TRR
JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

Research Article

Transportation Research Record
2020, Vol. 2674(7) 385–397

DOI: 10.1177/0361198120922851
journals.sagepub.com/home/trr
SAGE

Evolution of Transportation Network Companies and Taxis through 2013–2018 in Chicago

Sneha Roy[1], Anurag Komanduri[1], and Kimon Proussaloglou[1]

Abstract

The objective of this paper is to highlight important differences between taxis and transportation network companies (TNCs) in a large urban area. We analyze the publicly available dataset from Chicago which includes taxi and transportation network company (TNC) utilization and the level of service measures from five months in 2013–2014 and the same five months in 2018–2019. We compare and contrast the data from these two points in time to document utilization of taxis and TNCs and to measure differences in travel times, travel distances, fares, destinations served, and the spatial and temporal distribution of these trips. Travel to and from airports has been evaluated separately owing to the exceptionally high number of trips they generate. Striking differences between pooled and unpooled TNC trip volumes and other travel metrics have been assessed to highlight their operational diversity despite being considered as the same mode. The exploratory analysis has been carried out across the shared-ride, time, and mode dimensions. The study revealed both similarities and differences in taxi trip characteristics between the two evaluation periods and also outlined how the ridehailing market has grown over the years despite the near stagnation in population and employment in the city. We believe that assessing how taxis have fared through this time and highlighting the intrinsic differences between how the old and new mode of on-demand ride services coexist is important. This study aims to help understand how new-age mobility services are impacting transportation in one of the largest cities in the U.S.

The rapid growth of on-demand ride services such as Uber and Lyft, also called transportation network companies (TNCs), has prompted debate among policymakers and stakeholders for a variety of reasons in the context of business practices, negative effects on transit, and increased congestion. Since their introduction about a decade ago, they have tremendously influenced daily travel behavior, especially in urban areas. However, rigorous analyses of these modes and their effects has not been possible owing to the paucity of data. The spectrum of arguments about the effect of the rapidly growing ridesharing market is wide and vastly polarized. Consequently, the direction of their gross impact is also contested via several recent studies. An increasing number of researchers have demonstrated the importance of taking due diligence in distinguishing between pointed and self-conclusive designs of experimenting with transportation network company (TNC) data to avoid furthering either school of thought about the presumed holistic effect of TNCs on the transportation ecosystem (*1–4*).

As cities cannot manage what they cannot measure, city officials in most major metropolitan cities like Boston, Chicago, New York and San Francisco have been discussing ordinances to be able to access TNC trip data to carry out an unbiased and wide-range explorations of their effects. The push to promote data transparency to enable better informed development of transportation infrastructure has been strengthening. This has been followed by different regulations to mandate TNC data sharing using a few metropolitan agencies, and also addressing the heightened security concerns that accompany them. The City of Chicago recently published raw trip data of two TNCs from November 2018 through March 2019. We use this dataset, in conjunction with the taxi dataset that Chicago has

[1]Cambridge Systematics, Los Angeles, CA

Corresponding Author:
Sneha Roy, sroy@camsys.com

been releasing for many years, to conduct the transportation analysis described in this paper.

Theoretically, taxis and TNCs share a host of similarities: both are on-demand ride-sourcing services operating on a publicly owned and shared infrastructure. However, the dissimilarities between the two modes need to be better understood. TNCs have grown rapidly in the past decade and their absolute numbers have dwarfed taxis. TNC advantages such as shorter wait times, ease of payment, spatial and temporal accessibility of TNC services, and ratings offered by TNCs have contributed to the growth and popularity of these services.

An increasing number of recent studies have shown that TNCs contribute to traffic congestion which affects overall vehicle travel in urban areas. In this exploratory study, we compare the equitability, distribution and service attributes of these two similar modes of transportation—taxis and TNCs. We aim to provide a baseline of observed trends to help establish the role of TNCs on studies that examine questions related to the environment, labor, public policy and optimization of the roadway networks.

This study leverages this dataset to explore differences and similarities between taxis and TNCs across several trip-making dimensions including fares, trip lengths, and the accessibility of service in different geographies. The temporal resolution of this study covers average weekdays, weekends and five time periods during the day. We hope that this analysis will contribute to the discussion and the further analysis of TNC travel in different cities and encourage policy decision makers to agree on open data sharing agreements in their own city.

Literature Review

Studies have examined differences between key performance indicators for taxis and TNCs such as speed, travel time reliability, passenger expense and quality of service. Such studies have reported TNCs to be more affordable than traditional taxis (*5*). However, observations with greater spatial resolution could not be made owing to the lack of publicly available data. A panel data-based study in San Francisco revealed that TNCs are correlated with a rise in congestion, caused uniquely by the sheer magnitude of their volume. The increase in vehicle volumes was shown to be greater than the increase in travel expected owing to population and employment increases in economically healthy cities such as San Francisco (*3*). Pickup and drop-off venues have also been shown to force disruptions in traffic flow in streets that are congested to begin with (*4*). Studies based in Denver and Austin calculated deadheading times, elasticities for wait time and fares, and distinctly different travel patterns between TNCs and other conventional modes, inferring trip characteristics differ across geographies and socioeconomic classifiers (*6*,*7*).

The majority of existing studies are survey-based as TNCs were not required to publicly report their trip data until recently and then only for a few cities (Chicago, Seattle, and New York). An intercept-survey based study in San Francisco comparing TNCs and taxis found that less than 50% of TNC trips replace taxi trips (*8*). Despite being similar, taxis and TNCs contrasted significantly with regards to user characteristics, wait times and trips served. Several metropolitan cities (e.g., New York) have historically evaded the unchecked rise of taxis operating within their boundaries by a variety of means such as stringent safety and insurance laws, and cordon-based medallion limits. The separation of commercial enterprises from private entities (vehicles and residences) has provided a method of identifying and regulating commercial transactions. As the shared service economy continues to grow, it is getting more complex to standardize enterprises such as AirBnB, TNCs such as Uber and Lyft and shared commodity services like Turo, Zipcar and Getaround adhere to a set of governing rules. In an ideal world, service equity, financial implication of contribution to network congestion, and increased competition with primarily public-interest services such as transit would be factored into their functioning modus. Additionally, the methods of operation and target clientele of these services are innovative and novel, thus pre-existing umbrellas of rules governing similar but standardized services such as the hotel and the taxi industry are not applied as-is to these enterprises. Although this is rapidly changing, the current lack of standardization combined with the ease of use of the TNC application-based interface, has resulted in their rapid growth.

