# Ride-Hailing's Climate Risks

*Steering a Growing Industry toward a Clean Transportation Future*

www.ucsusa.org/ride-hailing-climate-risks
Methodology

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CONTENTS

**FIGURES, TABLES, AND BOXES**

# Introduction

This document describes the methodology and underlying assumptions for the emissions estimates presented in Ride-Hailing's Climate Risks: Steering a Growing Industry toward a Clean Transportation Future.

This study compared emissions from private car trips with trips via a transportation network company (TNC, also known as a ride-hailing company) in an average large urban metropolitan area, modeled after seven large, dense cities where TNC ridership is high: Boston, Chicago, Los Angeles, New York City, San Francisco, Seattle, and Washington, DC.

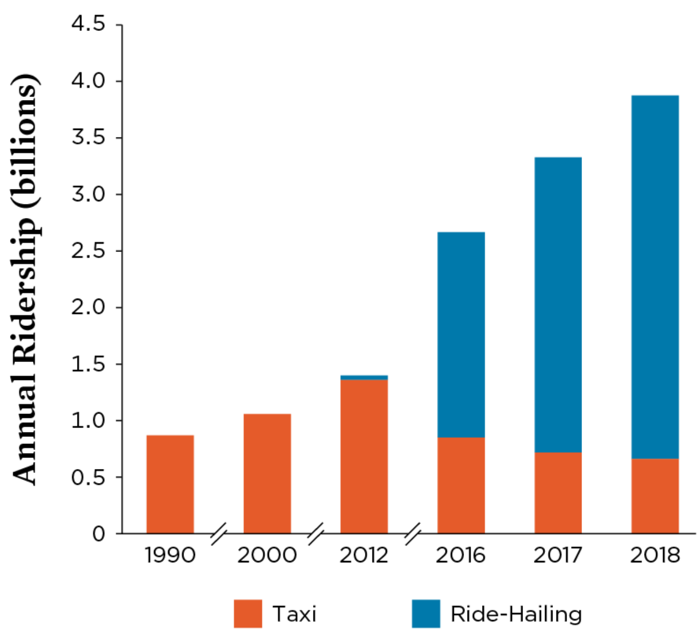
The study compared emissions ($CO_2$-equivalent, or $CO_2e$) from private car trips to those from TNC trips. It also compared public transit emissions and the emissions of trips displaced by TNC trips to car and TNC trip emissions.

The analysis relied on several publicly available data sources, including ride-hailing data from the seven metropolitan areas as well as the percentage of deadheading relative to the total trip, grid emission factors, and other parameters. The data were averaged over the seven metropolitan areas to estimate the parameters characterizing an average ride-hailing trip. Other parameters were not city-specific, such as fleet fuel economy, pooling, and percentage of displaced transportation modes. Literature data and other available data were used for the estimates. Assumptions made to estimate averages are discussed below.

The five sections in this document correspond to the five figures in the report.

# Chapter 1
# Ride-hailing Ridership is Rising Rapidly, Vastly Surpassing Taxi Ridership

Figure 1. Ride-Hailing Ridership Is Rising Rapidly, Vastly Surpassing Taxi Ridership




*TNC and Taxi Ridership in the United States, 1990–2018. Since Uber and Lyft's introduction, ride-hailing has quickly displaced taxis and led to an overall increase in for-hire vehicle ridership.*

*SOURCE: Private communication with Bruce Schaller on January 22, 2020, updating his analysis in Schaller 2018.*

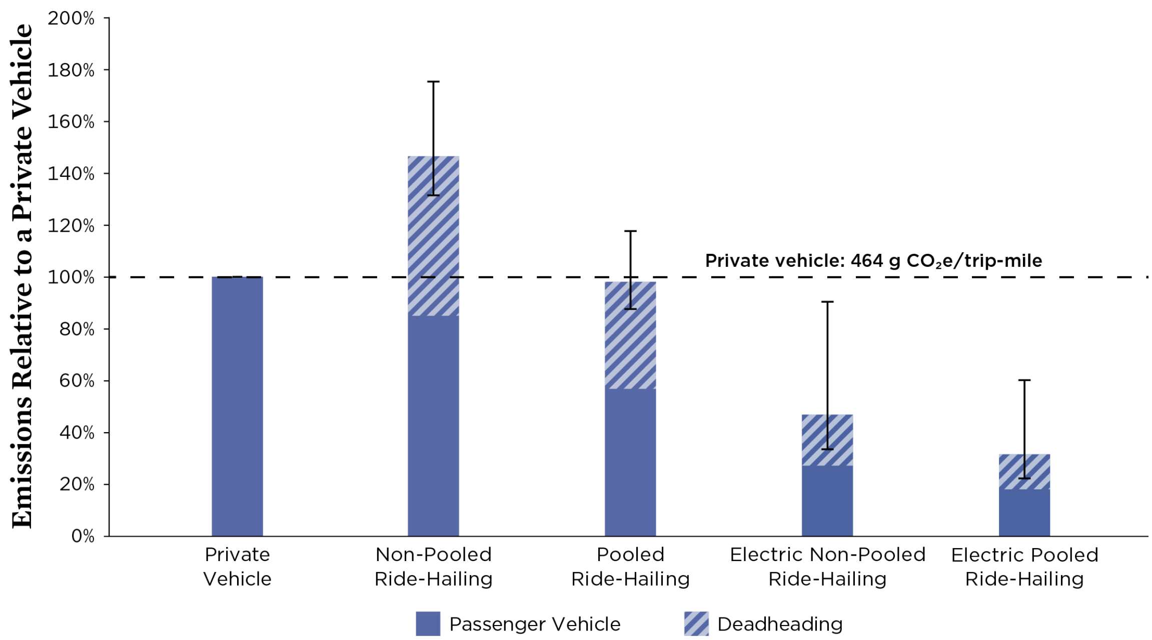
Table 1. TNC and Taxi Ridership in the United States, 1990–2018 (billions)

| Year | Taxi | Ride-Hailing |
|---|---|---|
| **1990** | 0.9 | 0.0 |
| **2000** | 1.1 | 0.0 |
| **2012** | 1.4 | 0.0 |
| **2016** | 0.8 | 1.8 |
| **2017** | 0.7 | 2.6 |
| **2018** | 0.7 | 3.2 |

