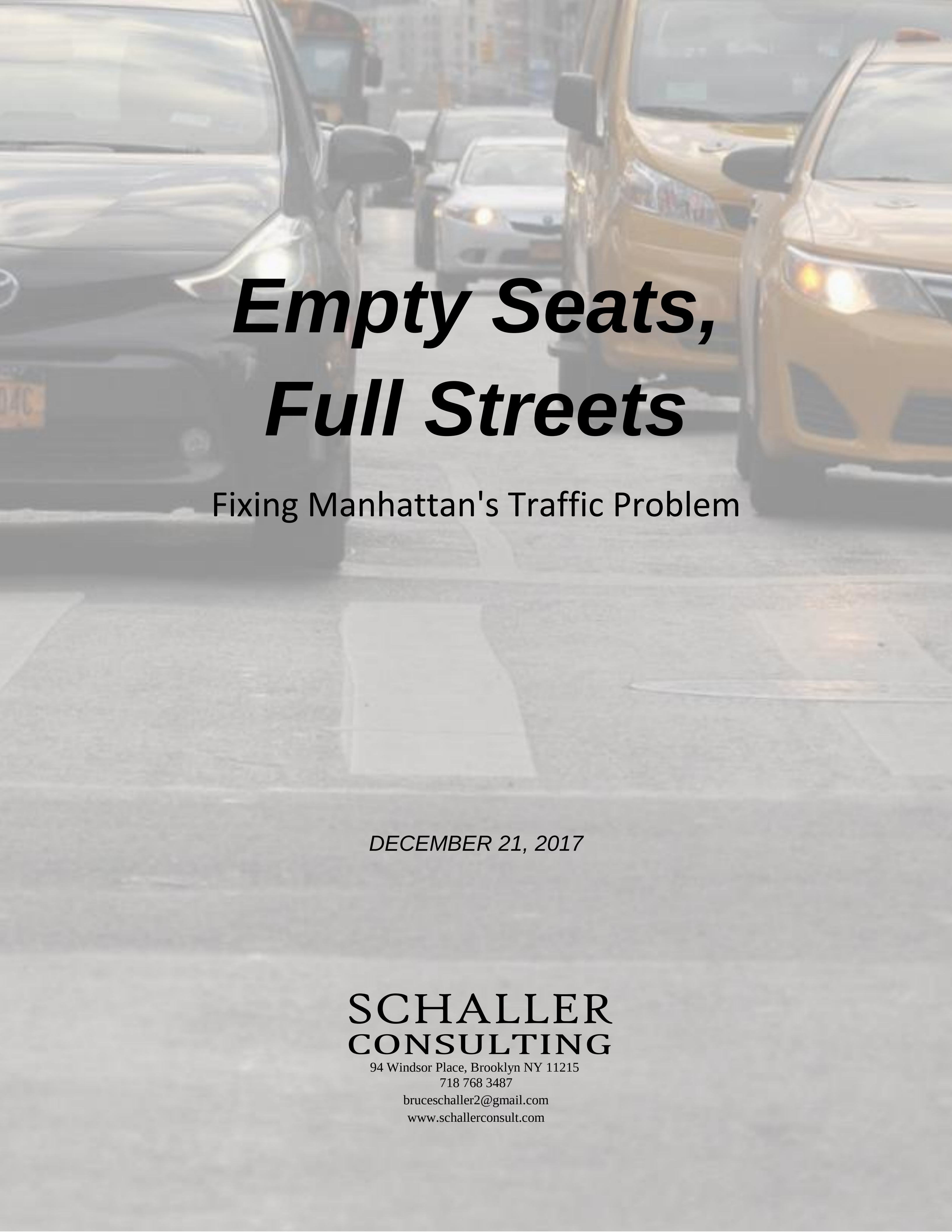

Empty Seats, Full Streets

Fixing Manhattan's Traffic Problem

DECEMBER 21, 2017

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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 widely acknowledged expert" on issues related to taxis, Uber and Lyft (*Politico)* and a "nationally recognized expert in the cab business" (*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 for the purpose of furthering 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. The author would like to thank staff at the Taxi and Limousine Commission and NYC Department of Transportation who provided information and insight for the analysis. The analysis and conclusions are the sole responsibility of the author.

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Summary

The rapid growth of app-based ride services such as Uber and Lyft has raised concerns in large U.S. cities such as New York. San Francisco, Chicago and Seattle about their impacts on traffic congestion and public transportation ridership. In New York City, the growth of app-based ride services (often called "Transportation Network Companies," or TNCs) has raised questions about how anti-congestion plans being developed by Governor Andrew Cuomo and Mayor Bill de Blasio should address TNCs' contributions to traffic congestion.

This report examines the impact of TNC growth on traffic conditions in the Manhattan Central Business District (CBD), defined as 60 Street to the Battery, river to river. Using newly available data on TNC trips, the report presents a more detailed analysis of CBD traffic conditions than has been possible previously, isolating the impact of TNC growth in the Manhattan CBD during the most congested part of the day -- weekdays between 8 a.m. and 7 p.m.

The analysis takes account both the rapid growth of TNCs and declines in yellow cab activity, thus focusing on net growth of the combined taxi/TNC sector. Key findings are:

- Taxi/TNC trips increased by 15 percent on the average weekday in June 2017 compared with June 2013.
- Total taxi/TNC weekday mileage in the CBD increased by 36 percent from 2013 to 2017. Mileage increased more rapidly than trips due to a trend toward longer trips and lower utilization rates (percentage of mileage with passengers).
- The number of taxi/TNC vehicles in the CBD increased by 59 percent. Vehicles increased more rapidly than mileage due to slower traffic speeds.
- Total hours spent transporting passengers increased by 48 percent over the last four years, slightly less than the overall growth of vehicles in the CBD because utilization rates declined.
- The number of unoccupied taxi/TNC vehicles increased by 81 percent, more rapidly than overall vehicle hours due to declining utilization rates.
- Increases in trips, mileage and the number of vehicles in the CBD vary considerably during the day. The largest increases were from 4 p.m. to 6 p.m.., with the number of taxi/TNC vehicles more than doubling during this time period.