The presence of TNCs affects mode choice decisions and mode market shares (*9,10*). TNCs can potentially act as buffer modes of transportation offering first and last mile services; can induce travel demand which may increase traffic congestion in urban areas; and may also take riders away from public transit after controlling for other drivers affecting transit ridership such as rising gas prices, declining auto ownership (where applicable), and changing service levels of transit and roadways (*11–16,31,32*). They have also been shown to disrupt mobility, as we know it, on a scale sufficient to beg reevaluation of energy estimates (*17*).

A preliminary study using TNC data for New York reinforced the theorized substitution between taxis and TNCs and showed their ability to complement transit (*18,20*). The study in Austin identified hotels and airports as ridesharing hotspots in the city. In 2016, TNCs accounted for 15% of all intra-San Francisco vehicle trips, which is 12 times the number of taxi trips

(*1*). In New York, TNC ridership in 2016 equaled that of yellow cabs and TNC utilization doubled annually between 2014 and 2016 (*19*). Studies based in New York and Boston found that TNCs are fundamentally much closer to taxis than modes that principally strive to share rides (e.g., vanpools) (*19*,*21*). It is important to explore the similarities and differences in travel metrics between these two modes to gain insights that support public policy, enable improved easement for modes preferred by the community, and ensure equitable sharing of public resources (*22*).

Studies have explored the capacity of TNCs to provide equitable services across different demographic groups in metro areas - a metric that traditional taxis have not commonly been judged against (*23,25*). Evidence exists for both sides of the argument (socioeconomically distributive in Seattle (*24*) and found significantly lacking in Los Angeles and other U.S. cities wherein service equitability is measured as a function of the wait times and availability of TNC (*22*,*26*,*27*). Taxis have also been charged with being non-compliant when it comes to offering equitable service (*28*). Existing research has also theorized the possibility and the procedure of how TNCs can potentially coerce taxis into improving service reliability and quality by competing with them at claiming ride-hailers (*29*). An empirical case study on qualitative factors of taxi services in Chicago revealed a marked improvement in consumer satisfaction among taxi users since the advent of TNCs (*30*).

Data Description

The study is structured as a before/after analysis of the changes that affect the magnitude and operations of taxis within the City of Chicago. Characteristics and travel patterns of taxis between November 2013 and March 2014 are used as the base case to reflect a point in time when TNC activity in Chicago was negligible. Thus, the lack of availability of TNC data from 2013 is, in general, not considered to be an impediment to this analysis, it is assumed that TNC trip characteristics in 2013 were similar to those of taxis when their attrition was not comparable to or overwhelming taxis in the city. This five-month period is compared against the operating characteristics and travel patterns of both taxis and TNCs between November 2018 and March 2019.

As part of its licensing process for Transportation Network Providers, Chicago requires TNCs to report on their activities monthly, like the requirements set earlier for taxis. (Please see https://data.cityofchicago.org/Transportation/Transportation-Network-Providers-Trips/m6dm-c72p for the TNC trip data hosted by the city of Chicago and https://data.cityofchicago.org/Transportation/Taxi-Trips/wrvz-psew for the same schema of data for taxi trips. A statement related to the data reporting guidelines that TNCs in Chicago have to adhere to is mentioned here: https://chicago.github.io/tnp-reporting-manual/. A brief description of the privacy statement and the method of collection of the taxi data is given here: https://digital.cityofchicago.org/index.php/chicago-taxi-data-released/.) The taxi dataset comprises of trip start and end tract, actual trip length, trip time-of-day, travel time, and trip fare. Apart from the same information for TNCs, an additional data item in the TNC trip dataset is whether a trip was pooled. Timestamps are rounded to the nearest 15 min. Owing to the data reporting process, not all rideshare trips are reported, but the City believes that most are reported, we specifically looked to quantify travel patterns for major holidays and found TNC data to be lacking on these days. However, given the overwhelming presence of TNCs otherwise, we assume that a few unreported trips would only make the analysis slightly more conservative and would not cause a significant skew in our interpretation of the data. Additional filters were applied to remove erroneous records from the dataset with unreasonably short or long trip lengths and travel times.

We categorize the data to enable weekday/weekend analysis and to compare differences by the time of day. The following time-periods were used:

- Early AM (EA): 00:00–06:00;
- Morning Peak (AM): 06:00–09:00;
- Mid-day (MD): 09:00–16:00;
- Evening Peak (PM): 16:00–19:00; and
- Evening Shoulder (EV): 19:00–24:00.

It must be noted that the City of Chicago has taken excellent precautions to protect the privacy and integrity of the data. This means that researchers seeking to answer particular policy questions must allocate sufficient time to clean, organize, and structure the dataset before analyzing it.

Overview of Methods and Research Questions

The City of Chicago has not seen major changes in the population and employment between 2013 and 2018 suggesting that the underlying factors of background change can be considered to be constant across this time period. In our analysis we sought insights on how trip characteristics for ride-hailing trips may have changed between 2013 and 2018. The aim is to identify differences in ride-hailing travel trends for both taxis and TNCs. These trends were expected to have progressed differently for the two modes, both temporally and spatially.

For this exploratory study, we have used Python-based data wrangling and Tableau-based visualization procedures to provide concise analyses that seek to answer our research questions. Performance metrics across the two study periods were derived for datasets pertaining to each of the two study years separately, normalized to scale and then compared. Statistically significant distinctions between trends have been analyzed through two-sample *t*-tests, wherever applicable, to confirm differences in performance, or the lack thereof, between the two study periods (2013 and 2018).