*SOURCE: Private communication with Bruce Schaller on January 22, 2020, updating his analysis in Schaller 2018.*

# Chapter 2
# When Is Ride-Hailing Better for the Climate than Using a Private Vehicle?

Figure 2. When Is Ride-Hailing Better for the Climate than Using a Private Vehicle




*Comparison of $CO_2$-equivalent Emissions from an Average Gasoline-Powered Personal Car Trip and TNC trips (Non-Pooled and Pooled, Gasoline and Electric). A pooled trip in an EV is the lowest-carbon option for ride-hailing, while non-pooled trips in today's ride-hailing vehicles emit 47 percent more emissions than a trip of the same length in a private vehicle.*

*Note: Results are based on data from seven U.S. metropolitan areas. The private-vehicle trip assumes a fuel economy of 23.8 miles per gallon. A pooled trip is assumed to displace two vehicle trips, with the passengers sharing the ride for half of the distance of their trips. Pooled trip results represent the trip emissions per passenger. Error bars represent uncertainty in the percentage of deadheading miles. The error bars for electric trips (pooled and non-pooled) also include variability in electricity grid emissions among the seven metropolitan areas. Upstream emissions are included for all gas-powered vehicles as well.*

*SOURCE: For assumptions used in calculations, see Section 2.2.*

## 2.1. Methodology of Calculation of Emissions per Trip

Emissions were first calculated for the total trip, including deadheading. The emission factor for gasoline included upstream emissions, so the emission units are $CO_2$-equivalent. For a gasoline-powered vehicle, the emissions are given by:

Equation 1

$$\frac{CO_2e}{trip} = \frac{\frac{COe_2}{gallon} * total\ trip\ length}{miles/gallon}$$

For a trip in an electric vehicle (EV), the emissions were given by:

Equation 2

$$\frac{CO_2e}{trip} = \frac{\frac{CO_2e}{kWh} * total\ trip\ length}{miles/kWh}$$

Table 2 lists the emission factors (gasoline and electricity carbon intensities), fuel economy, and EV efficiency for private cars and TNCs. The assumptions for total trip lengths discussed are in Section 2.2.1.

To obtain the emissions for pooled TNC trips, the emissions per trip were divided by the average number of passengers on the trip (also referred to as the occupancy). In other words, each passenger was assigned a share of the pooled trip emissions. Equation 3 applies only to pooled rides.

Equation 3

$$\frac{CO_2e}{passenger\_trip} = \frac{\frac{CO_2e}{trip}}{average\ number\ of\ passengers}$$

We defined pooled rides as rides shared by strangers requesting a pooled TNC ride which resulted in displacing two (or more) trips. This is distinct from rides "shared" among family members, co-workers, friends, or neighbors who would have traveled together in a single vehicle otherwise.

Overall, publicly available data regarding pooled-ride occupancy rates were limited and based on limited sample sizes. For pooled rides, occupancy data collected by California for over 300 pooled rides indicated an average of 1.57 passengers, indicating that pooled passengers shared roughly half of the pooled trip (CARB 2019). A study for Denver estimated an average vehicle occupancy of 1.4 passengers per ride, including pooled and non-pooled rides (Henao and Marshall 2019). That study assumed that a pooled ride was shared for half the part of the ride. For example, it assumed that for a shared ride with two passengers, the average number of passengers per ride was 1.5. Here we make the same assumption. In the equation below, we assumed f=0.5.

In general, if a shared ride with two passengers was shared for a fraction "f" of the trip, then:

Equation 4

$$\# \text{ passengers } / \text{trip} = 1 * (1 - f) + 2 * f$$

## 2.2 Assumptions

Table 2 summarizes the assumptions used to estimate the emissions per trip in Figure 2.

Table 2. Assumptions Used to Calculate Emissions per Trip in Figure 2, Figure 3 and Figure 5

| Variable | Value | Reference |
|---|---|---|
| **Deadheading** | 41.8% of total trip length (average for seven cities). Assumed to be the same for pooled and non-pooled TNC rides. Taxi deadheading assumed to be the same as for TNCs. | See 2.2.1 |
| **Fraction of pooled ride miles with two passengers** | 0.5 (assumes the fraction of the trip with passengers has two passengers for half the miles with passenger) | See 2.1 |
| **Average occupancy for two-passenger pooled ride** | 1.5 (assumes that half of the miles with passengers are with two passengers) | See 2.1 and Equation 4 |
| **Range of emissions (error bars)** | Includes deadheading range, and when the ride is electric, the electricity carbon intensity range as well | Deadheading: Fehr & Peers 2019<br>Electricity: Reichmuth 2018 |
| **Private car fleet fuel economy** | 23.84 mpg (2019 light-duty fleet average), includes alternative fuels | EIA 2019; See 2.2.3 |
| **TNC fleet fuel economy** | 27.89 mpg (17% higher than private car). Taxi fuel economy assumed to be the same as for TNCs. | Ride Austin 2019; CARB 2019<br>See 2.2.3 |
| **EV efficiency** | 0.3385 kWh/mile | Reichmuth 2018<br>See 2.2.3 |
| **Fraction of EV in private and TNC fleet** | Accounted for in fleet fuel efficiency | See 2.2.3 |
| **Gasoline carbon intensity** | 11,072 $gCO_2e$/gallon gasoline, includes upstream emissions | Argonne 2018 |
| **Electricity carbon intensity** | 377.5 $gCO_2e$/kWh (average for 7 cities weighed by TNC VMT), includes upstream emissions | EPA 2016; Reichmuth 2018<br>See 2.2.4 |

The following sections discuss the assumptions in more detail.