Large increases in the number of taxi/TNC vehicles in the CBD are an important source of slow traffic conditions in the Manhattan CBD. The very rapid growth in unoccupied vehicles in the CBD is of particular note since the increased time and mileage that drivers spend between trips exacerbates congestion but does not contribute to the mobility needs of New Yorkers. Reducing unoccupied time thus presents an opportunity to reduce Manhattan traffic congestion and improve both mobility (through less congested traffic) as well as driver incomes (through less time waiting for the next trip).

This report focuses on ways to reduce unoccupied time in the CBD by taxis and TNCs. The most promising option is for the City or State to mandate that Uber, Lyft and other TNCs limit the time that their drivers spend waiting for their next trip request, which now averages 11 minutes between trips. TNCs already utilize dispatch methods at airports across the country that could dramatically shorten unoccupied time between trips if utilized for dispatching CBD trips.

Yellow cabs could also be mandated to reduce their unoccupied time between trips. Since they predominantly respond to street hail rather than dispatch, however, the mechanism to achieve reductions in unoccupied time would be different for taxis than TNCs. The report discusses an approach of allocating yellow cabs a set amount of time that they can operate in the CBD during the business day.

A policy to reduce unoccupied time between trips would need to balance the benefits of reducing the number of vacant vehicles in congested traffic with the goal of maintaining good availability of TNC and taxi service when customers want a ride. Both unoccupied time of vehicles and waiting times for customers should be monitored during implementation and adjustments made as appropriate.

Reducing unoccupied time between trips for taxis and TNCs can substantially reduce overall vehicle mileage in the CBD and thus overall congestion levels. The report estimates that overall vehicle mileage could be reduced by 7 percent to 11 percent from eliminating unnecessary unoccupied time between trips.

These reductions, if combined with congestion pricing and a per-trip fee on taxi/TNC trips beginning in Manhattan (now being discussed as part of a comprehensive program to reduce congestion and raise money for public transit), would reverse most of the drop in CBD speeds since 2010. A program with these elements would reduce the number of vehicles in the CBD by 20 percent or more, offsetting most if not all of the 23 percent drop in traffic speeds since 2010.

Finally, the report discusses implications of this research for other cities, and for the anticipated arrival of autonomous vehicles in the near future. Although New York City presents unique circumstances compared with other large U.S. cities, there are clear lessons to be gained from the New York experience. Chief among these is the importance of the driver-driven nature of the supply of TNC service in which overall service hours are a product of decisions made by individual TNC driver about where and when to work and how many hours to drive. The dynamics underlying a driver-driven supply of service is likely to lead to excessive time spent between trips in cities across the country.

These findings also have significant implications for how fleets of shared autonomous vehicles are likely to affect traffic conditions in major cities as they are introduced in coming years. It is anticipated that for many years to come, Uber, Lyft and other ride service companies will have mixed fleets composed of both autonomous vehicles and human-driven vehicles. In the absence of policy intervention, expanding mixed fleets will further balloon the number of vacant vehicles occupied only by drivers waiting for their next trip request. The results in this report thus heighten concerns about traffic impacts from the arrival of autonomous vehicles. The results also underscore the need for public policy to address traffic impacts of both today's TNCs and tomorrow's fleets of mixed human driven and autonomously driven ride services.

Introduction

Manhattan traffic congestion is back in the news. In an interview this August, Governor Andrew Cuomo said the "time has come" to institute congestion pricing in the busiest and most congested parts of Manhattan.[1] In October, Cuomo formed a 16-person panel to recommend steps to reduce congestion in New York City and produce a dedicated funding stream for the city's subway and bus system.[2] Also this fall, Mayor Bill de Blasio announced a series of steps to combat a 23 percent decline in Midtown traffic speeds since 2010, including banning deliveries on certain cross-streets and stepping up enforcement of parking and traffic rules.[3]

Manhattan's traffic problem imposes significant costs on both motorists and on people who never get into a motor vehicle. Most directly, congestion impedes the city's buses, contributing to rapid declines in bus ridership over the last four years, as well as other motor vehicles. Congestion also increases the cost of freight movement, goods delivery and provision of on-site services ranging from construction of new commercial buildings to home repairs. These costs are passed on to consumers whether or not they personally have an automobile.

The drop in CBD speeds since 2010 is attributable to a variety of factors. These include rapid employment and population growth, increasing tourism and construction activity, and the rise of on-line shopping and growth in package deliveries, to name a few. Growth in all of these areas generates increased pressures on the unchanging amount of Manhattan street space.

Another important factor is the rapid expansion of Uber, Lyft and other "Transportation Network Companies" (TNCs) in New York City. There are now over 68,000 licensed TNC vehicles in the five boroughs. A previous Schaller Consulting study found that from 2013 to 2016, TNC growth added 600 million miles of travel to city streets. The study estimated that over half of citywide growth in mileage occurred in Manhattan and western Brooklyn and Queens.[4]

This report builds on the previous study with a more fine-grained analysis that focuses on daytime traffic impacts in the Manhattan CBD -- where congestion is most acute. The analysis utilizes newly available data on TNC trips that show where passengers were dropped off as well as where trips began. Inclusion of trip destination makes possible a far more detailed analysis of traffic conditions in the Manhattan CBD than has been possible previously. The analysis isolates the impact of TNC growth in the Manhattan CBD focusing on weekdays during the business day and in particular the afternoon peak, the most congested parts of the day.

Results show the net effects of several distinct trends. These include a continuing decline in yellow cab ridership and rapid growth in TNC ridership, the net result being increased overall trip-making by TNCs and taxis. This growth, combined with a trend toward longer trips (measured by mileage) and lower vehicle utilization, has led to rapid growth in vehicle miles of travel in the Manhattan CBD by the taxi/TNC sector. Compounded by slower traffic speeds, the number of taxi and TNC vehicles operating on CBD streets has increased even more rapidly than trips or mileage.

As trips and mileage have increased, the taxi/TNC sector has contributed to the worsening of congestion in the Manhattan CBD. It is difficult to quantify how much of the problem is attributable to these vehicles, however, due to lack of data on mileage by other types of vehicles (e.g., commercial vehicles, personal autos, etc.).