In particular, the following questions are being tackled by this paper:

- Has there been a decline in the total taxi trips with the introduction of TNCs? How much have total ridehailing trips changed over this period?
- Where are taxis and TNCs most used within the city? Is there a difference between sections of the city being served predominantly by taxis and those by TNCs?
- How are taxi fares per mile different from those of TNCs? Have taxi fares responded to the advent of the highly subsidized TNCs over the years?
- How do the typical trip lengths associated with the two modes compare with one another? Have the new ridehailing modes improved the equity and accessibility of transportation across the study area?
- How far could ridehailing fares take you in 2013–2014 and how different are these measures today?

Analysis and Findings

Trip Counts

Table 1 provides the big picture statistics for key socioeconomic attributes and trip making characteristics. It shows no, or modest, changes in the population, households and employment compared to the major changes in taxi and TNC utilization. The total number of ridehailing trips during the study period (counting both TNCs and taxis) more than quadrupled from 9 million in 2013 to 37 million in 2018. However, during this time, total taxi trips declined by about 54% and they declined by 67% on the weekends. TNC trips, on the other hand, exploded onto the scene and we encountered over 40 million such trips within the 5 months of observation.

Other key takeaways from this analysis include the following:

- In the 2018 period of observation, more than 60% of Census tracts in the region registered at least 1,000 daily ridehailing trips.
  - The same statistics were much lower in 2013 (about 21%) as taxis were the only significant modes available for ridehailing customers. This key finding underscores the greater dispersion of service provided by TNC services.
  - When looking at 2018 taxi use, less than 10% of all Census tracts recorded 1000 or more trips, again suggesting the greater TNC penetration across the region (Figure 1*a*–ii).
- A stronger concentration of taxi hails in 2018 is observed at the downtown core and the O'Hare airport regions than existed in 2013.
  - In 2013, Census tracts in downtown and the two airports—Midway and O'Hare—accounted for 73% of all taxi trip starts.
  - In 2018, these Census tracts account for about 90% of all taxi trips. This indicates that taxi trips have become more focused on serving key zones and locations.
- TNCs, on the other hand, serve a wider variety of spaces across the City. Several low income and some transit-poor communities on the South and West sides of Chicago are served by TNCs along with rides close to major rail and bus corridors.
  - This suggests that TNCs have expanded ridehailing service to communities that suffered from a lack of taxi service in the past.
  - Some researchers have argued that the large number of trips served by TNCs has been gained at the cost of significant declines in transit ridership, especially for short distance trips.

Table 1. Change in Ridehailing Trips between 2013–2014 and 2018–2019

Metric	2013–2014	2018–2019	Percentage change
Population	2,695,000	2,720,000	+0.93%
Households	1,192,790	1,046,789	–12.24%
Total non-farm employment	4,472,300	4,751,100	+6.23%
Total ridehailing trips	13,826,078	52,957,921	+283.03%
Total taxi trips	13,826,078	6,316,479	–54.32%
Weekend taxi trips	1,851,225	614,723	–66.79%
Total TNC trips	NA	46,641,442	NA
Weekend TNC trips	NA	14,786,199	NA

Note: TNC = transportation network companies; NA = not applicable; study.

Table 2 shows the distribution of pooled versus non-pooled TNC trips in the City.

- Out of about 47 million TNC trips, only 8.5 million (or 18%) trips were pooled. Shared trips were found

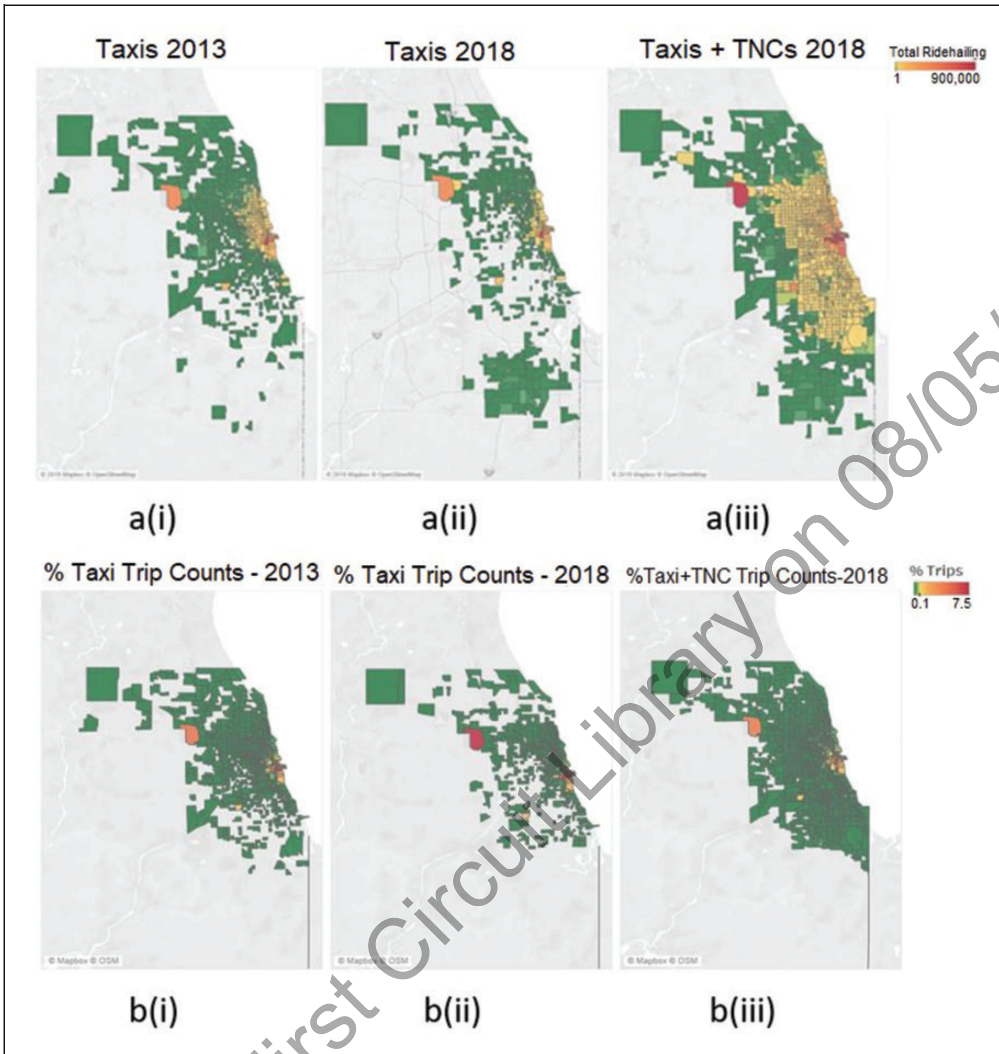

Figure 1. Shifts in taxi and transportation network company (TNC) trips between 2013–2014 and 2018–2019—A spatial overview: (*a*) (i) taxis in 2013, (ii) taxis in 2018, and (iii) taxis and TNCs in 2018; (*b*) (i) percentage of taxi trip counts in 2013, (ii) percentage of taxi trip counts in 2018, and (iii) percentage of taxi and TNC trip counts in 2018.

