents of Boston, Chicago, Los Angeles, New York, San Francisco, Seattle and Washington DC areas)

Use TNC instead of **personal auto**:

- Avoid DUI
- Parking is difficult to find
- Parking is expensive
- Often going to airport

Use TNC instead of **transit**:

- Transit too slow
- Not available/too few stops or stations
- Transit unreliable

[Clewlow 2016]

Boston area (919 Boston area residents; multiple responses)
Use TNC instead of other options:

- 61% quicker than transit
- 35% no car available
- 23% parking difficult/expensive
- 19% weather
- 18% no available transit
- 12% cannot drive
- 9% multitasking options

[MAPC 2018]

Denver area (survey of 300 Uber and Lyft users)
Use TNC instead of other options:

- 37% going out/drinking
- 20% parking is difficult/expensive
- 17% do not have car available
- 9% cost
- 4% do something while I am riding
- 2% time (e.g. in a rush)
- 2% weather

[Henao 2017]

Sources: see next page.

TNC trips are concentrated in dense urban centers where parking is most likely to be scarce and expensive, and show heavy trip volumes in the late evening when the bars let out.

Notably, only a few percentage of auto users choose TNCs due to convenience or speed of travel. TNCs are thus not attracting drivers on the core mode choice attributes of speed, reliability or comfort. By contrast, the main reasons that people switch from transit to TNCs involve these core attributes: transit too slow, unavailable or unreliable.

In sum, TNCs mainly draw from sustainable and space-efficient modes. They show little appeal for the vast majority of auto trips which do not involve significant parking cost or the desire to avoid driving while under the influence.

SUPPORTING MULTI-MODAL TRAVEL?

There are clearly instances in which the availability of TNC service results in additional public transportation, walking or biking trips. One might take the train or bus to work in the morning, for example, then use a TNC for the late-evening trip home. TNCs can help people use a combination of public transportation and TNCs rather than renting a car when traveling out of town. They also provide valuable access to transit service, as when people take a TNC to a major rail station. People can also combine TNCs, transit, walking and bike share for different portions of a day's itinerary, as they are not tethered to where their car is parked.

Sources used on previous two pages:

[*Circella 2018*] Giovanni Circella, Farzad Alemi, Kate Tiedeman, Susan Handy, Patricia Mokhtarian, "The Adoption of Shared Mobility in California and Its Relationship with Other Components of Travel Behavior," Institute of Transportation Studies, University of California, Davis, March 2018.

[*Clewlow 2017*] Regina R. Clewlow and Gouri Shankar Mishra, "Disruptive Transportation: The Adoption, Utilization and Impacts of Ride-Hailing in the United States," Institute of Transportation Studies, University of California, Davis, October 2017.

[*Henao*] Alejandro Henao, "Impacts of Ridesourcing–Lyft and Uber –on Transportation including VMT, Mode Replacement, Parking, and Travel Behavior," Doctoral Dissertation Defense, January 2017.

[*MAPC*] Metropolitan Area Planning Council, "Fare Choices: A Survey of Ride-Hailing Passengers in Metro Boston," February 2018.

[*NAS 2018*] National Academies of Sciences, Engineering, and Medicine, *Legal Considerations in Relationships Between Transit Agencies and Ridesourcing Service Providers*, The National Academies Press, 2018;

[*NYCDOT 2018*] New York City Department of Transportation, "NYC Mobility Report," June 2018.

[*Schaller 2018*] Schaller Consulting, "Making Congestion Pricing Work for Traffic and Transit in NYC," March 2018

[*SFCTA 2017*] San Francisco County Transportation Authority, "TNCs Today," June 2017.

These examples show that TNCs support a multi-modal network for some trips, enabling travelers to leave their car at home for the day.

But one needs to look beyond individual examples to assess whether on TNCs' overall effect is to support the goal of a multi-modal system by helping shift people from personal auto to more space-efficient and environmentally sustainable modes, or the opposite. The answer from survey data is quite clear. Overall, TNCs contribute much more to automobility than to transit or other non-auto modes:

- As cited above, most TNC trips involve shifting from sustainable modes (transit, walking, biking) than from the personal auto. The net result is more driving mileage and less use of public transit.
- Remarkably few TNC trips are for the purpose of connecting to public transit. TNCs try to suggest the opposite by pointing to a substantial number of trips that start or end near a transit station. Yet those trips do not necessarily involve transferring to transit at that station; passengers could simply be going to local destinations near the transit stop. Research in the Boston area found that 9 percent of home-based TNC trips were used to reach a transit connection and 4 percent of trips returning home were from a transit connection.[8] A New York City survey found that 0.4 percent of transit trips used a for-hire vehicle to connect to transit and 0.9 percent used a for-hire service to connect from transit.[9] A national survey found that only 7 percent of TNC users combine TNC trips with public transit on at least a weekly basis, while 35 percent do so at least occasionally.[10]

Overall, then, while TNCs can be a useful part of a multimodal system, just as taxis have been for many years, their growth has clearly subtracted rather than added to the use of transit, walking and biking which are the cornerstones of a healthy multi-modal system.

REDUCING TRAFFIC WITH SHARED RIDES?

A now-defunct company named Sidecar was the first to offer door-to-door service using nonprofessional drivers. Sidecar called its service "rideshare" because its goal was to enable smartphone users to "hitch a ride" with people already driving for their own purposes between two locations.[11]

When this new form of carpooling did not catch on, Sidecar – quickly followed by Lyft and Uber -- switched to a service model in which drivers go where the customer wants to go, not vice versa.

This taxi-like service continues to be the bedrock of Lyft and Uber's business. Their remarkable growth has been built on offering what customers view as a better version of conventional taxicabs. But while most TNC trips continue to be private rides, Uber and Lyft are now heavily investing in improving and promoting their shared services.

Their efforts have lifted UberPOOL to 20 percent of Uber trips in the major cities where it is offered, according to the company. Lyft says that 37 percent of users in cities with a Lyft Line option request a Lyft Line trip. But the number of matched trips which results in the ride being shared is substantially lower (22 percent in New York City compared with 23 percent for Uber in February 2018, the latest month available).[12]

Uber, Lyft and others believe that increasing the number of shared rides will serve to reduce overall miles of driving. This assertion has rarely been questioned, perhaps understandably given the intuitive appeal of the idea that putting several people in a car together will economize on the overall vehicle miles.

This assertion should be examined closely. If shared rides reduce overall driving, then shared rides could be effective in reducing congestion and deserving of supporting public policy actions. Conversely, if shared rides are like private rides (e.g., UberX and Lyft), and add to congestion, then pushing more people into shared vehicles will be ineffective in offsetting the substantial increases in driving that occur with UberX and Lyft private rides.

Fortunately, there is now enough publicly available data to determine effects on overall mileage.

The starting point is to compare mileage impacts from private ride TNC service with using one's own vehicle, and then add shared rides to the equation. Table 7 shows trip characteristics for cities where data is available. The average TNC trip among these cities is 5.2 miles (similar to results from NHTS) with 3.0 miles between trips. The latter figure includes 2.1 miles while drivers wait for their next trip and 0.9 miles to drive to the pick-up location. These averages are used to reflect typical TNC operations in major U.S. cities.

The baseline case is a personal auto trip in which both the traveler and vehicle travel 5.2 miles. (See Column A in Table 8 on the next page.)

Private ride TNC trips also involve 3 additional miles between passenger trips for a total of 8.2 miles from a private ride TNC trip. Assuming that the passenger is replacing a personal auto trip with the TNC trip, the switch increases total

WHAT'S BEING SAID

RIDE SHARING

"We think carpooling is very much the way of the future. Not only for our service, but we think the transformation of car ownership towards carpooling is going to be tremendously beneficial for cities, for the environment, for congestion, pollution, etc."
– Ethan Stock, Uber director of product for shared rides

"You share a car with someone else, and it kind of feels a little weird. ... and then the question of, 'when exactly am I going to get there?' are real friction points that we have had to fight, and that's why we are investing very heavily in this mode of transport."
– Uber CEO Dara Khosrowshahi

"We're making a really strong commitment about shared rides. We're making a commitment that by 2020, 50 percent of all Lyft rides will be shared.... We believe Lyft and shared rides are extremely complementary to public transit."
– Joseph Okpaku, Lyft V.P. of government relations

* * *

This report: "***Even with highly optimistic assumptions about shared ride adoption, TNC growth adds substantially to traffic in major U.S. cities***."