### 2.2.1 TNC TRIP LENGTH AND DEADHEADING

TNC vehicle miles are classified by phase where:

- p1 = miles while driver waits for a request with at least one 'app' open
- p2 = miles after driver accepts a request and drives to pick-up location with no passengers
- p3 = miles with at least one passenger in the car

The total trip length is then:

Equation 5

$$T = p1 + p2 + p3$$

The deadheading percentage is defined as:

Equation 6

$$d = \frac{p1 + p2}{T}$$

Average TNC trip lengths for the seven cities were not readily available. Instead, we assumed p3 = 1, which enabled us to present the relative emissions of private car trips and ride-hailing trips. In other words, the deadheading percentage is sufficient for calculating relative emissions.

We estimated the average deadheading percentage weighted by vehicle-miles traveled (VMT) for the seven cities based on Fehr & Peers (2019). This yielded a deadheading percentage of 41.8 percent (see Table 3). Note that the Fehr & Peers study reported monthly VMT and deadheading percentages for six cities in September 2018, but it did not report trip lengths. That study did not include New York City; instead, we assumed Schaller's estimate of 40.7 percent for that city.

We used the total TNC VMT for each city to estimate the weights needed to calculate averages such as the electricity carbon intensity for the seven cities. Since VMT was not reported in Fehr & Peers (2019) for New York City, we estimated the city's VMT by scaling Chicago's VMT with passenger miles (p3) and then applied Schaller's deadheading to estimate the deadheading VMT (p1 + p2).

To scale Chicago's VMT (p3), we applied two multipliers: the ratio of TNC trips in November 2018 for the two cities (2.6) and the ratio of the trip lengths with passenger (1.1). See Table 3 for trips numbers and trip lengths for the two cities. The deadheading estimate from Schaller's study was then used to estimate New York City's deadheading VMT. While this was an imprecise measure of NYC ride-hailing VMT, the impact on the overall results was limited as we used a weighted average for all cities.

For the average city, assuming an average deadheading of 41.8 percent, the total trip length "T" of an average TNC ride was 72 percent longer than the fraction of the trip with passengers. This follows from:

Equation 7

$$T = \frac{1}{1 - d}$$

This study assumed taxis to have the same deadheading percentage as TNCs. A study in San Francisco reported a taxi deadheading range of 43.6 to 45.5 percent, within the range of the estimated TNC deadheading (SFCTA 2017). Due to the lack of reliable data for all cities, other taxi characteristics, such as fuel economy, were also assumed to be identical to the assumptions made for TNCs.

Table 3. TNC Monthly VMT and Deadheading Averages for Seven Cities

| | TNC Monthly VMT | Deadheading Monthly VMT | Deadheading Percent |
|---|---|---|---|
| **Boston** | 51,265,000 | 22,985,000 | 44.8 |
| **Chicago** | 98,930,000 | 44,330,000 | 44.8 |
| **Los Angeles** | 172,535,000 | 68,405,000 | 39.6 |
| **New York City*** | 240,589,911 | 97,890,800 | 40.7 |
| **San Francisco** | 126,130,000 | 50,980,000 | 40.4 |
| **Seattle** | 33,080,000 | 15,530,000 | 46.9 |
| **Washington DC** | 83,040,000 | 37,050,000 | 44.6 |
| **Average** | | | 41.8 |

** Estimated from Chicago VMT from Fehr & Peers (2019) and deadheading from Schaller (2018). Trips per day in November 2018 (Schneider 2019a; 2019b): New York City: 691,379 ; Chicago: 292,680 Trip length with passenger (Schaller 2018): New York City: 5.1 miles; Chicago trip: 4.7 miles*

*SOURCES: Fehr & Peers 2019; Schaller 2018*

### 2.2.2 POOLING

We assumed that 15 percent of current TNC trips were pooled, based on assuming that 20 percent of trip requests were pooled, but only 75 percent of the trips were matched to drivers. Data for Chicago showed that 15 to 20 percent of requests were for pooled rides, and 64 to 75 percent of the rides were matched (Schneider 2019a). We assumed the higher end of these ranges, resulting in 15 percent (75 percent of 20 percent). For more on pooling assumptions, see Section 2.1

### 2.2.3 FUEL ECONOMY

We assumed a 2019 fuel economy of 23.84 mpg for a light-duty fleet, based on annual VMT and fuel consumption. This included passenger cars and light trucks (EIA 2019). This fuel economy included alternative fuels so it was not necessary to account separately for the penetration of electric vehicles in the private or TNC fleets.

On average, TNC fleets have a higher proportion of new vehicles, with more efficient powertrains, so their fuel economies generally rate higher than those of the overall private vehicle fleet. To estimate their fuel economy, we looked at two studies. The California Air Resources Board estimated an average TNC fleet fuel economy that was approximately 20 percent higher than the passenger fleet average car (CARB 2019). A recent study conducted in Austin, Texas, estimated the fuel economy of the TNC fleet to be about 14 percent higher than the overall private fleet (Wenzel et al. 2019). Based on those two studies, we assumed the TNC average to be 17 percent higher than the passenger fleet average, midway between the two estimates.