Table 2. Shares of Pooled and Non-Pooled TNC Trips[a]

	Weekday			Weekend		
TOD	Pooled	Non-pooled	% Trips pooled	Pooled	Non-pooled	% Trips pooled
EA	389,595	2,109,823	16%	370,730	2,246,964	14%
AM	940,323	3,745,964	20%	180,272	735,407	20%
MD	1,829,887	8,038,402	19%	822,463	3,825,976	18%
PM	1,413,081	5,037,729	22%	450,238	2,260,034	17%
EV	1,497,900	6,852,540	18%	600,556	3,293,559	15%
Total	6,070,786	25,784,458	19%	2,424,259	12,361,940	16%

Note: TNC = transportation network companies; TOD = time of day; EA = early AM (00:00–06:00); AM = morning peak (06:00–09:00); MD = mid-day (09:00–16:00); PM = evening peak (16:00–19:00); EV = evening shoulder (19:00–24:00).
[a]In Figure 1, a–i and b–i represent taxi trips (total and percent distribution) from November 2013 to March 2014. a–ii and b–ii show all taxi trips and their distribution in 2018. Between November 2018 and March 2019, taxi trips account for about 13% of all ridehailing trips. a–iii and b–iii represent taxi and TNC trips (total and percent distribution) between November 2018 and March 2019.

to be less prevalent on weekends at all times of the day, possibly owing to reduced sensitivity for travel time. PM peak periods saw the most shared rides on weekdays.
- In 2018–2019, weekend taxi trips make up 10% of all taxi trips, this same number was 13% in 2013 suggesting that the share of weekend taxi trips has remained about the same. In contrast, weekend TNC trips make up about 32% of all TNC trips potentially suggesting that weekend leisure travelers prefer TNCs over taxis.

Trip Lengths

Next, the average trip length was calculated and plotted for taxis in both years of observation and for TNCs in 2018. Table 3 shows the average trip lengths and durations for ridehailing trips and also breaks down these two measures by each of the five time periods.

- Taxis in 2018 have consistently longer trip lengths both on average (**two-tailed *t*-statistic = –5.39**) and by the time of day compared to 2013. The shift toward longer trips, especially in the 50th–75th quantile, appears to be a result of a higher share of taxis for airport travel.
- The same pattern holds for trip durations with taxis in 2018 showing longer travel times compared to 2013 (**two-tailed *t*-statistic = –2.53**). These increases in travel time may be partly attributable to the steady rise in congestion in the region.
- Trip lengths vary across modes for similar fares (Table 4), TNC trips are longer than taxi trips per unit fare

Table 3. Difference in Distributions of Trip Length and Durations

	Trip length						Trip duration (minutes)					
Distribution and means	EA	AM	MD	PM	EV	Daily average	EA	AM	MD	PM	EV	Daily average
Taxis 2013												
25th percentile	0.60	0.80	0.70	0.70	0.70	0.70	6.00	6.00	6.00	7.00	6.00	6.00
50th percentile	1.70	1.50	1.40	1.40	1.57	1.50	9.00	10.00	10.00	11.00	10.00	10.00
75th percentile	3.70	3.70	3.10	3.00	3.40	3.30	14.00	18.00	16.00	18.00	15.00	16.00
Mean	3.14	3.71	3.39	3.13	3.06	3.24	11.31	14.99	13.54	15.20	12.20	11.89
Taxis 2018												
25th percentile	0.80	0.80	0.80	0.86	0.90	0.84	5.00	6.00	6.00	7.00	6.12	6.00
50th percentile	1.80	1.39	1.40	1.40	1.70	1.50	9.00	9.08	9.28	11.00	10.10	10.00
75th percentile	4.60	3.20	3.30	3.20	5.10	3.77	14.97	16.00	16.00	18.92	18.00	17.00
Mean	4.12	3.76	3.96	3.62	4.46	3.99	12.14	14.11	14.14	16.34	14.52	14.48
% change in taxi trip characteristics between 2013–2014 and 2018–2019												
25th percentile	33%	0%	14%	23%	29%	20%	–17%	0%	0%	0%	2%	0%
50th percentile	6%	–7%	0%	0%	8%	0%	0%	–9%	–7%	0%	1%	0%
75th percentile	24%	–14%	6%	7%	50%	14%	7%	–11%	0%	5%	20%	6%
Mean	31%	1%	17%	16%	46%	23%	7%	–6%	4%	8%	18%	22%
TNC-shared 2018												
25th percentile	3.50	3.00	3.00	2.70	3.00	3.00	12.55	14.85	13.78	14.62	12.78	13.70
50th percentile	6.10	5.20	5.20	4.60	5.20	5.10	18.87	22.50	21.10	22.20	19.10	20.73
75th percentile	10.20	8.70	8.80	7.80	8.70	8.70	26.97	32.82	31.02	32.40	27.40	30.23
Mean	7.63	6.58	6.67	5.94	6.64	6.58	20.79	25.24	23.77	25.04	21.13	23.33
TNC-non shared 2018												
25th percentile	1.90	1.70	1.60	1.50	1.50	1.60	7.35	8.98	8.38	8.87	7.55	8.17
50th percentile	4.00	3.60	3.30	2.90	3.10	3.30	11.98	14.78	13.63	14.37	12.00	13.18
75th percentile	8.50	7.90	7.50	5.90	6.10	6.90	19.03	24.37	22.38	22.95	18.22	21.10
Mean	6.59	6.22	6.10	5.16	5.26	5.77	14.52	18.57	17.30	18.15	14.25	16.48
% difference between shared and non-shared TNC trip characteristics												
25th percentile	84%	76%	88%	80%	99%	88%	71%	65%	64%	65%	69%	68%
50th percentile	53%	44%	58%	59%	68%	55%	58%	52%	55%	54%	59%	57%
75th percentile	20%	10%	17%	32%	43%	26%	42%	35%	39%	41%	50%	43%
Mean	16%	6%	9%	15%	26%	14%	43%	36%	37%	38%	48%	42%

Note: TNC = transportation network company; EA = early AM (00:00–06:00); AM = morning peak (06:00–09:00); MD = mid-day (09:00–16:00); PM = evening peak (16:00–19:00); EV = evening shoulder (19:00–24:00).