In addition to documenting growth in trips, vehicle mileage and vehicle hours of taxi and TNC drivers, the analysis also points to ways that these vehicles could help fix the congestion problem. The most promising avenue is to reduce the unoccupied time and mileage of taxis and TNCs. Over one-thirds of drivers' time in the CBD is spent unoccupied between passenger trips. The report discusses methods of reducing this unoccupied time and estimates the potential benefit to traffic speeds.

The report also discusses implications of this analysis for other cities. Of most note is the way that driver-driven supply of TNC services creates a dynamic that appears to make highly likely that dense, congested downtown and entertainment districts have more waiting vehicles than are needed for prompt pick-ups. The recommendations to reduce this unnecessary time between trips thus may be applicable to other U.S. cities, although further analysis is needed to confirm this.

There are also implications for the anticipated arrival of shared autonomous vehicles, particularly in the long transition period during which TNC fleets have a mix of autonomous operations and human drivers. These implications are also discussed in the report.

1. Methodology

Findings in this report utilize extensive trip data on yellow cab and TNC operations available from the New York City Taxi and Limousine Commission (TLC). TLC rules require that taxi owners and TNCs submit these data to TLC on a regular basis. The main datasets used in this report are posted periodically on TLC's website, while additional data was obtained through Freedom of Information requests, as described below. The report also uses monthly vehicle speeds in Manhattan provided by the New York City Department of Transportation which DOT compiles from the taxi trip data.

Starting in June 2017, TNC trip files include information on trip destinations as well as trip origins. Having both origin and destination information makes possible a fine-grained analysis of travel patterns in the most congested parts of Manhattan. The results represent the most in-depth examination of TNC impacts in the core of a major American city, with public policy implications for both New York City and other major cities. This section describes source data and how they are used in this report.

TNC and taxi trip data files posted on TLC's website include start and end times of each trip and origin and destination (using geographic zones). Taxi files also include distance, fare and the number of passengers. Until recently, trip files for TNCs contained the origin time and zone but not destination time or zone. Starting with data for June 2017, however, under a new TLC rule, destination times and zones are also included.

This report presents results from these files for June 2017 for yellow cabs and TNCs and June 2013 for yellow cabs. Since there were very few TNC trips in 2013,[5] the period 2013 to 2017 shows the changes in the for-hire landscape produced by the emergence and rapid growth of TNCs.

These public files are supplemented with trip data obtained through Freedom of Information Law (FOIL) requests. These include taxi trip data which show information for the previous trip (start and end times and origin and destination zones) for selected weeks in March/April 2013 and April 2017. Because information about the previous trip is indicated, the unoccupied time between trips (i.e., from drop-off of one passenger to pick-up of the next passenger) can be calculated.

Also through a FOIL request, trip data showing previous-trip information was obtained for Uber trips for the first half of 2016.[6] This dataset was used to calculate unoccupied time between trips for typical TNC operations.

Results from these two datasets were integrated with trip volumes for June 2013 and June 2017. For taxis, the percentage of "live time" (time with passengers) from the March/April data was applied to June trip volumes. Using this spring data with June data is not expected to distort the results because "live time" was virtually unchanged between the spring and June months of 2013 and 2017, according to monthly data available on the TLC website.

For TNCs, the question might be raised whether unoccupied time between trips changed between the first half of 2016 and June 2017 in light of rapid growth from 2016 to 2017. Unoccupied time appears to be quite stable over time, however. A recent report co-authored by economists from Uber and New York University found that, absent a change in fares, vehicle utilization is consistent over time in major Uber markets.[7] Specific to New York City, trip duration and time between trips was unchanged for CBD trips from February to June 2016, even as trip volumes increased rapidly each month.

Further evidence that unoccupied time between trips tends to be constant over time is the fact that trip volumes and the number of TNC vehicles grew at the same rate between spring 2016 and June 2017. For utilization rates to change, trip volumes would need to change at a different rate than the number of vehicles (assuming that vehicles mileage is constant over time, which appears to be the case based on TNC odometer readings).

Findings in this report are based on analysis of these datasets which include over 30 million trip records. The analysis focuses on trips that begin and/or end in the Manhattan Central Business District (CBD), defined as the area from 60th Street to the Battery.

Results focus on several key metrics: trip volumes, time spent with and without passengers, vehicle speeds, and vehicle mileage. Trip volumes, trip durations and unoccupied time between trips are calculated directly from the datasets as described above. The calculation of time between trips takes into account likely rest and meal breaks. Only the portion of time that was likely spent waiting for or looking for the next trip is included in the results. Maximum unoccupied time between trips was assumed to be 30 minutes, and in most cases, is much shorter. Time between trips that exceed 30 minutes is assumed to be used for meal and other breaks.

Vehicle speeds are calculated based on taxi trip distance and duration. (Distances are not available for TNC trips.) Because CBD speeds vary from month to month, average CBD speeds derived from June trips are benchmarked so that the change from 2013 to 2017 matches the change in speeds for the first six months in each year.

Mileage is based on speeds calculated from the taxi trip files (based on distance and duration for each trip) and trip duration. Trip distances are not captured for TNC trips nor for unoccupied time by either TNCs or yellow cabs. These speeds are likely to be similar to the speed that yellow cabs travel with passengers, given that cab and TNC drivers are operating in the same traffic conditions throughout the day, and are used for estimating total mileage by these vehicles.

This report focuses on trips, time and mileage for trips that start and/or end in the Manhattan CBD. For trips that enter or leave the CBD, an estimate was made of the time and mileage that was inside the CBD, using as a guideline trip distances and duration for trips that ended just inside and outside the CBD.

The analysis incorporates rates of "pooled" trips in which two or more passengers, traveling independently, share a vehicle for at least part of the trip. "Pooling" effectively reduces total time with passengers. Pooling also eliminates unoccupied time between trips for the second and any subsequent passengers who join during the ride. TNC trip data obtained through FOIL for June 2017 was used for this purpose.

This report uses the following terms to refer to the main industry sectors:

- *Yellow cabs* are licensed vehicles authorized to pick up street hails throughout the city. The number of yellow cabs, which has been regulated since the 1930s, is currently 13,587.
- *Transportation Network Companies* (TNC) are app-based ride services, sometimes also called rideshare services. Four TNC companies are currently operating in New York City: Uber, Lyft, Via and Juno.