For electric TNCs, we assumed an efficiency of 0.3385 miles/kWh, based on a recent study (Reichmuth 2018). This efficiency represents the average efficiency of all EVs sold between 2010 and 2017.

#### 2.2.4 ELECTRICITY CARBON INTENSITY

The average carbon intensity for EV charging was estimated as an average weighted over the VMT corresponding to the total TNC trip length as reported by Fehr & Peers 2019 (see Appendix 2).

Table 4. Electricity Emission Factors for Seven Cities

| | Sub-region | $gCO_2$/kWh | Weight |
|---|---|---|---|
| **Boston** | NEWE | 322.1 | 6.4% |
| **Chicago** | RFCW | 647.7 | 12.3% |
| **Los Angeles** | CAMX | 300.8 | 21.4% |
| **New York City** | NYCW | 365.7 | 29.9% |
| **San Francisco** | CAMX | 300.8 | 15.7% |
| **Seattle** | NWPP | 341.1 | 4.1% |
| **Washington, DC** | RFCE | 413.5 | 10.3% |
| **Average** | | 377.5 | |

*Note: Weight is the share of the TNC trip VMT in each city relative to the total VMT for all seven cities. See Appendix 2 for city VMTs, as reported in Fehr & Peers 2019. Upstream emissions are included. 100-year GWPs for $CH_4$ and $N_2O$ from IPCC AR5 were used in upstream emission factor calculations (IPCC 2014).*

*SOURCES: U.S. EPA 2016; Reichmuth 2018; Fehr & Peers 2019 (for weights).*

## 2.3 Results

Tables 5 and 6 summarize the emissions shown in Figure 2. Table 5 shows absolute emissions for p3 = 1 (that is, assuming the fraction of the trip with passenger is one mile). Table 6 shows emissions relative to those of a private car.

Table 5. Summary of Emissions Used in Figure 2 ($gCO_2e$/trip)

| Type of Trip | Emissions from deadheading miles (p1 + p2) | Emissions from miles with passenger (p3) | Emissions from total trip miles (p1 + p2 + p3) |
|---|---|---|---|
| **Private vehicle** | 0 | 464 | 464 |
| **Non-pooled, ride-hailing** | 286 | 397 | 683 |
| **Pooled, ride-hailing** | 191 | 265 | 456 |
| **Electric, non-pooled, ride-hailing** | 92 | 128 | 220 |
| **Electric, pooled, ride-hailing** | 61 | 85 | 147 |

*Note: Emissions per trip are shown for private vehicles and for pooled and non-pooled, gas-powered and electric TNCs. Each row corresponds to a column in the figure, from left to right.*

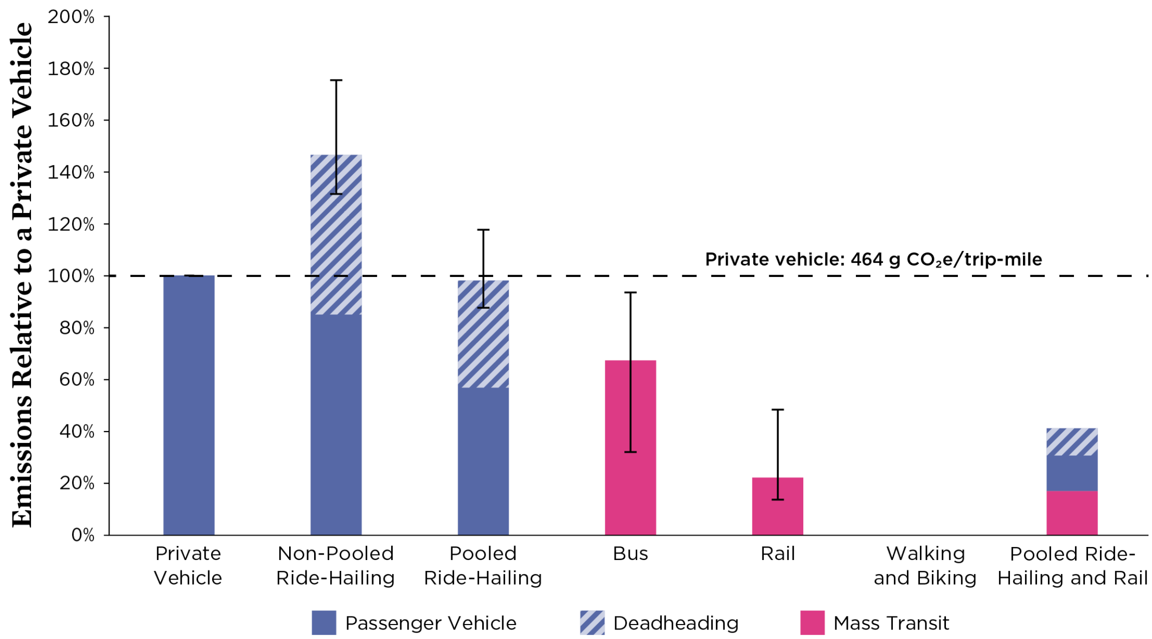
Table 6. Summary of Relative Emissions as Shown in Figure 2, Percent Relative to Private Car

| Type of Trip | Deadheading Miles | Miles with Passenger | Total Trip Miles | High Error | Low Error |
|---|---|---|---|---|---|
| **Private vehicle** | 0% | 100% | 100% | | |
| **Non-pooled, ride-hailing** | 62% | 85% | 147% | 28% | 16% |
| **Pooled, ride-nailing** | 41% | 57% | 98% | 19% | 11% |
| **Electric, non-pooled, ride-hailing** | 20% | 27% | 47% | 43% | 14% |
| **Electric, pooled, ride-hailing** | 13% | 18% | 32% | 29% | 9% |