Table 7. Passenger miles and total miles for TNC trips

	Miles between trips			Passen-ger trip	Total miles per trip	Pct miles with pax
	Waiting	Drive to pick-up	Total			
New York City	2.8	0.7	3.5	5.1	8.6	59%
Chicago	2.5	0.7	3.2	4.7	7.9	59%
San Francisco	1.4	0.6	2.0	4.1	6.1	67%
Denver area	1.5	1.4	2.9	7.0	9.9	71%
Average	**2.1**	**0.9**	**3.0**	**5.2**	**8.2**	**63%**

Sources: Carolyn Said, "Lyft trips in San Francisco more efficient than personal cars, study finds," *San Francisco Chronicle,* January 5, 2018; Alejandro Henao, "Impacts of Ridesourcing–Lyft and Uber –on Transportation including VMT, Mode Replacement, Parking, and Travel Behavior," Doctoral Dissertation Defense, January 2017; and author's analysis of NYC Taxi and Limousine Commission TNC trip data. Mileage with passenger of 63% is consistent with statewide California average of 61%; see Simi Rose George and Marzia Zafar, "Electrifying the Ride-Sourcing Sector in California," California Public Utilities Commission, April 2018.

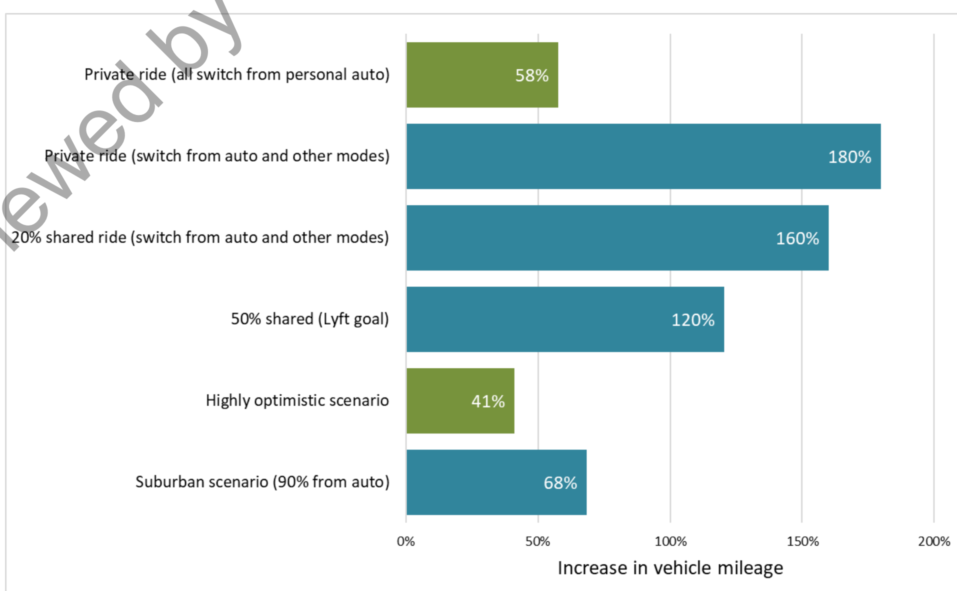
miles by 58 percent. (See Column B.) Even if one allows for somewhat higher mileage for personal trips from searching for parking, TNC trips clearly result in higher overall miles driven.

The next column takes account of the fact that most TNC trips do not replace personal auto trips. As shown in Table 8, TNC trips mostly replace transit, walking and biking trips; this switch creates entirely new miles on city streets. About 20 percent of TNC users in major U.S. cities would have used a personal vehicle if the TNC were not available, and 20 percent would have taken a taxicab. (This distinction is important because taxis have cruising miles between trips, which is accounted for in this analysis.)

Table 8. Change in overall mileage from TNC private ride and shared ride trips

Column:	A	B	C	D	E	F	G
	Personal vehicle	Private ride (all switch from personal auto)	Private ride (switch from auto and other modes)	20% shared ride (switch from auto and other modes)	50% shared (Lyft goal)	Highly optimistic scenario	Suburban scenario (90% from auto)
Mileage							
Between passenger trips	0	3.0	3.0	3.0	3.0	1.1	4.0
Per passenger	5.2	5.2	5.2	5.2	5.2	5.2	7.0
Shared trips							
Pct of all trips		0%	0%	20%	50%	75%	10%
Amount of trip shared		0%	0%	52%	65%	75%	52%
Pct with 3+ pax		0%	0%	2%	13%	38%	1%
Amount of trip shared		0%	0%	67%	80%	80%	67%
Previous mode							
Driving		100%	20%	20%	20%	20%	90%
Taxicab		0%	20%	20%	20%	20%	0%
Transit/walk/bike/no trip		0%	60%	60%	60%	60%	10%
Total vehicle miles per passenger							
Using TNCs		8.20	8.20	7.62	6.46	4.14	10.61
Using previous mode	5.2	5.20	2.93	2.93	2.93	2.93	6.30
Change		3.00	5.27	4.69	3.53	1.20	4.31
Percent change in vehicle miles		**58%**	**180%**	**160%**	**120%**	**41%**	**68%**

Figure 13. Summary of change in overall mileage from TNC private ride and shared ride trips



Column C shows the effect of taking account of this distribution of previous modes: a 180 percent increase in overall mileage. Put another way, before taking account of shared trips, TNC usage replaces each mile of personal motor vehicle use taken off the road with 2.8 TNC miles.

Taking account of shared trips modestly mitigates this large increase. Using typical 2017 levels of sharing (20 percent), produces a 160 percent increase in overall mileage. (Column D.) With sharing, each mile taken off the road is replaced with 2.6 TNC miles.

Applying these results to the trip volumes for large, densely-populated metro areas and specific cities where trip counts are available yields the following estimates for additional mileage due to 2017 TNC operations. These estimates assume that 40 percent of TNC trips "replace" auto trips (split evenly between personal auto and taxi), and the mileage figures in Column D of Table 8.

Overall, TNCs are estimated to add 5.7 billion miles of driving in the 9 large metro areas. City-specific estimates range from 94 million additional miles in Seattle to 352 million miles in San Francisco and nearly 1 billion miles in New York City.

These estimates underscore the results of other recent studies finding that TNCs lead to increased miles of driving in large, dense, multi-modal cities that account for most TNC trips.

Table 9. Estimated additional mileage from TNC growth

	TNC trips (M)	Add'l mileage (M)
9 large/dense metros	1,224	5,742
City		
San Francisco	75	352
Washington DC	45	211
Boston	35	164
Seattle	20	94
New York City	159	976

Additional mileage includes miles with passengers and mileage between trips and takes account of mileage reductions from patrons switching from personal vehicle and taxi. Does not include driving at the start and end of the day between drivers' home and positioning for the first trip.

Individual cities are central cities (not metro areas).

Sources: TNC trips are from Table 1. Additional mileage is based on 4.69 additional miles per TNC trip from Column D of Table 8, except for New York City. Source for NYC is more detailed analysis and results presented in Schaller Consulting, "Making Congestion Pricing Work for Traffic and Transit in NYC," March 2018.

These large increases in miles driven come about because of the combination of several factors:

- Fewer than one-half of TNC trips take a car trip off the road, meaning that most TNC trips represent entirely new miles of driving on city streets;
- TNC drivers must drive to the pick-up location, and drive between trips, also adding to overall mileage; and
- Only part of every shared trip involves multiple passengers, since there is generally some mileage between the first and second passenger pick-ups, and between the last and second-to-last drop-offs.[13]

TNCs have said that their operations will reduce overall traffic as the use of pooling grows. Lyft recently announced a goal of 50 percent of trips being pooled by 2022. Results in Column E are based on 50 percent of trips being shared (more than double the current rate) and assume that a quarter of shared trips involve sharing among three passengers rather than just two. As shown in Column E, achieving Lyft's goals would still create a 120 percent increase in overall mileage.

It is notable that even in extremely optimistic scenarios, TNC growth produces more miles of driving. Column F shows a case that assumes a very high rate of pooling (75 percent), many fewer vacant miles between trips and much more time is spent with multiple passengers in the vehicle. The result is still a 41 percent increase in overall mileage on city streets. (Column F.)

These results make clear that even with highly optimistic assumptions about shared ride adoption, TNC growth adds to traffic in major U.S. cities, with potentially quite large implications for both traffic congestion and transit ridership.