  Uber, Lyft and Juno primarily provide exclusive-ride services, with relatively low levels of pooled or shared rides. Via primarily operates pooled services, with passengers entering and exiting the vehicle during a sequence of several customer trips.

2. Findings

This section presents key results for TNC and yellow cab activity for weekdays in the Manhattan CBD, when traffic is most congested. Results are reported for passenger trips, vehicle speeds and mileage and hour that taxis and TNCs spend in the CBD in June 2013 and June 2017, and net increases for combined taxi/TNC operations.

Results show how overall taxi/TNC trip growth has combined with slower speeds and somewhat longer trips overall to produce substantial increases in mileage traveled and in the number of taxi/TNC vehicles in CBD traffic.

Results are presented first for average weekdays (24 hours) and then by hour of the day.

Overall results (average June weekdays)

1. Passenger trips increased by 15 percent from 2013 to 2017.

From 2013 to 2017, decreases in taxi trips that began and/or ended in the Manhattan Central Business District (CBD) were more than offset by the growth of TNC trips. Taxi trips declined from 378,000 to 250,000 on an average weekday (a decline of 128,000 trips per day), while TNC trips increased from virtually none to 202,000 trips per day. The combined change in taxi/TNC trips, after adjusting for TNC trips being dispatched to black cars vehicles and a small number of TNC trips in 2013 (see Methodology), was 56,000 trips per day, an increase of 15 percent. See Figure 1 on the next page.

2. Vehicle miles increased by 36 percent, reflecting trip growth, a trend toward longer trips and lower utilization rate.

In 2013, yellow cabs operated 1.05 million miles in the CBD on the average weekday. Two-thirds of these miles were to transport passengers and about one-third involved cruising for the next fare.

Yellow cab mileage declined to 696,000 miles on an average weekday in 2017; the utilization rate (mileage with passenger as a percentage of total mileage) dropped slightly to 65 percent. TNCs operated 802,000 miles in 2017 with a utilization rate of 60 percent.

Combining yellow cab and TNC mileage (with the adjustment for black car dispatches and a small amount of 2013 TNC trips) produces an increase of 378,000 miles per day. Combined taxi/TNC mileage in the CBD thus increased 36 percent from 2013 to 2017. See Figure 2.

TNC trips are generally somewhat longer in mileage than taxi trips. Due to longer trips and lower utilization, overall mileage increased more rapidly than trip volumes.

3. Traffic speeds declined 15 percent overall, and by 18 percent during the day.

Traffic speeds are measured directly for yellow cab passenger trips, which show both duration and distance. June data are benchmarked to results for the first six months of 2013 and 2017 due to month-to-month fluctuations in traffic speeds, to accurately reflect the decline in speeds over this period.

The overall decline in speeds from 2013 to 2017 was 15 percent. Focusing on the period from 8 a.m. to 7 p.m. when traffic speeds are much lower and the focus of congestion concerns, the decline was 18 percent, bringing average June speeds down to 6.8 mph from 8.2 mph in 2013.

4. The number of taxi/TNC vehicles in the CBD increased by 59 percent from 2013 to 2017.

Growth in the number of taxi/TNC vehicles in the CBD is affected by increased trip volumes, longer trips and slower speeds. In 2013, yellow cabs spent a total of 103,000 hours in the CBD over the course of the day. In 2017, taxi vehicle hours dropped to 81,000 while TNCs added 92,000 vehicle hours per day. After making the adjustments described above, there was a net increase of 62,000 taxi/TNC vehicle hours in the CBD. This is a 59 percent increase from 2013. See Figure 3.

Dividing vehicle hours by the number of hours in a given time period translates to the number of vehicles in the CBD at any given time. Setting aside overnight hours, there were an average of 9,100 taxis or TNCs in the CBD weekdays between 8 a.m. and midnight in June 2017.

Figure 1. Taxi and TNC trips in the Manhattan CBD, 2013-17 (15% increase)

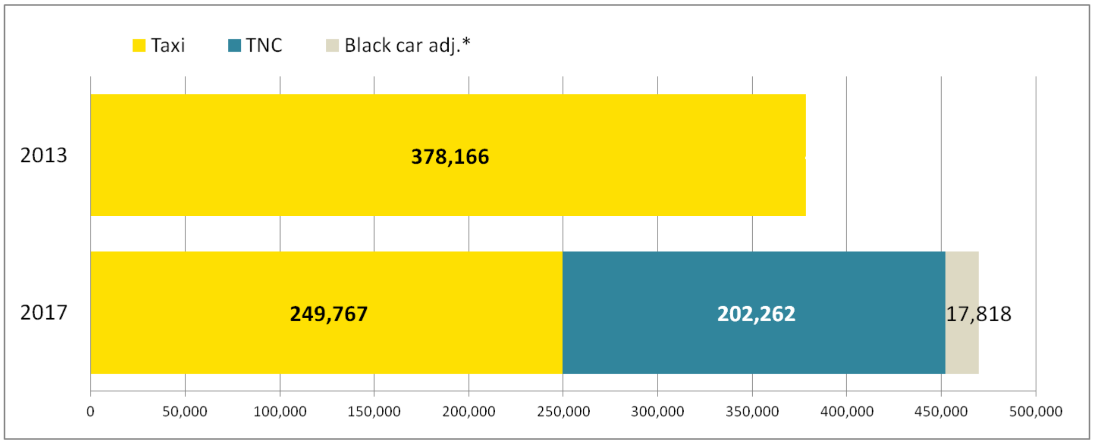


Figure 2. Taxi and TNC total mileage in the Manhattan CBD, 2013-17 (36% increase)