*Notes: Emissions per trip are shown for private vehicles (baseline at 100 percent) and for pooled and non-pooled, gas-powered and electric TNCs. Each row corresponds to a column in Figure 2, from left to right. Private vehicles baseline emissions for a one-mile trip is 464 $gCO_2e$/trip (see Table 5). The high and low errors were calculated based on the low and high estimates for the p1 phase of the trip relative to the p1 midpoint, as shown in Appendix 2.*

# Chapter 3. Emissions Impact of Ride-hailing vs. Other Travel Modes

Figure 3. Emissions Impact of Ride-Hailing vs. Other Travel Modes




*Comparison of $CO_2$-equivalent emissions from an average gasoline-powered personal car trip, a non-pooled TNC trip, bus and rail trips, and a mixed mode with 25 percent pooled TNC ride and 75 percent rail. The first three columns in Figure 3 are the same as in Figure 2, repeated for comparison. In urban areas, rail, bus, walking, and biking are lower-carbon alternatives to ride-hailing. Rail and bus also help reduce congestion. Using ride-hailing to enable a passenger to use mass transit instead of driving is also a lower-carbon alternative.*

*Note: Car and ride-hailing emissions are per trip-mile, regardless of how many people are in the vehicle on the same trip, but emissions are adjusted for pooled trips. Bus and rail data are emissions per passenger based on average occupancy in the same seven metropolitan areas as in Figure 2. Error bars for bus and rail emissions represent variability among cities. Mass transit emissions do not indicate how emissions would change with increased ridership. Bus and rail operate on fixed schedules and are often less than fully utilized, so additional passengers do not always increase emissions. Upstream emissions are included.*

*SOURCE: For assumptions used in calculations, see Section 3.1*

## 3.1 Buses and Rail

To calculate the average bus and rail emissions for the seven cities, we first calculated the average emissions for each city, based on reported 2016 annual fuel consumption and passenger miles for the various agencies and bus and rail types (FTA 2019). Bus types included main buses, commuter buses, bus rapid transit, and trolley buses. For buses, fuels included diesel, natural gas, gasoline, and electricity. Rail types included streetcars and light, commuter, and heavy rails. Emission factors for buses and rail accounted for upstream emissions. Table 7 shows the emission factors for diesel, gasoline and natural gas. Tables 8 and 9 list the emissions for buses and rail in the seven cities, and the average emissions weighted by passenger-mile.

Table 7. Emission Factors

| Fuel | Emission Factor | Unit |
|---|---|---|
| **Diesel** | 12,916 | g$CO_2$e/gallon diesel |
| **Natural gas** | 10,553 | g$CO_2$e/diesel gallon equivalent |
| **Gasoline** | 11,072 | g$CO_2$e/gallon gasoline |

*Note: Upstream emissions are included.*

*SOURCE: Argonne 2018.*

Table 8. Average Bus Emissions per Passenger Mile for Seven Cities

| | Bus Type | Annual Passenger Miles | Annual g$CO_2$e | Emissions per Passenger Mile (g$CO_2$e) |
|---|---|---|---|---|
| **Boston** | TB, MB, RB | 301,268,940 | 110,183,721,242 | 365.73 |
| **Chicago** | MB | 613,043,935 | 207,646,751,557 | 338.71 |
| **Los Angeles** | CB, MB, RB | 1,247,107,062 | 438,432,085,619 | 351.56 |
| **New York City** | MB, CB, RB | 2,030,271,381 | 654,226,704,934 | 322.24 |
| **San Francisco** | TB, MB | 369,206,995 | 99,308,975,019 | 268.98 |
| **Seattle** | CB, MB | 740,290,506 | 110,413,594,737 | 149.15 |
| **Washington, DC** | MB | 374,136,333 | 162,786,060,472 | 435.10 |
| **Average (weighted by passenger mile)** | | | | 314.17 |

*Note: TB = Trolleybus; MB = Bus; CB = Commuter Bus; RB = Bus Rapid Transit*

*SOURCE: FTA 2019*

Table 9. Average Rail Emissions per Passenger Mile for Seven Cities

| | Rail Type | Annual Passenger Miles | Annual $gCO_2e$ | Emissions per Passenger Mile ($gCO_2e$) |
|---|---|---|---|---|
| **Boston** | LR, CR, HR | 1,414,392,329 | 241,458,066,907 | 170.72 |
| **Chicago** | CR, HR | 2,936,372,612 | 664,578,455,514 | 226.33 |
| **Los Angeles** | LR, CR, HR | 1,143,375,251 | 182,772,988,658 | 159.85 |
| **New York City** | CR, HR | 16,003,115,717 | 1,036,413,743,379 | 64.76 |
| **San Francisco** | SR, LR | 150,072,285 | 19,899,407,288 | 132.60 |
| **Seattle** | SR, LR, CR | 264,830,231 | 26,634,675,567 | 100.57 |
| **Washington, DC** | SR, HR | 1,327,092,353 | 162,786,060,472 | 171.91 |
| **Average (weighted by passenger-mile)** | | | | 103.27 |