Table 4. Distribution of Trip Lengths for Different Prevalent Average Taxi and TNC Fares

Metric	Taxis 2013	Taxis 2018	TNC 2018 non-pooled	TNC 2018 pooled
Trip lengths for $10				
25th percentile	0.70	0.70	0.90	1.80
50th percentile	0.90	0.90	1.20	3.20
75th percentile	1.30	1.20	1.60	5.30
Mean	1.02	0.96	1.36	3.82
Trip lengths for $15				
25th percentile	0.70	0.71	1.00	2.00
50th percentile	1.00	1.00	1.50	4.10
75th percentile	1.40	1.33	2.60	6.70
Mean	1.25	1.12	2.11	4.70
% increase in $15 trip distances with respect to $10 trip distances				
25th percentile	0%	1%	11%	11%
50th percentile	11%	11%	25%	28%
75th percentile	8%	11%	63%	26%
Mean	23%	17%	55%	23%
Trip lengths for $20				
25th percentile	0.70	0.73	1.10	2.10
50th percentile	1.00	1.00	1.60	4.30
75th percentile	1.50	1.40	3.80	7.20
Mean	1.40	1.22	2.65	5.05
% increase in $20 trip distances with respect to $10 trip distances				
25th percentile	0%	4%	22%	17%
50th percentile	11%	11%	33%	34%
75th percentile	15%	17%	138%	36%
Mean	37%	27%	95%	32%

Note: TNC = transportation network company.

all across the city as taxi trip lengths per unit fare do not appear to have changed between the two observed years.

- Non-pooled TNC trips are similar to taxi trips with regard to the ride service offered. Nevertheless, we observed that non-pooled TNC trips have longer average trip lengths than taxis in 2018. This may reflect the substantially lower prices that TNCs offer, especially outside peak hours. Does this hold in peak hours?
- The average speeds of taxis have remained stable even across the years. However, the average speeds of TNCs were much faster than taxis in 2018. This is probably because TNCs serve every corner of the region, unlike taxis that focus more on the congested urban core and the airport region.
- As expected, PM speeds are the lowest and both taxis and TNCs travel fastest in the early AM.

Figure 2, shows that the TNC trip lengths vary but are uniform within different regions: they include a cluster of uniformly short trips near the Loop and a group of longer trips further away from the central business district (CBD). Airport-bound trips appear to be much longer and stand out as the darkest red Census tract.

Pooled versus Non-Pooled TNC Trips. Table 3 shows the distribution of trip lengths and trip durations for taxis in

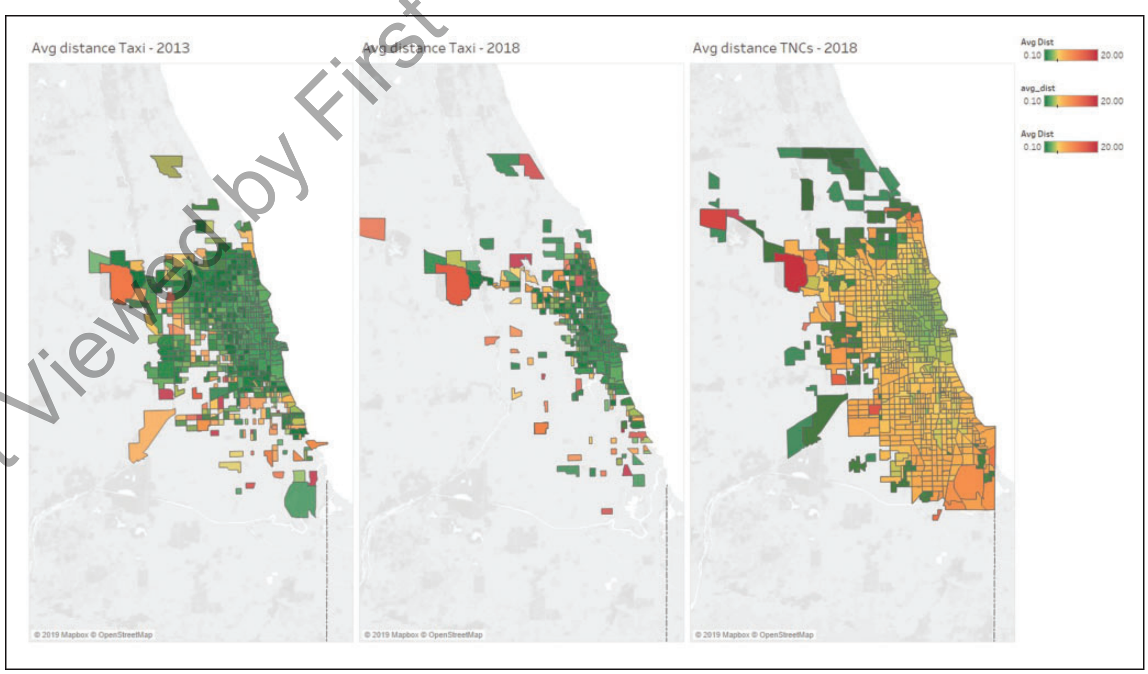

Figure 2. Taxi and transportation network company (TNC) trips by average trip lengths, 2013 and 2018.

2013 and 2019 and for pooled and non-pooled TNC trips in 2018.

Pooled trips match multiple riders along the way, but charge a lower fee for individual riders sharing the ride. This results in longer trips on average, but at a lower fare.