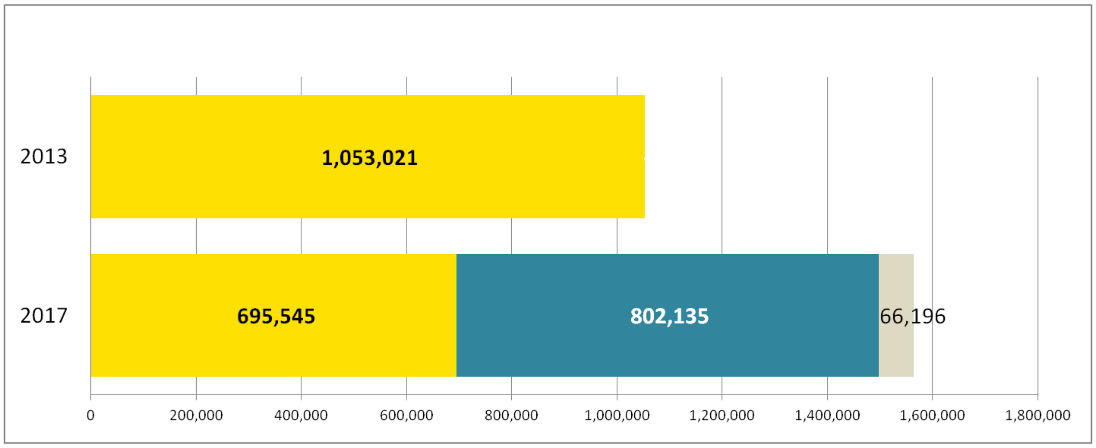


Figure 3. Taxi and TNC vehicle hours in the Manhattan CBD, 2013-17 (59% increase)

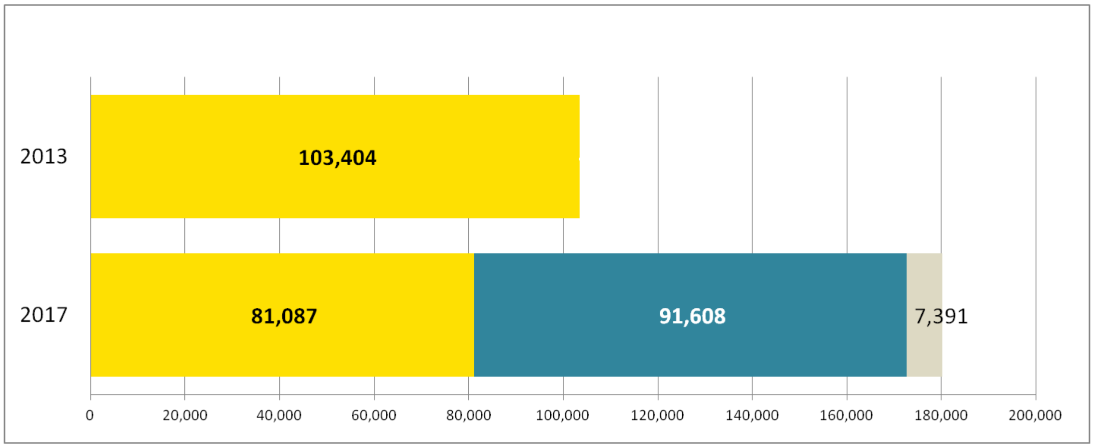


Figure 4. Taxi and TNC occupied vehicle hours (with passengers) in the Manhattan CBD, 2013-17 (48% increase)

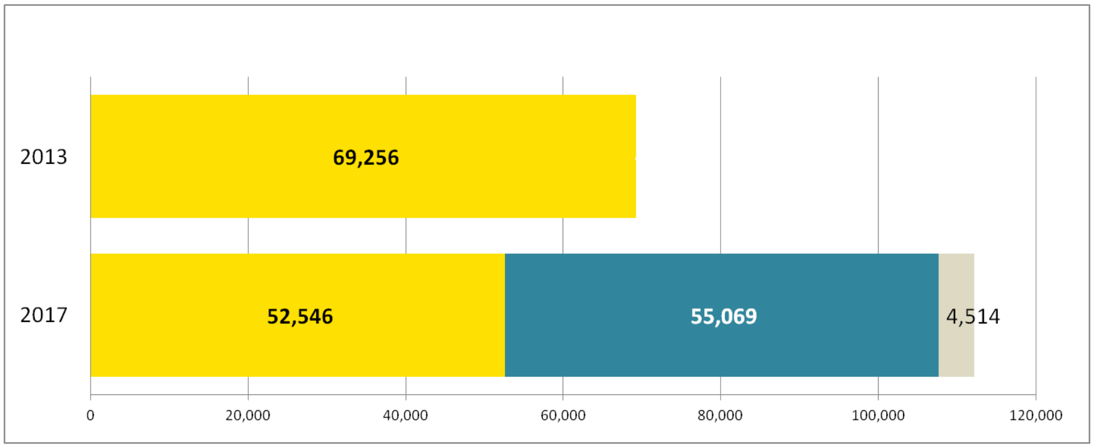
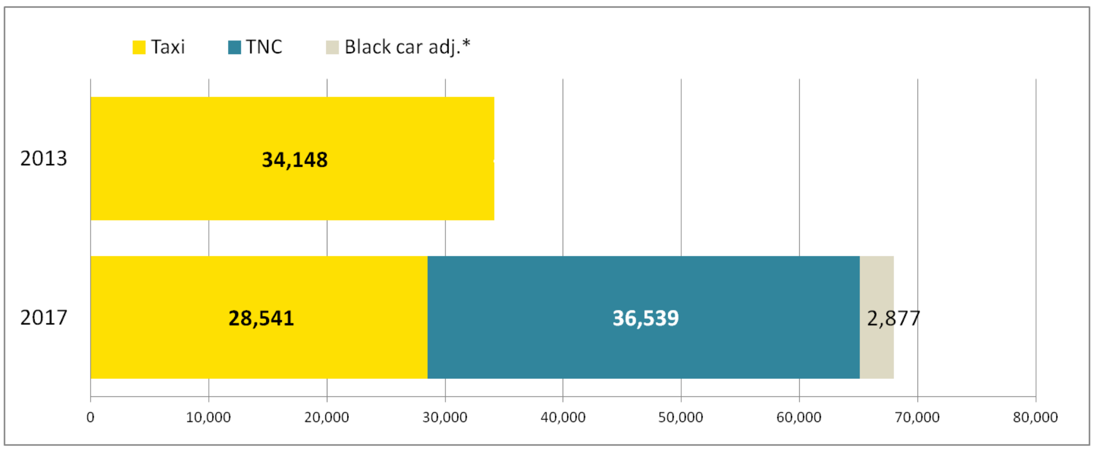


Figure 5. Taxi and TNC unoccupied vehicle hours (between passengers) in the Manhattan CBD, 2013-17 (81% increase)



*Black car adjustment accounts for trips dispatched by TNCs to black cars. These trips appear to be offset by declines in black car trips over this period, and thus are not counted toward increases in combined taxi/TNC trip volumes, mileage and time in the CBD. The adjustment for the small number of Uber trips in 2013 is also included in this figure (1% of the taxi figure).