*Note: SR = Streetcar; LR = Light Rail; CR = Commuter Rail; HR = Heavy Rail*

*SOURCE: FTA 2019*

## 3.2 Results

Table 10. Summary of Emissions Shown in Figure 3 ($gCO_2e$/ trip)

| Type of Trip | Emissions from Deadheading Miles | Emissions from Miles with Passenger | Emissions from Total Trip Miles |
|---|---|---|---|
| **Private vehicle** | 0 | 464 | 464 |
| **Non-pooled, ride-hailing** | 286 | 397 | 683 |
| **Pooled, ride-hailing** | 191 | 265 | 456 |
| **Bus** | - | 314 | 314 |
| **Rail** | - | 103 | 103 |
| **Pooled ride-hailing (25%) and rail (75%)** | 48 | 144 | 192 |

*Note: Emissions per trip are shown for private vehicles and for non-pooled and pooled, gas-powered TNCs, and for bus and rail trips, and a mixed mode with 25% pooled TNC ride and 75% rail. Each row corresponds to a column in Figure 3, from left to right.*

*SOURCE: See Sections 2 and 3 for assumptions.*

Table 11. Summary of Relative Emissions as Shown in Figure 3, Relative to Private Vehicle

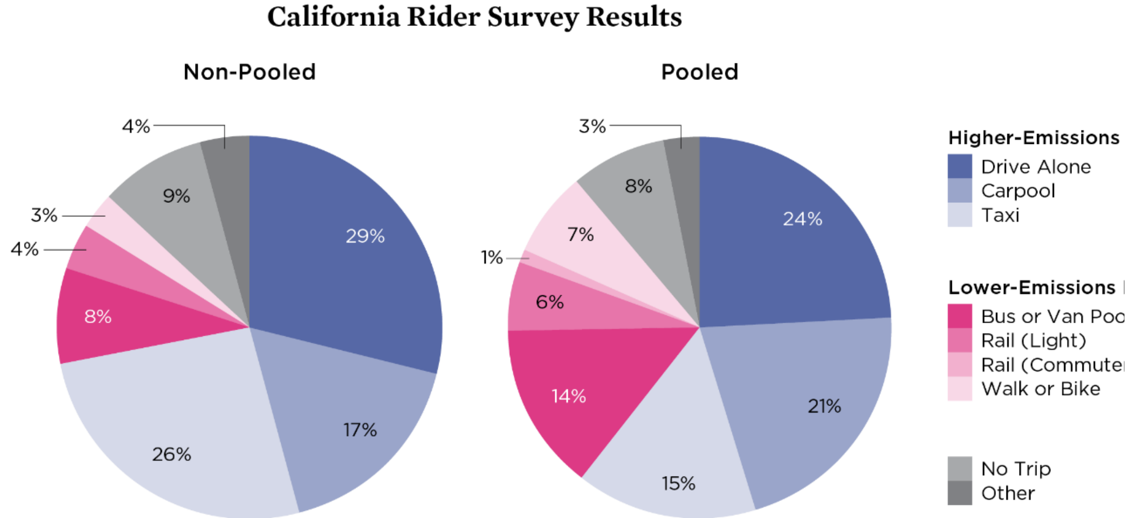
| Type of Trip | Deadheading | With Passenger | Total Trip | High Error | Low Error |
|---|---|---|---|---|---|
| **Private vehicle** | 0% | 100% | 100% | | |
| **Non-pooled, ride-hailing** | 62% | 85% | 147% | 28% | 16% |
| **Pooled, ride-hailing** | 41% | 57% | 98% | 19% | 11% |
| **Bus** | | 68% | | 26% | 36% |
| **Rail** | | 22% | | 26% | 8% |
| **Pooled ride-hailing (25%) and rail (75%)** | 10% | 31% | 41% | | |

*Notes: Emissions per trip are shown for private vehicles (baseline at 100 percent) and for non-pooled, gas-powered TNCs. Each row corresponds to a column in Figure 3, from left to right. Private vehicles baseline emissions for a one-mile trip are 464 $gCO_2e$/trip (see Table 10). The error ranges were calculated as the difference between the highest or lowest emission from all cities and the average emissions for the seven cities. For buses, the high estimate is based on Washington, DC (at 435 $gCO_2e$/passenger-mile) and the low estimate on Seattle (at 149 $gCO_2e$/passenger-mile). For rail, the high estimate is based on Chicago (at 226 $gCO_2e$/passenger-mile) and the low estimate on New York City (at 65 $gCO_2e$/passenger-mile).*

*SOURCE: See Sections 2 and 3 for assumptions.*

# Chapter 4
# Travel Modes Displaced by Ride-Hailing

Figure 4. Travel modes displaced by Ride-Hailing




*Rider surveys in California indicate that 24 percent of non-pooled trips and 36 percent of pooled trips would have been by mass transit, walking, or biking, or not taken at all. In other words, ride-hailing users often would have use lower-carbon modes rather than cars.*

*SOURCE: Circella et al. 2019*

A critical set of parameters determining the differences resulting from switching from previous transportation to TNCs are the "mode switch" percentages, corresponding to the percentage of trips displaced by TNC trips. Surveys in various cities asked respondents to describe what modes of transportation they would have taken if TNC rides had not been available. In some cases, the questions were about all TNC services, in other cases about Uber and Lyft, in particular. Table 12 summarizes surveys examining these mode shifts for several cities, groups of cities, and California.