- Pooled trips take significantly longer, by about 42%, to complete compared to non-pooled trips (**two tailed *t*-statistic = 6.20**).
- However, trip lengths are only 14% longer, reflecting the slower speeds on pooled trips. These differences are most pronounced during the evening period and for shorter trips.

It is often argued that by pooling rides, the net passenger car equivalents (PCEs) on the network can be reduced. However, it should also be noted that the passenger miles driven by a rider in a pooled TNC ride can be substantially more than passenger miles driven by a rider in a non-pooled ride between the same locations. Therefore, the ability to add information about deadhead miles and the additional distance added by detours among ridesharing passengers could provide useful information if it is released by the City of Chicago.

Travel Fares

The average fare per mile of travel could possibly explain one of the major underlying differences between TNC and taxi travel. We calculate this in two different ways: first, we compare the average cost of travel per mile for taxis and for TNCs. Next, we pick a fairly busy Census tract in downtown Chicago and measure the farthest distance that is covered in the data for different fare bands.

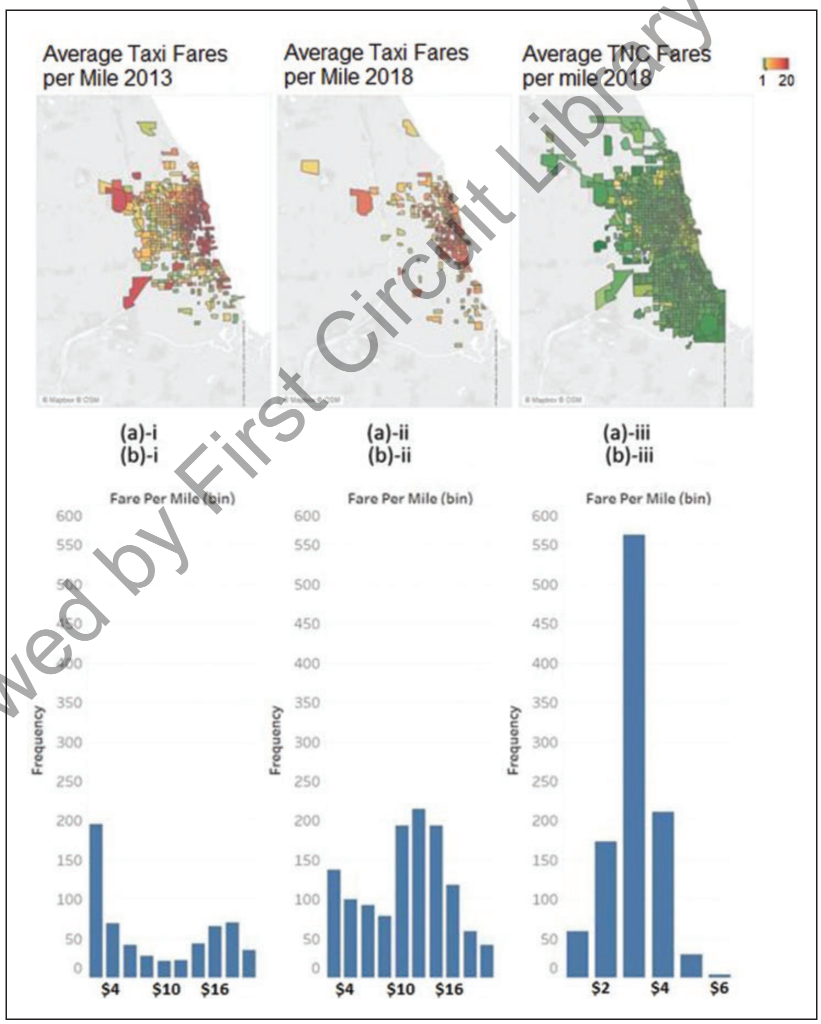

Figure 3. Distribution of average fare per mile for taxis and transportation network company (TNC) in 2013 and 2018—A spatial overview: (a) (i) taxis in 2013, (ii) taxis in 2018, and (iii) taxis and TNCs in 2018; (b) (i) percentage of taxi trip counts in 2013, (ii) percentage of taxi trip counts in 2018, and (iii) percentage of taxi and TNC trip counts in 2018.

Fares per Mile. Figure 3 shows the average taxi fares for 2018 and 2013 and contrasts them with the average TNC fares for 2018.

- In Figure 3*a*–i, we observe that the average fare per mile in the downtown and nearby Census tracts were higher than the other catchment areas for taxi trips in 2013 (the dollar amounts in 2013 are adjusted for inflation using a factor of 1.46%). Taxi fares in Chicago are driven both by distance and time spent riding. As the downtown areas are more congested over time, a higher average fare per mile near the downtown area makes sense.
- We also observe that the competition offered by TNCs may have capped the upper limit of taxi trip fares in 2018 to a much lower amount than in 2013 (Figure 3*b*–ii).
- For purposes of a clearer comparison of taxi and TNC fares, only the non-pooled TNCs have been plotted. As is shown in Figure 3, the non-pooled TNCs offer significantly lower fares per mile compared to taxis and their rates are fairly consistent throughout the city.

Millennium Park Travel Shed. Figure 4 describes the trip end activity for ridehailing services under different price points for trips starting near Millennium Park. Each figure in a row is a superset of the figure(s) to their left. Table 4 shows how trip lengths for these trips are distributed across all modes.

- The distances covered by a $10 fare are much shorter by taxi when compared to the distance covered by TNC on the same fare.
- The same patterns are true when examining the distance covered by $15 and $20 fares by taxi and TNC services in 2013 and 2018.
- In 2013, a shift in taxi fares from $10 to $15 translated to a larger access area for the riders. The change in the catchment area for the same increase in taxi fares was less pronounced in 2018.
- In 2018, the TNC travel market shed for $10 exceeds the travel market shed observed with a $20 taxi fare. For $20, riders of TNCs can pretty much reach all corners of the Chicago region.