These results do not significantly change in suburban settings, even though far more people would have taken their own vehicle for the trip instead of a TNC. The one study that looked systematically at mode shifts outside large, dense cities was conducted in California. It showed that about 90 percent of TNC users would have driven their own motor vehicle instead of taking a TNC. Shared options generally are not offered in suburban settings, but assuming that 10 percent of trips are shared, the increase in mileage would be 68 percent. (Column G.)

Figure 13 summarizes the results of this analysis. In every conceivable case, TNCs increase miles of driving on city streets as well as on suburban streets. Even with extremely optimistic assumptions about how far TNCs can take shared trips, there is more mileage.

In areas where TNCs comprise a tiny fraction of traffic volumes, these increases amount to small additional traffic. It may well be worth the trade-off for greater mobility, particularly for people who do not currently have access to a motor vehicle. For most places that TNCs operate, the added mileage may not merit attention from public policy-makers.[14]

Where TNC trip volumes are large, however, the increased traffic can be considerable and likely merits attention. Public policy options suitable to these areas are discussed in section 6 of this report.

MAKING THE PERSONAL AUTO OBSOLETE?

TNCs have recently begun to boldly say that their goal is to make the personal auto obsolete. Their vision for transforming the transportation system involves shared trips replacing most if not all personal auto travel. They believe this will make for a far more efficient (and with self-driving cars, safe) transportation system.

For this to occur, people who now drive themselves around town would obviously need to decide to switch over to TNCs. But while TNCs see this is producing benefits, the above analysis shows that the result would be catastrophic for cities, adding about 68 percent more mileage to suburban streets and nearly tripling mileage in large central cities.

Even if, as TNCs envision, most people used shared trips, central city traffic would still increase very substantially even under the most optimistic scenarios. The transformation assumes that people would voluntarily give up the convenience of jumping into their own cars in favor of shared trips that involve walking to a pick-up location and waiting for the vehicle to arrive. The evidence supports this assumption when they save on parking costs or avoid drinking and driving. Otherwise, few auto users make the switch to today's TNCs and are unlikely to do so in the future.

NEW AUTOMOBILITY – PERSONALLY OWNED VEHICLES

While this report focuses on increased auto usage from the rise of TNCs, there is larger and equally important picture of trends in auto use in American cities.

After leveling off or even declining earlier in this century, vehicle miles of travel (VMT) has increased nationally since 2011.[15] Unfortunately, city-level VMT data are not generally available. Vehicle ownership can be used as a proxy for vehicle mileage, however, as changes in auto ownership tend to be reflected in changes to auto use.

Census data show that auto ownership has increased in nearly all large U.S. cities since 2012 and in nearly all cases exceeded population growth. Table 10 shows that the aggregate number of household vehicles increased in each of the 9 large, densely-populated cities as well as the 11 large, less-densely populated cities discussed in earlier sections. The average increases were similar – 8 percent for the first group and 11 percent for the second group. In all but three cities (Washington DC, Seattle and San Antonio), the rate of vehicle growth exceeded the rate of population growth.

These findings are consistent with studies showing increases in vehicle registration in the Los Angeles area and in Washington DC and New York City.[16]

Table 10. Aggregate Household Vehicles by City, 2012-16

	Aggregate HH vehicles				
City	2012	2016	Change	Pct change	Popn. change
9 large/dense cities					
Miami	183,041	214,068	31,027	17%	10%
Boston	218,673	252,757	34,084	16%	6%
Seattle	397,873	443,564	45,691	11%	11%
Los Angeles	2,050,488	2,233,586	183,098	9%	3%
San Francisco	362,766	395,087	32,321	9%	5%
Philadelphia	568,504	610,005	41,501	7%	1%
New York	1,842,155	1,961,602	119,447	6%	2%
Chicago	1,114,784	1,182,970	68,186	6%	0%
Washington	228,918	242,612	13,694	6%	8%
Total	**6,967,202**	**7,536,251**	**569,049**	**8%**	**3%**
11 large/less-dense cities					
Dallas	705,973	817,739	111,766	16%	6%
Denver	408,493	472,271	63,778	16%	9%
Houston	1,198,358	1,383,986	185,628	15%	7%
Phoenix	838,147	951,352	113,205	14%	8%
San Jose	614,614	677,914	63,300	10%	4%
San Diego	826,760	893,725	66,965	8%	5%
San Antonio	793,972	849,515	55,543	7%	8%
Detroit	279,563	298,618	19,055	7%	-4%
Minneapolis	219,583	232,763	13,180	6%	5%
Milwaukee	293,808	304,831	11,023	4%	-1%
Baltimore	253,992	260,881	6,889	3%	-1%
Total	**6,433,263**	**7,143,595**	**710,332**	**11%**	**8%**

Source: U.S. American Community Survey. Data are for central cities (not metro areas).

6. Opportunities for Public Benefits

TNCs' benefits to individual users – fast, reliable and affordable taxi-like service -- have fueled their popularity and rapid growth. Their mostly affluent customers feel that the service is a good value for the money and are willing to pay the full fare.

For some types of trips, however, the full fare is unaffordable but there is a public interest that supports public subsidies. This section reviews the experience with various pilot programs across the country in cities of widely varying size, where officials saw public benefits and contracted with TNCs or other private providers.

Experience with these pilots is valuable in pointing to which approaches hold the most promise for larger-scale implementation, and how they can best fit with more conventional transit services.[17] As will be seen, a central takeaway is that TNCs and microtransit tend to best fit where trips are thinly dispersed over a geographic area and in cases where users need to be picked up at their doorstep.

LIFELINE TRANSPORTATION

There is a long history of taxicabs participating in Dial-A-Ride programs for seniors and persons with disabilities who lack access to a personal car or the financial means to pay for a taxi. Public subsidies are needed for patrons to obtain medical care, go shopping, socialize at senior centers, attend religious services and so forth. The policy rationale for these subsidies is the public interest in the health and well-being of seniors, persons with disabilities and other eligible participants such as non-senior low-income persons.

TNCs have recently started to participate in these programs, sometimes alongside taxis and other companies that provide contracted transportation service, and in some cases substituting for discontinued bus services. Laguna Beach, for example, contracted with Uber to supplement transportation for senior and disabled passengers following curtailments of local bus service.

The Pinellas Suncoast Transit Authority in the Tampa and St. Petersburg, Florida area, conducted a two-year pilot with Uber, a cab company and a wheelchair van provider for on-demand trips at night to or from work to participants in an agency program for transportation-disadvantaged persons.

After an initial microtransit pilot involving the now-defunct company Bridj, the Kansas City Area Transportation Authority is using taxis in its RideKC Freedom program, serving older adults and persons with disabilities with same-day service scheduled through a mobile app or by telephoning a call center. Via is developing with the city of Berlin, Germany a van service that complements existing transit service, focusing on late night and weekend travel.[18]

SUPPLEMENTING ADA PARATRANSIT

Somewhat similar to this historically has been taxi participation in transit agency paratransit programs that are mandated under the federal Americans With Disabilities Act (ADA). Cost savings have been the main impetus for transit agencies to contract with taxi companies to provide ADA paratransit trips. In some cases, taxis simply substitute for paratransit vans, usually at a lower per-trip cost. In other cases, taxis are used as a back-up to handle trips for which there are no paratransit vans readily available. Taxis can also be provided as an option to the regular paratransit vans and may be available for same-day trip requests rather than having to request a day or more in advance.[19]

TNCs have recently started to participate in these programs as well. A prime example is the pilot by the Boston area transit agency (MBTA) that involves Uber, Lyft and other companies. ADA paratransit users are offered the option of using one of these three companies instead of the regular ADA service. They can make same-day reservations instead of having to call a day or more in advance. Riders pay the same $2 fare and any amount over $15 (making for a subsidy of up to $13 per trip). Lyft provides a call center under its Lyft Concierge program, while Uber addressed smartphone issues by giving away smartphones to some users.

Another example is the transit agency in Las Vegas, Nevada, which began a pilot earlier this year with Lyft to provide on-demand paratransit service.

CONNECTING TO PUBLIC TRANSIT

There has been a great deal of interest across the country in using new mobility services to complement available public transportation services. Among the most discussed are "first mile" and "last mile" services that connect the customer's starting point or final destination to transit and offering publicly subsidized transportation in areas without any conventional public transit.