Source: TLC trip files; see Methodology. Data are for trips that start and/or end in the Manhattan CBD, defined as 60 Street to the Battery, river to river. Data are for weekdays in June of each year.

5. Taxi and TNC vehicle hours spent transporting passengers increased by 48 percent from 2013 to 2017.

From 2013 to 2017, the amount of time that yellow cabs spent transporting passengers declined from 69,000 hours on an average weekday to 53,000 hours. TNCs more than made up the difference, with 55,000 hours with passengers in the CBD. After making the above-mentioned adjustments, combined taxi/TNC vehicle hours with passengers increased by 34,000, an increase of 48 percent from 2013. See Figure 4.

6. Unoccupied taxi/TNC vehicle hours grew by 81 percent from 2013 to 2017.

While hours spent transporting passengers showed a large increase, unoccupied hours grew even more quickly. Taxis spent 34,000 unoccupied hours in the CBD in 2013, decreasing to 29,000 in 2017. Meanwhile, TNCs added 37,000 unoccupied vehicle hours. After making the adjustments described above, the net increase was 34,000 vehicle hours in the CBD on weekdays. This is an increase of 81 percent from 2013. See Figure 5.

Unoccupied vehicle hours grew more rapidly than occupied vehicle hours due to lower utilization rates. While yellow cabs were occupied with passengers 67 percent of the time in 2013, the utilization rate for combined taxi/TNC operations dropped to 62 percent in 2017.

Results by time of day

1. Passenger trips increased most rapidly in the late afternoon and early evening, with the least rapid growth occurring in the morning peak and midday.

Trip volumes grew most rapidly during the afternoon peak period, with increases of about 50 percent from 4 p.m. to 6 p.m. (See Figure 6.) The faster growth in the afternoon peak is largely due to smaller declines in yellow cab trips during this period, compared with other times of the day. In addition, TNC trip volumes ramp up starting in the mid-afternoon, adding to growth in the afternoon peak.

Growth was also relatively rapid in the "shoulder" hours of 3-4 p.m. and 6-7 p.m.

2. Vehicle miles shows the same time-of-day pattern, with mileage increasing by 46 percent or more from 3 p.m. to 7 p.m.

As mentioned earlier, TNC trips generally cover more mileage than taxi trips. As a result, the addition of TNCs has led to more rapid growth of vehicle miles traveled than trips. As with trips, mileage increased most rapidly in the afternoon peak period. Total mileage grew by 68 percent or more from 4 p.m. to 6 p.m. and about 50 percent in the adjoining "shoulder" hours.

3. Speeds declined about the same throughout the day, with slightly larger reductions during the afternoon peak.

Time-of-day variation for the change in taxi speeds are much less pronounced than for trips and mileage. Speeds declined 19 percent from 3 p.m. to 7 p.m., compared with 17 percent earlier in the day and 16 percent in the evening.

4. The total number of taxi/TNC vehicles more than doubled between 4 p.m. and 6 p.m., and increased by 50 percent or more every hour from 1 p.m. to 8 p.m.

Following from the larger increases in trips and mileage, the number of taxi/TNC vehicles in the CBD more than doubled from 4 p.m. to 6 p.m., and by at least 50 percent every hour between 1 p.m. and 8 p.m.

5. The number of occupied taxi/TNC vehicles nearly doubled, and the number of unoccupied vehicles nearly tripled, between 4 p.m. and 6 p.m.

Because of the decline in utilization (percentage of time with passengers), the most rapid increases were in the number of unoccupied vehicles, particularly in the late afternoon when they nearly tripled. There are over 3,200 unoccupied taxi/TNC vehicles in the CBD from 5 p.m. until midnight in the CBD.

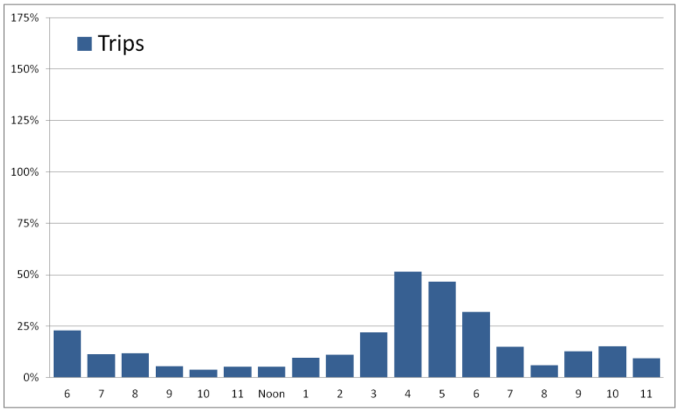
Figure 7 shows the number of taxi/TNC vehicles in the CBD hourly from 6 a.m. to midnight. The number of vehicles peaks at over 10,000 vehicles from 4 p.m. to 6 p.m., and remains above 9,000 vehicles until 11 p.m.

* * *

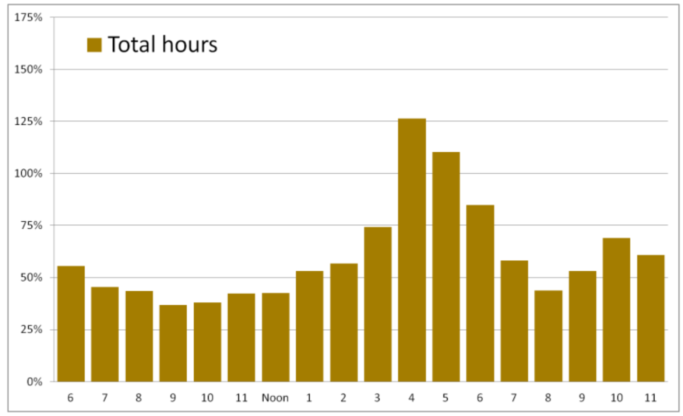
As evident from the hourly bar charts, there are large time-of-day differences in the growth of trips, mileage and the number of taxis and TNCs in the CBD. Figure 8 shows the changes in these metrics from 2013 to 2017 for two time periods, weekday daytime hours between 8 a.m. and 7 p.m. and in the afternoon period between 3 p.m. and 7 p.m.