Owing to demand-based pricing, the catchment areas for TNC trips for each of these price points do not increase uniformly with the fare. Figure 5 shows how trip counts (representative of larger travel sheds for Millennium Park) during each time of the day increase with an increase in the average fare and compares them to the corresponding lower price points. Note that

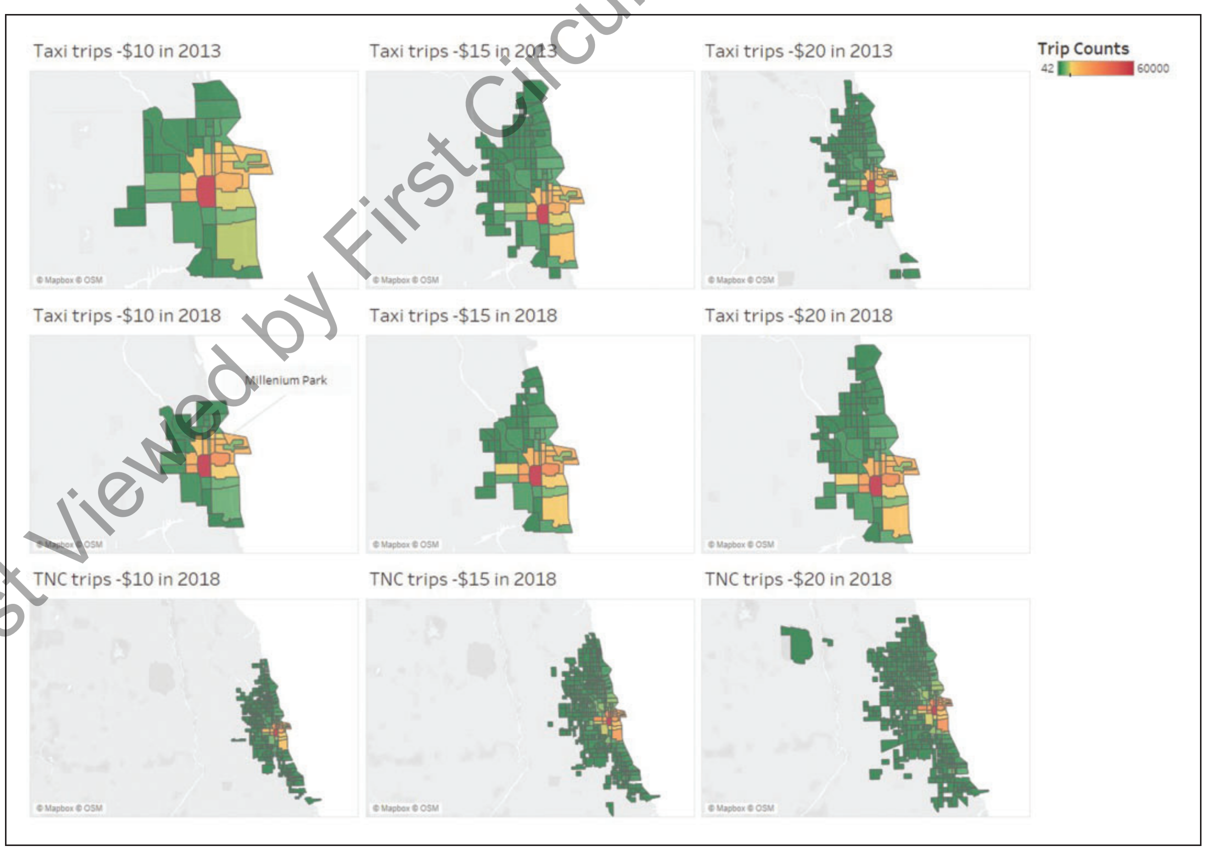

Figure 4. Taxi and transportation network company (TNC) distances from Millennium Park for a fare of $10, $15 and $20.

non-shared TNC trips have a greater percent difference from lower price points than shared TNC trips.

Table 5 quantifies this observation for non-shared TNC trips. It shows the percentage share of TNC trips made by spending $10, $15 and $20 for each time period. Shares of pooled TNC trips for the three price points do not vary as sharply as those for unpooled TNC trips.

- The average difference in the percentage share of trips between the three fares is about 5–6% for pooled TNC trips and about 11–12% for unpooled TNC trips.
- Catchment areas for trips between incremental price points vary more for pooled TNCs than unpooled, as price sensitivity is higher for non-shared TNC trips.

Figure 5. Trip counts per fare threshold for shared and non-shared transportation network company (TNC) trips by the time of day.
Note: EA = early AM (00:00–06:00); AM = morning peak (06:00–09:00); MD = mid-day (09:00–16:00); PM = evening peak (16:00–19:00); EV = evening shoulder (19:00–24:00).

- The sharpest difference in travel sheds for the pooled NC trips was observed during evening and not peak hours, as price sensitivity is lower during peak hours.

Airport Travel

TNCs have been trending as the most popular ride hailing option for residents of major metropolitan centers, and airports are one of the most active hotspots of their operation. The same holds true for taxis, despite losing market share to TNCs at a regional level, airport travel has continued to serve as a key market for taxi services. Figure 6 gives a boxplot analysis of how these trips are distributed across an average day for the two Chicago airports, O'Hare and Midway.

- The share of taxi trips made to and from the two airports rose from 6 to 8% despite the continuing decline of taxi ridership in the City.
- About the same fraction of all TNC trips was also associated with travel to/from the airports, although TNC trips are much larger in volume than taxis, of course.
- On comparing total taxi and TNC trips to the airport, TNC traffic appears to be only about 1.5 times more than taxis in 2018. This is a much understated fraction compared to what was found when trip counts for the entire region were compared between the two modes.
- Despite the similar fraction of trips that airports appear to draw, the two modes have inherently different trip characteristics. Taxi trip frequencies to and from airports differ by the time of day.
    - In 2013 most taxi trips were made to the airports in the evening, and most taxi trips from the airports were made during the AM peak and mid-day periods. In 2018, most taxi trips to and from the airports were made during the mid-day period.
    - For TNCs, time-specific trends were much less pronounced. Most trips to the airports were made during the evening, while most trips from the airports were made during the middle of the day.

- In 2018, the fewest trips to the airports were made during the evening by both TNCs and taxis.