The earliest pilots in this area were generally in smaller towns where a mayor or transit agency head championed the idea of piloting the use of TNCs or microtransit. Pilots included "first mile/last mile" services sponsored by city governments in Almonte Springs, Florida; Centennial, Colorado; and Summit, New Jersey; and by transit agencies in Pinellas County, Florida; Sacramento, California and Dayton, Ohio. Pilots provided subsidies that covered part of the Uber or Lyft fare for residents traveling to or from transit hubs and in some cases other local destinations.

Several larger transit agencies are exploring the feasibility and value of various microtransit service models. For example, King County Metro in the Seattle, Washington area recently began serving first mile/last mile trips between commuters' homes and transit hubs. The service was needed due to limited parking at Park & Ride facilities. Via currently operates a service in Kent, U.K., outside London, that serves mainly reverse-commuters.[20]

PROVIDING SERVICE IN HIGHLY DISPERSED TRAVEL MARKETS

Another approach explicitly seeks to use TNCs and sometimes taxis and other contract transportation providers where trips are too geographically dispersed to be served by conventional fixed-route buses. The idea is to design the service to go only where customers want to go, in contrast to fixed-route buses that serve stops where there are often no passengers.

One of the most widely-publicized pilots is in Innisfil, Ontario, a town of 36,000 about an hour north of Toronto. The city contracted with Uber to provide subsidized rides to key destinations such as a town hall/recreational complex, employment center, and regional bus stops and train stations. Passengers pay $3 to $5 and the city subsidizes the remainder of the Uber fare. Subsidies average $5.62 per trip, significantly lower than what the city estimated fixed route buses would cost.

Similarly, the City of Arlington, Texas contracted with Via to provide on-demand trips in a zone within the city. Riders pay $3 per person. Typical trips connect a regional rail station to employment centers and a University of Texas campus.

In the San Francisco East Bay communities of Fremont and Newark, AC Transit tested a "Flex" service using its own 16 passenger vans and its contracted paratransit provider. AC Transit's overall objective was to address declining ridership, improve service quality and redesign its route structure, particularly in low-density areas that had seen a 20 percent decline in bus ridership. The Flex service picked up and dropped off passengers at select bus stops where bus service had been discontinued. Two-thirds of trips started or ended at a BART station, so the program in large part functioned as a first mile/last mile service.

The Orange County (Calif.) Transportation Authority (OCTA) planned to begin this month (July) a one-year pilot on-demand, microtransit service. The pilot is being offered in two zones, each about six square miles. Service is being provided by Keolis under contract to OCTA.[21]

Los Angeles Metro is currently conducting studies with three potential private sector partners, Transdev, RideCo and Via, to develop door-to-door microtransit service.[22]

* * *

While much of the media attention has been focused on Uber, Lyft and Via providing subsidized services, there are a range of companies and service models available. Taxicabs and private transportation providers such as Transdev, Keolis, MV Transportation and First Transit can play an equally or even more useful role. TNCs may not be able to provide contracted service where federal funds are involved due to requirements for drug and alcohol testing. Taxis and private providers may have accessible vehicles where TNCs generally do not. Government agencies may want to insist on being provided detailed trip data that Uber and Lyft have often refused to provide (although, notably, Uber is providing detailed trip data to Innisfil).

Some of these arrangements also creatively split various aspects of the operation. Transloc and Via provide their software for others to operate a service. A Capital Metro pilot in Austin, Texas used Via's technology to dispatch contracted vans. Via is also working with the transit agency in Singapore to incorporate on-demand technology to enable buses to be deployed and dynamically routed on-the-fly in response to commuter demand.[23] The Contra Costa County (Calif.) Transit Authority is using a Transloc technology platform to provide connections to a BART station.

It should be noted that ridership on these services is low compared with typical fixed route bus operations. Pilots in Livermore, California and Pinellas County, Florida and the initial AC Transit pilot averaged 40 to 60 riders per day. Somewhat higher, Uber provided 200 trips per day in March 2018 in Innisfil, Ontario, and Via served 350 trips per weekday Arlington, Texas this spring (ridership is now lower while the university is in summer session).

Where a new service replaced discontinued bus routes, ridership dropped. In San Clemente, California, for example, where the city contracted with Lyft to provide rides along two corridors previously served by buses, Lyft averaged 70 passengers per day versus 650 passengers on the bus routes. The same was true for the AC Transit Flex service. An AC Transit manager concluded that "on-demand transit carries fewer passengers per hour than even a low ridership fixed route."

In sum, TNCs and microtransit and other services like Flex in the East Bay are most clearly valuable where conventional bus service would not be operated because of some combination of low ridership levels and geographically dispersed trips. They can be valuable extensions – not replacements -- for fixed route transit. This is the conclusion of AC Transit staff, which plans to use Flex to provide coverage in low-density areas and hopes to achieve savings that can be invested in high-frequency bus service elsewhere. This strategy helps reconcile sometimes competing transit agency goals for ridership growth on the one hand and providing wide geographic coverage on the other hand.

Continued testing of varied approaches will help create a better understanding of where there can be a public benefit to TNC and microtransit services.[24] Among the most promising are those that mirror time-honored senior and disabled services, and that reduce costs of ADA paratransit service. The use of TNCs and microtransit to provide coverage outside the bus network is also promising, particularly if it helps transit agencies focus resources on higher frequency where they can build ridership.

Many of the pilots thus far have shown modest levels of shared trips, although some have increased over time. For example, shared trips increased in Innisfil from 10 percent to 25 percent of trips between July and December 2017. The highest figure available is from Arlington, Texas, where many passengers are going between a regional TRE train station and a university or employment centers. The percentage of shared trips leveled off at about 60 percent a few months into the program – similar to Via's shared trip percentage in New York City.

As the Arlington experience suggests, there is likely the greatest opportunity for shared trips and resultant cost-efficiencies if passengers have a common origin or destination such as a transit station or park & ride stop. To the extent that shared trips lead to reasonably straight-line routes and attract growing ridership, these services may also build toward fixed route bus service.

While there are clear opportunities for public benefit, there are also caveats that should be noted.

First, making TNCs or microtransit full-fledged parts of a government-subsidized transit system will require that the service be available to all members of the public, including those without smartphones and people who use wheelchairs. Pilots have shown how this can be done. Via and Lyft have the capability to provide telephone reservations for their services; Uber plans to roll out its first telephone reservation option in Innisfil later this year.

For accessibility, several pilots use taxi companies that have accessible vehicles; the 16-passenger vans used for AC Transit's Flex service are accessible, and the City of Arlington made two vans (used in its paratransit program) available for wheelchair trips.

Second, while on-demand TNC and microtransit service has benefits in that drivers go only where the customer wants to go, the service is not necessarily more convenient or reliable than conventional bus service.

AC Transit found that Flex service ridership is 40 percent higher for trips originating at a BART station, where passengers can walk on without requesting a trip, than for trips going to the BART station.

> TNC and microtransit services can be valuable extensions of – but not replacements for – fixed route transit.

In Innisfil, the trip completion rate was only 75 percent in November and December 2018, meaning that one-quarter of prospective customers did not receive service. Innisfil city staff note that the service "may not have the same predictability as a fixed route system." Residents are advised to leave extra time if they are on a tight schedule. If no driver is available, the city suggests that they request their trip again in a few minutes.

Waiting times average 8-9 minutes in Inisfil and 11 minutes in Arlington, Texas, possibly greater than bus wait times for routes that run on a reasonably frequent schedule.

As new mobility evolves, there are also other considerations. These companies continue to show financial losses. Although Uber has claimed that it is profitable in major U.S. cities, it is anyone's guess how fares will be affected when their investors insist on a return on capital invested.

MOVING TOWARD SHARED, SUBSIDIZED, STRAIGHT-LINE SERVICES

Two key developments in recent months suggest that TNC and microtransit services are rapidly evolving into two distinct service models. One is the traditional door-to-door private ride service long provided by taxicabs. The other is straight-line routes in which passengers are picked up and dropped off along the way, often subsidized by government, much like traditional buses and jitneys.

1. Straight-line routing. "Rideshare" was supposed fill TNC cars with passengers; TNC advertisements conveyed this vision with pictures of strangers happily traveling together. The service model sought to combine the convenience of door-to-door service (like taxis) with lower fares. Over time, however, Uber and Lyft found that the zig-zag routing of shared, door-to-door rides limited the appeal of UberPOOL and Lyft Line. To address this, the companies recently introduced services (Uber Express POOL and Lyft Shared Rides) meant to minimize turns and thus minimize in-vehicle time and the uncertainties experienced with pooled options. Users are instructed to walk a block or two to a designated pick up location but benefit by traveling a more direct route once in the vehicle.