Figure 6. Hourly Change in Trips, Vehicle Miles, Speeds and Vehicles in the CBD, 2013 to 2017

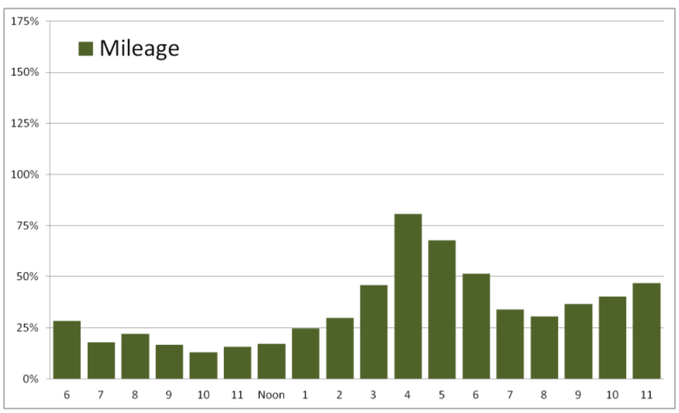
Change in trips (with passengers)



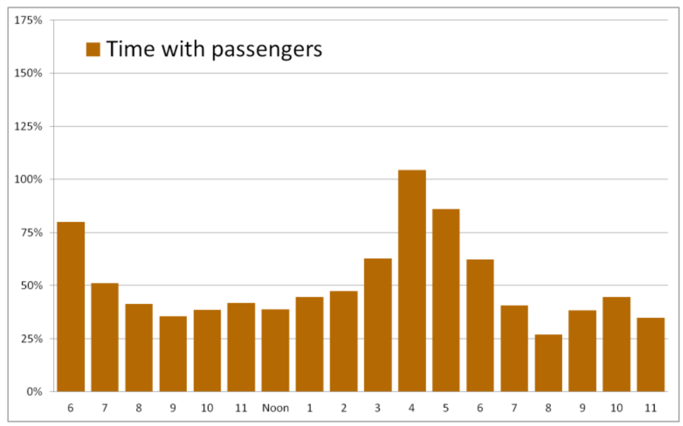
Change in total hours (with passengers and unoccupied)*



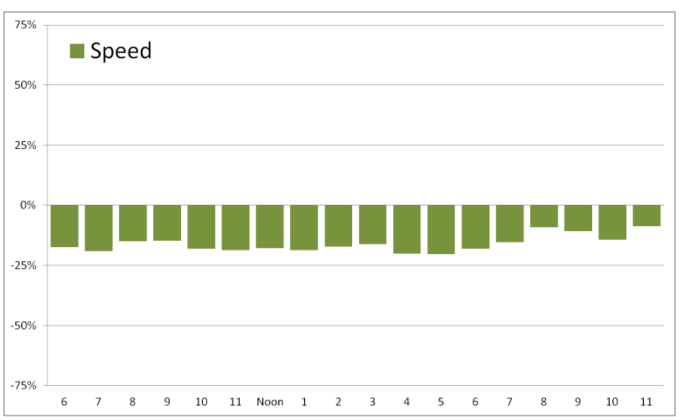
Change in total mileage (with passengers and unoccupied)



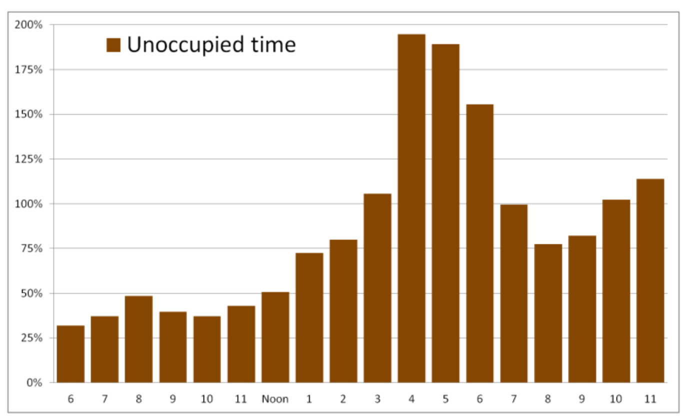
Change in occupied hours (time with passengers)*



Change in speeds



Change in unoccupied hours (time between trips)*



*Hours translate directly to the number of vehicles in the CBD on an hourly basis (i.e., one vehicle hour is equivalent to one vehicle present in the CBD during that hour period).

Source: TLC trip files; see Methodology. Data are for trips that start and/or end in the Manhattan CBD, defined as 60 Street to the Battery, river to river. Data represent changes between June 2013 and June 2017 (weekdays).