Table 12. Mode Shifts from Surveys in Several Cities, Groups of Cities, and California

| | Personal Car or Carpool | Taxi or Car Service | Transit | Walk, Bike | No Trip | Other | Sum | Source |
|---|---|---|---|---|---|---|---|---|
| **Seven Metro Areas (note a)** | 21% (carpool) + 18% (drive) | 1% | 15% | 24% | 22% | | 101% | Clewlow and Mishra 2017 |
| **California (non-pooled) (note b)** | 29% (drive) +17% (carpool) | 26% | 12% | 3% | 9% | 4% | 100% | Circella and Alemi 2018 |
| **California (pooled) (note c)** | 24% (drive) + 21% (carpool) | 15% | 21% | 7% | 8% | 3% | 100.5% | Circella and Alemi 2018 |
| **Boston** | 18% | 23% | 42% | 12% | 5% | | 100% | Schaller 2018 |
| **Denver** | 19% (drive alone) + 9.3% (carpool) + 4.2% (car rental) + 4.5% (get a ride) | 9.6% (taxi) + 5.5% (car service) | 22.2% | 1.92% | 12.2% | 1.6% | 98% | Henao and Marshall 2019 |
| **New York City** | 12% | 43% | 50% | 16% | 2% | | Multiple responses (note d) | Schaller 2018 |
| **New York City** | 9%-48% (note e) | | | | | | | Schaller 2017 |
| **San Francisco** | 7% | 39% (taxi) + 11% (different ride service, carsharing, shuttle) | 33% | 10% | - (note f) | | 100% | Rayle et al. 2016 |
| **Seven Metro Areas** | 66.5% | | 9% (bus) + 6% (rail) | 18.5% | | | 100% | Feigon and Murphy 2016 |

*Table 12 Notes:*
*a. Boston, Chicago, Los Angeles, New York City, San Francisco, Seattle, Washington, DC*
*b, c See text for explanation.*
*d. Surveys with multiple responses allowed respondents to choose more than one type of displaced trip.*
*e. Range reflects geographic variation; see section about New York City.*
*f. The study does not report a share of respondents who would have made no trip.*

The overall range of results for the various surveys varied considerably, given the varying characteristics of the regions surveyed and of survey methodology. The ranges were broad for all modes, so estimating representative shares for an average city would have involved choosing among the various surveys and averaging results. We chose a recent set of surveys of California that asked respondents to report what mode of transportation they would have used had Uber/Lyft not been available on their last ride; they were also asked if that last ride was non-pooled or pooled (Circella et al. 2019). Table 13 summarizes the responses.

Table 13. Mode Shifts Used in the High Estimate Case

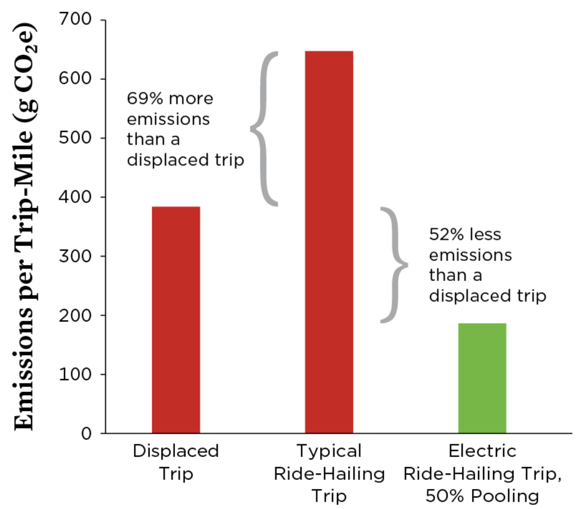
| | Respondent's Last Trip | |
|---|---|---|
| **Mode displaced** | Non-pooled | Pooled |
| **Drive alone** | 29.0% | 24.0% |
| **Carpool** | 17.0% | 21.0% |
| **Public bus** | 8.0% | 14.0% |
| **Light rail/tram/subway** | 4.0% | 6.0% |
| **Commuter rail** | 0.0% | 1.0% |
| **Bike or walk** | 3.0% | 7.0% |
| **Taxi** | 26.0% | 15.0% |
| **No trip** | 9.0% | 8.0% |
| **Other*** | 4.0% | 3.0% |

** The "other" category involved multiple kinds of transportation options, both car- and transit-based; we attributed a third of this category to private vehicle, carpooling, and average transit emissions.*

*SOURCE: Circella et al. 2019*

# Chapter 5
# Ride-Hailing Trips Are About 69% More Polluting as the Trips They Displace

Figure 5. Ride-Hailing Trips Are About 69% More Polluting as the Trips They Displace




*Comparison of $CO_2$-equivalent emissions from a typical TNC ride and the displaced trip. Emissions from a typical ride-hailing trip (pooled 15 percent of the time) are 69 percent higher than the average of the displaced trips it replaces. If ride-hailing companies increase pooling to 50 percent and convert to electric vehicles, they can reduce emissions by 52 percent compared with the displaced trips.*

*SOURCE: For assumptions used in calculation of displaced trip emissions, see text in this section. For ride-hailing emissions, see section 2.*

The "Displaced Trip" column shows the emissions that would have resulted from displaced modes of transportation. As discussed in Section 4, we chose two surveys based on whether the respondent's last trip was pooled or not. To obtain average emissions for a typical displaced ride, we weighed the emissions for each mode of transportation with the mode shift percentages for the pooled and non-pooled cases and weighed the two cases by the frequency of pooled trips (15 percent) and non-pooled trips (85 percent).

Tables 14 and 15 show the mode shifts for five displaced transportation modes, corresponding emissions per trip for that transportation mode, and the weighted emissions per trip. Table 16 shows the emissions for the displaced trip as an average of the two survey cases (non-pooled and pooled), weighted by the frequency of non-pooled and pooled trips (85%/15% for a current typical TNC, and 50%/50% for a future electric TNC).