Via and Chariot used this model from the beginning of their microtransit services, picking up and dropping off passengers along a route. Via assembles the routes on the fly while Chariot uses designated stops that do not change from day to day, although vehicle routing may vary depending on where customers are waiting.

This evolution toward straight-line routes that minimize turns shows the close link between sharing and routing. As the number of passengers sharing a trip moves beyond two strangers sharing part of a trip, it seems imperative to straighten out the routing.

2. Subsidized shared services. Government subsidies of TNC services began with relatively small local governments "partnering" with TNCs to provide trips to transit stops, downtown areas and so forth. Microtransit companies are also prominently involved with government contracting, as discussed earlier with Via's pilot in Arlington, Texas.

Private companies are also using these companies to subsidize commutes to office or university campuses (examples include JP Morgan Chase in Columbus, Ohio and UCLA).

In each of these cases, there are perceived to be benefits that extend beyond the person using them and thus likely beyond what users are willing to pay themselves. The external benefits can be employers' avoidance of the cost of new parking garages, or access to a downtown labor force that does not want to drive to work. Downtown businesses may subsidize circulator bus service to increase accessibility to their stores, restaurants and entertainment offerings.

The external benefits in these examples are specific to businesses who arrange and subsidize the service. But external benefits can also be quite diffuse, spread across multiple employers and other businesses. They also extend to the overall appeal of a city, helping to deliver people efficiently to walkable neighborhoods with a high density of employment, shopping, entertainment and dining opportunities.

The diffuse nature of the benefits means that fully realizing the benefits of high-efficiency modes like buses and trains requires subsidies. Users by themselves would only pay part of the cost of a transit system geared to fully exploit the benefits that come with dense urban development. The rest needs to be underwritten by public funds.

(There is also a converse side to this; external costs such as traffic congestion create the need for public policy intervention, as discussed in Section 7.)

The overall point is that on the spectrum of private to public benefits, some TNC and microtransit service is moving further toward providing clear public benefits that merit subsidies, due to the external and diffuse benefits they provide.

What all this means for the new mobility is that it fast becomes part of a "public transportation" system involving shared, subsidized, straight-line transportation. The challenge for policy-makers is to guide this evolution in ways that contribute toward building high-capacity networks that can provide maximal societal benefit.

7. Solving Big City Traffic Problems

In the six years since TNCs first set up shop in San Francisco, their rapid growth has resulted in billions of additional miles on crowded city streets. This growth is not offset by reduced car ownership; in fact, car ownership is growing across all large U.S. cities. (See page 21.) Thus, as travelers substitute TNCs for the bus or metro, travel by shared modes including transit has declined while automobility – using cars to get around – has grown.

While good for individual travelers, the result is unsustainable for big cities. Big cities thrive because of their dense concentrations of business, leisure and creative activity. Growing auto use works against the key ingredient of density to build economically and socially vital cities. The resulting tensions between the attractive benefits to individuals and the worrying overall effects on cities needs to be addressed.

This tension is most evident in cities like New York and San Francisco where both increased traffic congestion and falling transit ridership are most evident. Some combination of traffic and transit impacts are also evident, or seem to be evident, in Boston, Chicago, Washington DC and other big cities. Concerns are likely to intensify as TNCs continue their rapid growth. (TNC trips increased by 47 percent from 2016 to 2017 in Seattle and by 72 percent in New York; in Chicago, the number of active TNC drivers in Chicago tripled from March 2015 to December 2017.[25])

City officials grappling with this dilemma have taken or are considering a range of actions. These include incentives for shared rides, TNC trip fees, congestion pricing, dedicated lanes for buses and bikes, and traffic signal and street designs aimed at improving traffic flow.

This section discusses the potential of each of these approaches to manage the proliferation of TNCs. In addition, this section discusses a framework for reducing the overall amount of traffic on city streets with the goals of improved mobility for everyone across different modes and supporting growth in population, jobs and tourism.

STRATEGIES TO MANAGE CONGESTION

Shared trips

Uber, Lyft and some independent analysts assert that increased adoption of shared trip options will reverse the documented congestion impacts from TNC growth.

Yet in the last six years, TNC growth has added 5.7 billion miles of driving in the nine large metro areas that account for 70 percent of all TNC trips. Growth in shared trips only somewhat modifies the trendline. Overall mileage continues to increase because most riders are shifting from non-auto modes (so there is no reduction in personal vehicle mileage); the added "deadhead" miles between passenger trips adds driving even if the trip itself replaces a personal auto trip; and even then, only part of the ride is shared.

Shifting some private rides to shared rides will not change the overall picture. Even with high levels of shared trips, funneling travelers from space-efficient modes such as public transit, biking and walking, to space-hogging sedans, SUVs and minivans is not a productive strategy to speed traffic.

Some have suggested that while perhaps TNCs currently add to traffic, as they build their volume of shared trips they will attract predominantly auto users rather than predominantly people shifting from transit, walking and biking. This expectation runs counter to how shared services are developing, however. To attract customers to Uber Express POOL and Lyft Shuttle (or now Lyft's Shared Rides), TNCs are now moving toward straight-line routing to minimize travel time. This shift means that users need to walk short distances to the pick-up location. They may have to wait a few minutes to be matched to a driver, and they may also wait a few minutes for the driver to arrive at the pick-up location.

This obviously makes shared trips more and more like conventional fixed route transit service. There are valuable enhancements to TNCs like greater transparency and automatic fare payment. But it strains logic to expect that as TNC shared trips become more like conventional transit trips, this service will attract more people from their personal auto than has been the case up until now. It seems far more credible that TNCs will continue to attract predominantly non-auto users.

Another argument for why the future will be different than experience thus far involves fares. The argument is that lower fares will draw motorists to TNCs, first because shared trips are cheaper than private ride trips, and eventually because of autonomous vehicle technology.

This might be the case where travelers are comparing TNC fares with the cost of parking – already a prime reason for drivers to use TNCs. Lower TNC fares might change the "breakeven point" for switching to TNCs. However, relatively few auto trips involve a parking charge (surprisingly, even in Manhattan).[26] Parking cost is thus unlikely to drive many more motorists into shared TNCs.

Moreover, the impact of lower fares will be mitigated by the fact that cost is only one factor in mode choice. Travelers tend to give equal or greater weight to convenience, travel time, comfort and so forth. The popularity of SUVs and pick-up trucks testifies to the secondary place of cost (both vehicle purchase and gasoline prices) in consumer transportation choices.

Finally, faith in shared trips as a solution to traffic congestion overlooks the fact that even if a fast and cheap shared ride service attracts auto users, it would also draw heavily from public transit ridership. The new users would continue to be a combination of motorists, transit users and people coming from other modes. The result would also be the same – billions more miles, many on already congested city streets.

Trip fees and congestion pricing

In the most basic terms, the problem that big cities with dense job, population, retail and entertainment activity are facing is simply that TNCs combined with other users of street space are demanding more space than is available. This is the classic "tragedy of the commons," where herdsmen keep adding cattle to the common fields until the cattle lay bare the vegetation that sustains them.

Economists have a ready answer for this problem. Economic theory holds that pricing scarce road space is the best way to address overuse of the public commons. The theory has, helpfully, been shown to work in the form of congestion pricing in London, Stockholm and Singapore, and with high occupancy lane tolls on highways in the United States. Similar plans have been proposed in New York City and discussed in other major cities. Experience with these proposals, as well as with trip fees, shows the limits to pricing strategies for addressing TNC-related traffic congestion.

The most visible form of pricing is fees or taxes on TNC rides. Chicago, Washington DC, Seattle and New York have instituted surcharges or taxes on TNC fares ranging from around 10 cents to $2.75 per trip. These charges are valuable in producing revenue for transit or other purposes. They also start to establish the idea that TNCs are part of an overall transportation system in which cross-subsidies are required to make the overall system best serve urban mobility needs.

However, there is little expectation that trip fees or taxes will serve to combat traffic congestion. This is the case even in New York where the fee, which takes effect next January, will be $2.75 per trip.