Table 5. Trip Counts for Shared and Non-Shared TNC Trips by Time of Day

Mean fare	Trip type	EA		AM		MD		PM		EV	
$10	Non-pooled TNCs	16,603	22%	39,393	25%	148,720	23%	81,782	20%	95,006	21%
$15		26,903	36%	56,647	35%	228,554	36%	151,939	36%	168,640	36%
$20		30,911	42%	63,957	40%	258,622	41%	184,282	44%	198,543	43%

Note: TNC = transportation network company; EA = early AM (00:00–06:00); AM = morning peak (06:00–09:00); MD = mid-day (09:00–16:00); PM = evening peak (16:00–19:00); EV = evening shoulder (19:00–24:00).

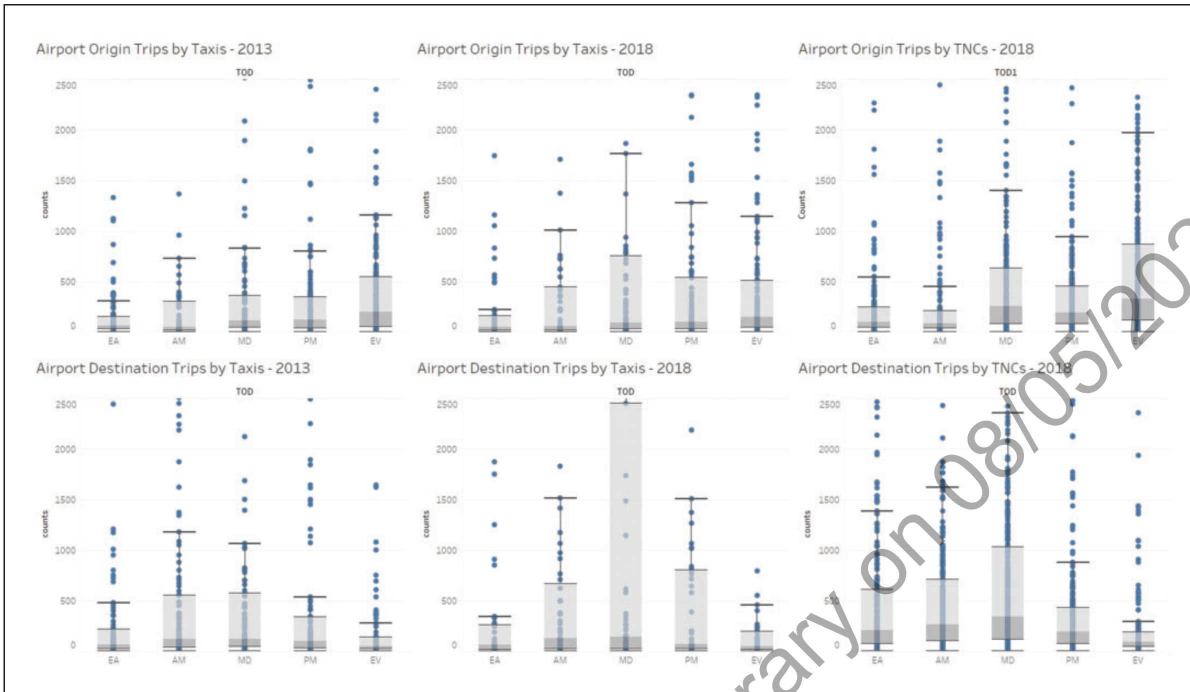

Figure 6. Distribution of average daily trips to and from Chicago O'Hare and Midway Airports, boxplots are plotted by the time of day. *Note*: EA = Early AM (00:00–06:00); AM = Morning peak (06:00–09:00); MD = Mid-day (09:00–16:00); PM = Evening peak (16:00–19:00); EV = Evening shoulder (19:00–24:00); TOD = time of day; TNC = transportation network company.

In addition, we sought to quantify the shift in trip characteristics during holiday travel, Thanksgiving, Christmas Eve, Christmas Day, New Year's Eve, New Year's Day, and Super Bowl, and the changes that we may have observed between 2013 and 2018. However, trips were only reported for the early AM time period on all of these days by both taxis and TNCs. A preliminary analysis suggested that dynamically set TNC fares were atypically high. As the number of available drivers is reduced, much higher fares than normal are registered on TNC platforms and there is no similar change in taxi fares. However, as trip information during other times of the day was not available, we did not pursue this line of analysis any further. It is also possible that many trips on these holidays went unreported.

Conclusion

Trips made by taxis in 2013 were substantial, but less than 2% of all trips in the region. This fraction has dramatically shrunk in 2018. On the other hand, TNCs have grown rapidly and now serve four times as many trips as taxis in 2013. TNCs have not just grown rapidly, they also cater to a different market segment, for instance, they provide service over a larger geographic area than taxis ever did, they also have a greater market share in the peak-shoulder periods which suggests they are being used for recreational travel, and riders are also traveling longer distances in them, because they are cheaper than taxis. Taxis used to focus on key business/commute markets even in 2013, but since the advent of TNCs, their service area has shrunk even more. They almost exclusively serve the downtown and airport market in 2018. While performing the exploratory analysis at Census Tracts is reasonable, if one were to perform equity or accessibility analysis, having the data at a more granular level will be necessary.

This is a rich dataset and several avenues of research can be pursued using this dataset. For instance, researchers can use the dataset to study average fare prices (per mile) for different zones and by different times of the day to understand the dynamic pricing structure of TNCs. This analysis can be particularly useful to pursue detailed equity questions. Researchers can also build trip generation and trip distribution models for both TNCs and taxis, which can then be integrated as stand-alone components of the regional travel demand model. Or, the TNC and taxi datasets can be used as calibration/validation targets for the existing model. This paper only focused on the demand portion of the analysis, but by looking at the number of active taxi and TNC drivers, one can also perform supply-side and economic theory analysis with this dataset.

Ultimately, this rich dataset strikes the right balance between providing policy and research analysis with detailed data, yet protecting data privacy and business secrets. More cities should explore similar data sharing agreements in their own city so they can better understand the effect that TNCs (and taxis) are having in their own region.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: A. Komanduri, S. Roy; data collection: S. Roy; analysis and interpretation of results: S. Roy, A. Komanduri; draft manuscript preparation: S. Roy. A. Komanduri, K. Proussaloglou. All authors reviewed the results and approved the final version of the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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