Table 14. Weighted $gCO_2e$/trip for Five Displaced Transportation Modes for Cases, Respondents' Last Trip Non-Pooled

| | Drive Alone | Car-pool | Taxi | Light Rail | Commuter Rail | Transit Bus | Walking, Biking, No Trip | Total |
|---|---|---|---|---|---|---|---|---|
| **Mode switch** | 30.3% | 18.3% | 26.0% | 4.0% | 0.0% | 9.3% | 12.0% | 100% |
| **$gCO_2e$/ passenger trip** | 464 | 232 | 683 | 103 | 103 | 314 | 0 | 464 |
| **Weighted $gCO_2e$/ passenger trip** | 141 | 43 | 178 | 4 | 0 | 29 | 0 | 394 |

*SOURCE: Circella et al. 2019 (mode shifts); see sections 2 and 3 for emissions estimates*

Table 15. Weighted $gCO_2e$/trip for Five Displaced Transportation Modes for Cases, Respondents' Last Trip Pooled

| | Drive Alone | Carpool | Taxi | Light Rail | Commuter Rail | Transit Bus | Walking, Biking, No Trip | Total |
|---|---|---|---|---|---|---|---|---|
| **Mode switch** | 25.0% | 22.0% | 15.0% | 6.0% | 1.0% | 15.0% | 15.0% | 99% |
| **$gCO_2e$/ passenger trip** | 464 | 232 | 683 | 103 | 103 | 314 | 0 | |
| **Weighted $gCO_2e$/ passenger trip** | 116 | 51 | 103 | 6 | 1 | 47 | 0 | 324 |

*SOURCE: Circella et al. 2019 (mode shifts); see sections 2 and 3 for emissions estimates*

Table 16. Emissions for Figure 5 Showing Absolute Emissions for a One-Mile Ride with Passenger and Emissions Relative to a Private Car

| | Private Car | Displaced Trip | Current Ride-Hailing Trip (15% Pooled/85% Non-pooled) | Future Electric Ride-Hailing Trip (50% Pooled/50% Non-pooled) |
|---|---|---|---|---|
| **Emissions ($gCO_2e$/passenger trip)** | 464 | 384 | 649 | 183 |
| **Emissions relative to private vehicle trip** | 100% | 83% | 140% | 39% |

*SOURCE: For emission estimates, see sections 2, 3 and 5.*

# Appendix 1
# TNC Trip Lengths and Deadheading Percentages from the Literature

Table 17. TNC Trip Lengths from Literature References

| | p1 + p2 (miles) | p3 (miles) | T (miles) | Reference |
|---|---|---|---|---|
| **New York City** | 3.5 | 5.2 | 8.6 | Schaller 2017 |
| **Chicago** | 3.2 | 4.7 | 7.9 | Schaller 2018 |
| **San Francisco** | 2.0 | 4.1 | 6.1 | Said 2018 |
| **Denver** | 4.9 | 7.0 | 11.9 | Henao 2017 |
| **Austin** | 4.4 | 5.4 | 9.8 | Ride Austin n.d. |
| **California** | - | - | 11.4 | CARB 2019 |

Table 18. TNC Deadheading Percentage from Literature References

| | Deadheading (Percent of Total Trip) | Reference |
|---|---|---|
| **New York City** | 41 | Schaller 2017 |
| **Chicago** | 41 | Schaller 2018 |
| **Chicago** | 45 | Fehr & Peers 2019 |
| **San Francisco** | 33 | Said 2018 |
| **San Francisco** | 40 | Fehr & Peers 2019 |
| **San Francisco** | 35.8–44.8 | Cramer and Krueger 2016 |
| **Denver** | 40.8 | Henao and Marshall 2019 |
| **Austin** | 45 | Wenzel et al. 2019 |
| **Boston** | 45 | Fehr & Peers 2019 |
| **Washington, DC** | 45 | Fehr & Peers 2019 |
| **Los Angeles** | 40 | Fehr & Peers 2019 |
| **Los Angeles** | 35.8 | Cramer and Krueger 2016 |
| **Seattle** | 47 | Fehr & Peers 2019 |

# Appendix 2
# VMTs Used for Calculating Deadheading Averages and Ranges

The first six rows list the VMTs reported by Fehr & Peers 2019, used to calculate the deadheading average and ranges for seven cities. See Section 2.2.1 for an explanation of New York City VMT.

Table 19. VMTs Reported by Fehr & Peers 2019 for Six Cities, for Calculation of Deadheading (miles per month)

| | Low p1 | High p1 | Mid p1 | p2 | p3 | Total |
|---|---|---|---|---|---|---|
| **Boston** | 14,700,000 | 20,590,000 | 17,645,000 | 5,340,000 | 28,280,000 | 51,265,000 |
| **Chicago** | 29,700,000 | 40,800,000 | 35,250,000 | 9,080,000 | 54,600,000 | 98,930,000 |
| **Los Angeles** | 38,300,000 | 63,190,000 | 50,745,000 | 17,660,000 | 104,130,000 | 172,535,000 |
| **San Francisco** | 31,500,000 | 46,600,000 | 39,050,000 | 11,930,000 | 75,150,000 | 126,130,000 |
| **Seattle** | 9,700,000 | 15,600,000 | 12,650,000 | 2,880,000 | 17,550,000 | 33,080,000 |
| **Washington, DC** | 24,400,000 | 33,500,000 | 28,950,000 | 8,100,000 | 45,990,000 | 83,040,000 |
| **New York City*** | | | | | 142,699,111 | 240,589,911 |

** New York City data was estimated. See section 2.2.1.*

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