Fees could be effective if set at a much higher level. A previous Schaller Consulting study estimated that a fee of $50 per hour in Midtown Manhattan, which translates to about $10 more in the cost of an average trip, would substantially reduce the number of TNC vehicles in operation. But a fee of this magnitude is not under consideration and would face daunting political headwinds.

In advocating for pricing approaches, some analysts argue for a more holistic approach that includes charges on all vehicle travel including personal autos, TNCs, trucks and so forth, paired with large investments to improve public transit.[27] This is certainly an attractive vision for the future of cities and should continue to be pursued. But cordon pricing on the model of London and Stockholm has never gone very far in American cities. Vehicle mile charges have been tested in several states, but implementation seems even further from reach.

In sum, pricing can have an important role in addressing traffic congestion, but obtaining public support is difficult, and in any case, it is not a panacea.

Street management

Over the past decade, major U.S. cities have made major strides in implementing dedicated lanes for buses and bikes and using traffic signal strategies and street designs to improve traffic flow, increase safety and prioritize public transportation. Another response to the pressures created by TNC growth is to redouble these efforts, especially with dedicated street space for buses and bikes.

Both of these space-efficient modes greatly benefit from being separated from the flow of general traffic. Bus lanes improve bus speeds, eliminate the friction that normally occurs as buses pull out of bus stops and help raise the visibility and "readability" of bus service. Bike lanes improve safety and comfort for bike riders. Where physical separation is not feasible, distinctive markings and camera enforcement improves motorist compliance with bus lane restrictions.

Traffic signals and street designs can help speed buses and bikes safely through intersections. Strategies such as queue jumps for buses and holding back right turns across bike lanes serve these goals.

More broadly, traffic signal strategies such as adaptive signal control can ease overall traffic congestion by tweaking traffic signal timing in response to current traffic conditions.

Trip fees, congestion pricing, bus lanes and traffic signal timing can help alleviate growing pressures on the fixed amount of street space. But….

While these are proven strategies to reduce congestion, they also have limits that should be recognized. Bus lanes work best where they can occupy a lane free from cross-traffic. Thus, they are ideal on limited access highways and along parks and waterfronts. In downtowns filled with storefronts, offices and cross-streets, bus lane design needs to allow for turns by general traffic and for access to land uses.

Another response to TNC growth receiving increasing attention focuses on busy pick-up and drop-off areas, most notably at downtown entertainment and sometimes office districts. Growth in TNC trips has affected traffic where drivers block moving lanes and bus stops. The goal of designated pick-up and drop-off locations is to make efficient use of curb space, keep vehicles out of adjacent traffic lanes, and to minimize localized traffic impacts from TNC and/or microtransit vehicles.

Washington DC is piloting this approach in DuPont Circle, dedicating formerly on-street parking to TNC pick up and drop offs. The District set aside 60 spaces on Connecticut Avenue between Thursday night and Sunday morning to reduce double and triple parking as bar patrons use TNCs and taxis to go home. San Francisco, Boston and New York are among other cities considering similar zones.[28] In addition, San Francisco designated areas where Chariot can pick up and drop off riders, in part to ensure that vans move out of traffic lanes to do so, and in part to ensure they do not block bus stops.

These accommodations align with public policy goals for efficient use of roadway and curb space, efficient bus operations, and to help people avoid drinking and driving. Pilots will help to show how well they improve traffic flow and safety, and how much space is required for successful implementation.

Policies for accommodating TNC and microtransit operations can also be integrated with a broader set of goals. Airports, for example, have paired allowing TNCs to enter their property to pick up passengers with trip fees, to defray their landside costs, and in some cases more stringent checks on drivers or vehicles to protect public safety.

Although these pilots are in their infancy, cities might also look toward leveraging their value to TNCs to minimize the number of empty vehicles in the congested "hot spots," by limiting the number of unoccupied TNCs on these streets. In addition, cities could require that companies using designated street space serve all potential patrons. Wherever space on public streets is reserved to accommodate TNC or microtransit operations, these services should be expected to accommodate all members of the public, including people using wheelchairs and people who do not have a smartphone available to request a ride.

… if traffic congestion remains unacceptable, policy makers should look toward a more far-reaching goal: less traffic.

STRATEGIES FOR LESS TRAFFIC

The above strategies seek to relieve the pressures that arise from TNC growth and myriad other demands on a fixed amount of real estate on big city streets. Each strategy has value and is worth pursuing, but it is also important to recognize the limits to the amount of traffic relief they can provide.

In some cities, the strategies may suffice to support city goals of mobility, safety, equity and sustainability. Others may find that they need to do more. In the latter case, policy makers should adopt the more far-reaching goal of less traffic. Rather than trying assorted techniques to wedge more vehicles into city streets, the goal should shift to reducing the number of vehicles. This means making space-efficient modes such as buses and bikes the preferred means of transportation on the core attributes that most affect mode choice, namely, speed, reliability, comfort and cost.

Currently, TNCs are highly attractive to their affluent and generally well-educated customers for perfectly rational reasons. Aside from cost, the individual traveler has every incentive to use the least space-efficient means of transportation – TNCs are most often faster and more reliable and provide a higher level of comfort and privacy.

The solution is to flip the incentives by making space-efficient modes more attractive than personal autos or cars-for-hire.

With less traffic, streets and intersections can be designed to provide turn lanes, areas for picking up and dropping off passengers and for freight deliveries that improve safety and traffic flow. Less traffic also creates room to make cycling feel safe and comfortable, as with separated bike lanes. Less traffic also alleviates conflicts between through bus movements and access to adjacent land uses for other vehicles, a key design issue for bus lanes.

The result is a street network in which all users – personal autos, buses, TNCs, microtransit, bicyclists and perhaps even people on electric scooters – can move safely and at a reasonable speed.

Getting to this can seem like a daunting task. But the rapid growth of TNCs is in a sense an opportunity. The resulting clogging of traffic has become an increasingly visible problem, putting in sharp relief the fact that crowded streets do not have room for everyone to move about with their own car and driver and the need to make buses in particular compete with TNCs.

The problem, to be sure, stems not simply from TNC growth. But the issue is not "who causes" (it is obviously a combination of TNCs and growth in deliveries, construction, population, jobs, tourism and so forth). The issue is what to do about it.

Three strategies can move cities toward the goal of less traffic, addressing use of personal motor vehicles, growth of TNCs and commercial vehicles, and the essential role of high-capacity transit.

1) Discourage personal vehicle use in congested areas.

This can be perhaps the most difficult of the three steps discussed here. The public has a very strong aversion to government limiting their option to drive into even the most traffic-clogged downtown. This aversion is not necessarily because they will choose to do so (although some obviously will), but because they want to reserve the choice of doing so when the benefits of driving outweigh the inconveniences of traffic and parking cost and hassle.

There are two demonstrated solutions to this issue.

The first involves parking supply. New York City eliminated parking requirements for new residential construction in the Manhattan business district in 1982 and limited the amount of other parking that could be built. The number of public parking spaces decreased from approximately 127,000 in 1978 to 102,000 in 2010.

Constraints on parking supply combined with population and employment growth pushed up the cost of off-street parking. One survey found that the average daily cost for off-street parking is $42 in New York City, well above the figures of $34 in Boston, $30 in Chicago and $28 in San Francisco. Monthly parking rates are also significantly higher in New York ($616) than in these other cities, which range from $265 to $425 per month.[29]

Due to the high cost of parking, only 11 percent of people entering the Manhattan business district during the morning peak travel by car, while 89 percent travel by public transportation.[30] Notably, many drivers entering the CBD either are driving through (and are unlikely to pay for parking at their destination), or avoid personally paying for parking because they park on-street, find free off-street spaces, or use employer-paid parking spaces.[31]

A proposal for a $20 or $30 tax to park in Manhattan would face even steeper odds against adoption than congestion pricing. But a policy to limit parking, which has had the same effect, has met with no opposition.

A second solution is to limit or even ban low-occupancy vehicles from certain streets at designated times of the day. Cars are banned from 16 Street in downtown Denver and Fulton Street in downtown Brooklyn, for example, making both into transit-only streets. Cars use parallel streets as an alternative.

A related approach is to allow drivers to use a street to access local stores, offices and the like, but not allow through movements. Seattle, which is nearly the only U.S. city to show recent transit ridership growth, limits Third Avenue to buses and cars that are then required to turn at the next intersection during the morning and afternoon peak period.

In Manhattan, this approach is also planned for 14th Street during the shutdown for repairs of the L line subway. It has also worked on Broadway, where drivers are forced to turn as they approach plazas installed in the late 2000s in Times Square and Herald, Madison and Union Squares. There is thus some auto and truck traffic on Broadway between these turn-off points, but it is very light throughout the day.

Either of these approaches, or some combination, can be used to limit (while not charging directly or eliminating) the number of personal motor vehicles in major congested areas. These steps can be tailored to specific goals and local circumstances – applying to short street segments or entire areas, throughout the day or for selected times of the day.

Over time, even limited steps to contain auto use are productive, yielding less traffic and opening up another opportunity to take further actions. Several European cities including Paris, Copenhagen and Amsterdam, have produced large drops in vehicle volumes through a long series of actions – none of which, notably, involved congestion pricing.

2) Set space-efficiency requirements for fleet-operated vehicles (e.g., TNCs, taxis and commercial vehicles)

The goal of space-efficiency requirements is to keep the number of vehicles within the capacity of the street for free-flow operation. Offering high-capacity transit, buses should have priority. As discussed above, personal autos need to be limited. Remaining capacity could then be used by fleets which would be limited through caps or some type of space-efficiency standards.

TNCs and taxis represent a low-hanging opportunity since they spend approximately 40 percent of their time between trips. In congested areas such as the Manhattan business district, this means there are an unnecessarily large number of empty vehicles clogging traffic, far more than needed to ensure satisfactory wait times for the next customer to request a ride.[32] Similarly, commercial vehicles often double park while making deliveries or plumbing, electrical or other repairs, also clogging traffic even when there may be curbside parking spaces nearby.

The result, like the "tragedy of the commons," is that TNC and taxi drivers, delivery drivers and everyone else gets one thing they want at the moment (quick pickup, park across from the premise entrance), but at the increasing cost for everyone of how long it takes to move around town.

Public policy has long tried to address these issues for taxicabs. Vehicle caps have been used for taxicabs for decades in major cities across the country. They have been applied to overall fleet size, however. Rather than reducing traffic in the most congested part of town, the result has been that cab drivers tend to concentrate in congested downtown areas where trip demand is most intense.

A better approach is to limit the number of vehicles in the congested area (e.g., downtown, or an entertainment district) at any one time.

The limit would apply to all phases of drivers' operations -- transporting passengers and time between trips. TNCs would have strong incentive to reduce time between trips and maximize time transporting passengers, as well as to encourage shared trips. Companies might alter dispatch procedures to discourage drivers from deadheading into congested areas when they are not needed. They might provide faster pick-ups to pooled than private-ride customers.

Another approach is to mandate passenger occupancy levels. TNCs typically have an average of 1.1 passengers at any one time, taking into account the size of the typical traveling party (estimated at 1.5), rate of pooling (assumed to be 20 percent) and amount of time with passenger versus between trips (approximately 60 percent versus 40 percent, respectively). Cities could mandate that TNCs average a higher occupancy rate. The goal would be to reduce vacant time between trips (now around 40 percent) and reach much higher vehicle occupancy rates.

Commercial vehicles could also be subject to efficiency standards tailored to their operations. Much of the traffic impacts from commercial vehicles arises from double-parking to make deliveries and while repair or installation personnel are inside nearby premises. Cities could use in-vehicle GPS technology to track where commercial vehicles are during the day and impose fines or other sanctions for vehicles that do not use designated curb space for deliveries and other activities. It would be incumbent on the city to also make sure there are adequate delivery zones for this purpose.

3) Provide frequent bus service (and rail service where available)

High-capacity transit is clearly the backbone of any big-city transportation system. Only high-capacity vehicles create efficiencies in the use of street space that make possible dense urban centers with lively, walkable downtowns; a rich selection of jobs, restaurants, entertainment and other activities; diversity of population; and intensive and

The overall vision is for less traffic and greater ease of movement for everyone regardless of mode for a given trip.

inventive face-to-face interactions that make cities fertile grounds for business and artistic innovation. If everyone drives their own car to the city center, the need for parking to accommodate the cars would make impossible this density of jobs and activities.

Less traffic on city streets makes buses far more attractive than they are today – faster trips, more reliable, and greater frequency even with the same number of buses on the street. Attractive bus service creates a virtuous circle since the more people ride the bus, the more service a transit agency will likely put on the street. It also becomes far easier to transfer between buses since the main impediment to transferring is uncertainty about wait times before the next bus arrives. Easier transfers allow for simpler route structures, since transit planners have less need to connect disparate trip ends. Simplicity itself is valuable in making it easier for potential patrons to find their way.

* * *

The overall vision is thus for less traffic and greater ease of movement for everyone regardless of mode for a given trip. Ideally, a combination of these steps would be implemented as a package in large geographic areas. Change does not come easily, of course, so it is valuable that these steps can be taken on a small scale as well. They could be put in place along a few blocks during select hours for special events (which is already often the case) or at peak nighttime entertainment hours, or during the morning rush hour. Officials can experiment, learn what works, show success, and create another virtuous cycle that supports expansion of these steps.

8. Implications for Autonomous Vehicles

After years of development and testing, several companies are operating truly autonomous vehicles in passenger service – vehicles without a "safety manager" who can intervene in case something goes wrong. Many of the early implementations involve shuttles that run short distances on fixed routes that can be mapped in detail, providing an opportunity for real-world testing and for the general public to experience autonomous technology.[33]

Beyond shuttles, Waymo is transporting passengers in the Phoenix area in fully autonomous vehicles that pick-up passengers who request a trip using a smartphone app. General Motors has indicated it plans a similar roll-out in one or more major cities, likely including San Francisco in 2019. Other companies are also likely to enter the mix such as Daimler/Mercedes Benz, Aptiv and others.[34]

Whether working with Uber or Lyft or setting up their own shared ride services, these companies are expected to use a TNC service model. They are also expected to deploy the service in dense urban centers where constant use will spread the cost of AV technology across many trips.[35]

A critical and much-discussed issue is whether this path leads to a "heaven" or "hell" outcome, to use the dichotomy coined by Robin Chase. In the "heaven" scenario, people rely on shared autonomous vehicles and expanded public transit; electric vehicles replace gasoline power thus reducing greenhouse gas emissions; and acres of surface parking are replaced with parks, affordable housing and other active land uses. In the "hell" scenario, autonomous vehicles induce sprawl as people are less concerned about long commutes; miles driven and traffic congestion increase in both cities and suburbs; empty cars cruise city streets instead of paying for parking; and public support for bus and rail service erodes, leaving lower-income people stranded.

Whether self-driving vehicles lead to heaven or hell depends in large part on whether people want to use shared autonomous services. A widely-cited travel model for Lisbon, Portugal, for example, found that traffic could increase by approximately 50 percent if travelers favored autonomous "regular taxis" that are not shared. On the other hand, the model showed a 37 percent decline in vehicle-kilometers, and total elimination of congestion, under a shared-taxi scenario. The latter, more heavenly, scenario envisioned six-seat vehicles providing on-demand, door-to-door shared rides; eight-person and 16-person mini-buses that serve pop-up stops on demand and provide transfer-free rides; and rail and subway services continuing to operate as currently.[36]

Other travel models have found either large increases in vehicle mileage or large reductions, depending on assumptions about which types of services – shared or private – prove most popular.[37]

Based on today's TNC experience, the service model of six-seat, on-demand, door-to-door shared rides does not appear viable. Even in the nation's densest urban areas, the large majority of Uber and Lyft rides are private rides – one traveling party per trip. Few door-to-door shared rides involve more than two traveling parties. Moreover, many customers who select the shared option are not matched to anyone else; they thus have the benefit of both the lower shared-ride fare and direct door-to-door service.

To try to put more passengers into their vehicles, Uber and Lyft are expending substantial resources promoting walk-to-the-stop services like Uber Express POOL and Lyft Shared Rides. They hope that straightening out the route will attract more passengers, even with walking to a pick-up location. (See discussion in box on page 26.) Whether this will substantially increase average vehicle occupancy remains to be seen. Already using relatively straight-line routing, Via (using mostly minivans) is averaging less than two-person occupancy in both Manhattan's high-density environment and in its Arlington, Texas pilot.

On the other hand, TNC experience has proven the appeal of private ride TNC service, e.g., the "regular taxis" in the Lisbon model that lead to large increases in traffic congestion. If autonomous technology reduces costs and lowers fares, growth of private ride (autonomous) TNCs would certainly accelerate. The result would be further increases in driving, whether patrons were converting from their own car or from public transit, walking, biking or not making the trip.

In sum, given current TNC experience, it is unlikely that shared, door-to-door services will become a major component of urban transportation systems in the autonomous future.

What seems far more likely is the continued centrality of two time-honored modes: door-to-door private ride taxis, and fixed-route transit. Both modes can be enhanced by technologies now in use by TNCs and microtransit to provide greater transparency and manage operations in real-time, and by autonomous technologies that promise to dramatically improve safety and reduce costs. But these two service models seem likely to be the mainstays of the autonomous future.

There are many benefits to public transit in this scenario. By eliminating labor costs, autonomous fixed-route transit can likely be operated at much higher frequencies and thus with smaller vehicles that make fewer pick-ups and drop-offs, further speeding service. They might be programmed like modern elevators, where customers indicate where they want to go and a smartphone app tells them which vehicle to take (not necessarily the next one) to further optimize efficiency. It may also become far easier to transfer between buses (or minibuses) since the main impediment to transferring is long and uncertain wait times for the next bus. Easier transfers mean that far more origin and destination trip pairs can be accessed readily, further strengthening transit offerings.

Without public policy intervention, however, the first steps into an autonomous future are almost certain to greatly exacerbate big-city traffic congestion. Cheaper, better taxi service may draw patrons from both personal auto and transit, but in either case will add mileage to city streets. Straight-line shared minivans, vans and minibuses will also add to vehicle mileage as people move to these services from high-capacity buses and trains. Add in induced trips and the effects of additional density from less need for parking, and the demand on urban streets intensifies further.

There are many issues beyond the scope of this report involved with planning for the self-driving future. But the issue of traffic, by itself, clearly highlights the central role that public policy must play in planning and implementation of self-driving services.

As with today's mix of personal autos, TNCs, taxis, commercial vehicles and buses, the central goal should be to reduce traffic and emissions and improve safety while ensuring quick and reliable mobility to the entire population. As is the case today, this will mean aligning individual incentives with societal goals to make high-efficiency modes the preferred means of transportation, particularly in dense urban centers. Buses and trains need to be the fastest, most convenient and reliable and most comfortable way to get around town.

The labor savings from AVs can be quite helpful in realizing this future, both in improving safety and increasing frequency and reliability. But unless there are public policy interventions (see discussion on pages 28-31), the likelihood is that the future mirrors today's reality: more automobility, more traffic, less transit, and less equity and environmental sustainability.

Without public policy intervention, however, the first steps into an autonomous future are almost certain to greatly exacerbate big-city traffic congestion.

The challenge for policy makers is to steer development of AV services away from this future. The good news is that policy makers need not wait until AVs arrive. Officials can start today with TNCs and personally driven autos. And in fact, it is critical that they do so. Officials must set public policy on the right path to reach goals of mobility, safety, equity and sustainability today, before auto makers, tech companies and TNCs – all of whom will have invested billions of dollars in autonomous technologies and will be competing fiercely for market share – arrive at their doorstep pressing AVs onto city streets.

9. Conclusion

Cities across the United States are seeing increased TNC ridership, car ownership, driving miles and traffic congestion. Increased access to auto modes brings notable benefits to individual users. Benefits are most compelling outside city centers where public transportation is less available or less frequent and many residents endure long commutes and difficulty getting around town.

As one moves toward the core of major U.S. cities, however, these trends become clearly problematic. The short-term risks are traffic-clogged streets that slow those in cars and buses, endanger pedestrians and cyclists and erode urban quality of life.

The new automobility's longer-term risk is that neighborhoods are simply overwhelmed by traffic volumes and become less desirable places to live, work and do business. The outcome could eventually be to decongest cities by de-densifying their cores. This has happened before – traffic flowed remarkably freely in Midtown Manhattan after New York City's severe employment and population declines of the mid-1970s.

Policy-makers can respond in several different ways. They can do their best navigating the tradeoffs between better individual mobility and more traffic and slower (and likely reduced levels) of transit service. Alternatively, policy-makers can intervene more decisively toward the goal of less traffic. As discussed in section 7, cities have the means (although public support is another matter) to limit auto use, control TNC operations and add frequent transit service.

The tensions between these choices are most evident today in New York City and San Francisco and to some extent in other large cities. As TNC ridership grows at double-digit rates, more cities are likely to feel pressures to formulate public policy responses.

The pressures are likely to accelerate when autonomous technology comes to large, dense urban environments. At that point, the clash between fundamental opposing forces will come fully into play – between cities' need for density of population, jobs and activities and individuals' preference for their own car and driver, or at least their nimble van or minibus a short walk away.

In addition to the risk for cities, there may also be far-reaching risks for companies providing autonomous vehicle services. The companies span quite a range, from TNCs that are now scooping up carshare, bikeshare and scooter companies in hopes of becoming one-stop transportation portals, to legacy automakers who see their future in "mobility as a service," with tech companies also in the mix.

The risk to these companies is that their vision becomes associated in the public mind with traffic-clogged streets, social inequity for those left behind in this transportation transformation – those without smartphones, disabled persons and TNC drivers whose profession will slowly disappear.

Recent history suggests that this is likely a blind spot for corporate leaders who deeply believe that their companies' missions and value propositions have broad societal benefits. Airbnb's goal was to help apartment dwellers make some money renting out a spare bedroom but was eventually perceived to fuel higher rents and gentrification. Similarly, Facebook's goal of connecting people around the globe eventually led to its use by a foreign government seeking to interfere with an American presidential election.

But just as herdsmen cannot by individual action fix the problem of overgrazing on the town commons, TNCs and prospective AV companies can do little to stem movement toward a traffic-clogged future. The task thus goes to city officials who will have to decide whether to control the proliferation of smaller vehicles and make public transit competitive with "your own car and driver."

For cities, the stakes are quite high. In a highly competitive global economy, cities thrive only if they create the conditions for innovation and excellence. Density and diversity of firms, talent, culture and entertainment are the essential ingredients.

For that, cities need less driving, not more. Cities that figure out the path toward that goal will emerge the winners.

Appendix. Commuting and Vehicle Ownership in 20 Large Cities

Characteristics of selected large cities discussed in Section 2. Except for the first column (2015 city population), data are for urban zip codes within each city, defined as zip codes with 4,000 or more persons per square mile. Data shown are from the American Community Survey for 2011 to 2015 (5-year average).

			Urban zip codes only					
City	2015 city popn	Pct of popn. in urban zip codes	2011-15 popn	Popn density	Pct commute by public transit	Pct walk to work	Pct of HH with no vehicle	Aggregate vehicles per household
9 large/densely-populated cities								
New York	8,550,405	96%	8,206,846	27,655	56%	10%	55%	0.6
Los Angeles	3,971,896	82%	3,239,225	10,083	12%	4%	14%	1.5
Chicago	2,720,556	100%	2,714,734	11,333	27%	7%	27%	1.1
Philadelphia	1,567,442	95%	1,489,299	12,060	27%	9%	34%	1.0
San Francisco	864,816	94%	817,031	17,229	33%	10%	30%	1.1
Boston	669,469	93%	624,550	12,813	33%	15%	36%	0.9
Washington	672,228	92%	618,846	10,143	38%	12%	37%	0.9
Seattle	684,443	85%	581,968	7,407	20%	9%	16%	1.4
Miami	440,989	77%	341,612	10,658	11%	4%	19%	1.2
11 large/less densely-populated cities								
Houston	2,298,628	53%	1,208,147	5,463	5%	2%	12%	1.4
Detroit	677,124	100%	730,918	5,179	9%	3%	24%	1.1
Dallas	1,300,082	51%	658,194	4,725	4%	2%	10%	1.4
San Diego	1,394,907	46%	645,475	5,957	5%	4%	10%	1.6
Baltimore	621,849	98%	607,972	7,164	17%	7%	29%	1.1
San Jose	1,026,919	55%	561,839	8,441	4%	2%	6%	1.9
Denver	682,545	69%	470,745	5,453	7%	5%	13%	1.5
Phoenix	1,563,001	30%	466,055	3,504	5%	3%	15%	1.4
Milwaukee	600,154	75%	452,234	7,392	10%	5%	20%	1.2
San Antonio	1,469,824	29%	429,453	3,736	6%	4%	14%	1.4
Minneapolis	410,935	93%	384,130	6,606	13%	7%	18%	1.3

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