Figure 7. Number of taxi/TNC Vehicles in the CBD, by hour, weekdays June 2017

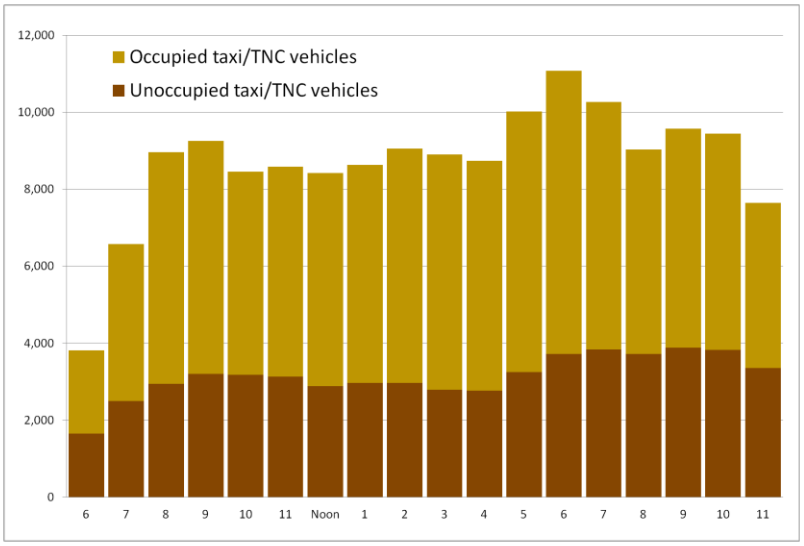
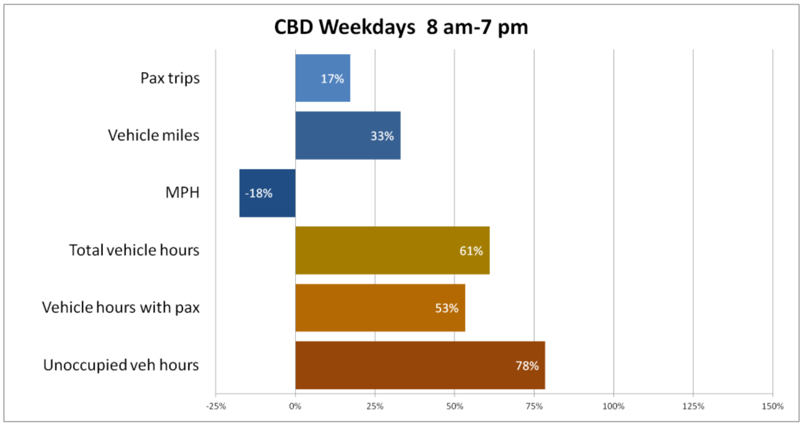
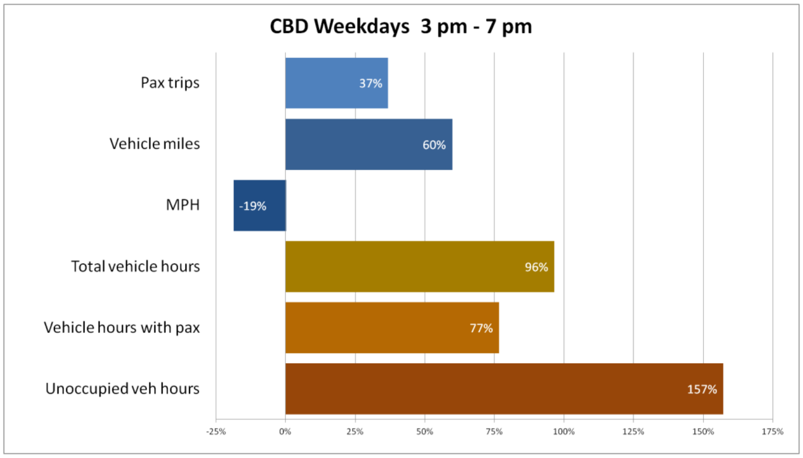


Figure 8. Change in Trips, Vehicle Miles, Speeds and Vehicles in the CBD, 2013 to 2017 Selected Time Periods





Source: TLC trip files; see Methodology. Data are for trips that start and/or end in the Manhattan CBD, defined as 60 Street to the Battery, river to river. Data represent changes between June 2013 and June 2017 (weekdays). See the Appendix for further detail.

Traffic impacts

These large increases in the number of vehicles (both occupied and unoccupied) in the CBD clearly have a very significant impact on CBD traffic flow. The growth in taxi/TNC vehicles is even more remarkable given that traffic counts at avenues crossing 60th Street and the East River crossings show steady declines in the number of vehicles entering the CBD. As a result of these two trends -- more taxis/TNC vehicles but an overall drop in vehicles entering the CBD -- taxis/TNC vehicles have become a very large part of overall traffic. Estimates for the 60th Street cordon indicate that during daytime hours, taxis and TNCs likely comprise 50 percent or more of total vehicles traveling north or south.

It is sometimes argued that traffic impacts from trip data are overstated because TNC drivers may not actually be driving around between trips, but waiting at the curb for their next trip. This is an important question worth considering. However, available data indicate otherwise.

First, an analysis of odometer readings taken from TNC vehicles at TLC inspection show that TNCs have a passenger in them for approximately 55 percent of *overall miles* driven (after accounting for personal use of the vehicle). Likewise, trip data show that about 55 percent of *time* is spent with passengers. (Both sets of data are citywide, 24/7.) In other words, for every 100 miles that a TNC vehicle is driven, about 45 miles are unoccupied. For every 10 hours of operation, about 4.5 hours are unoccupied. One can readily infer from these data that unoccupied time (45 percent) is spend in motion, since 45 percent of the mileage is unoccupied mileage.

Second, analysis of trip patterns shows that unoccupied vehicles crossing the 60th Street screenline are consistent with about one-third of TNC mileage in the CBD being unoccupied, consistent with the other results from this analysis.

Finally, as discussed in the next section, a main opportunity for TNCs to reduce congestion lies in reducing the deadheading of TNC drivers who return to the CBD after dropping off passengers elsewhere. This deadheading clearly involves time and mileage in traffic.

The large increase taxi/TNC vehicle hours is thus an important source of slow traffic conditions in the Manhattan CBD. Increases in unoccupied time are worth focusing on since the increased time and mileage spent between trips does not contribute to the mobility needs of New Yorkers while they do contribute to congestion. Reducing unoccupied time presents an opportunity to reduce Manhattan traffic congestion and improve both mobility (through less congested traffic) as well as driver incomes. This opportunity will be explored in more detail in the next section of this report.

2. Policy Options

Over the years, City officials have sought to use a range of policy and operational tools to speed up traffic in the Manhattan CBD. Technology-based remedies such as the City's real-time adaptive signal control systems are effective and widely supported by the public. Strategies involving allocation of street space, such as banning curbside parking during certain hours, turn restrictions and prohibiting "blocking the box" are generally welcomed by the public and are effective in improving traffic conditions if motorists comply with the rules. On the other hand, strategies such as congestion pricing that seek to discourage motor vehicle travel are highly controversial because motorists who would pay the congestion charge may not believe that the benefits to them are commensurate with what they would have to pay.

It is worth bearing these experiences in mind when considering policy options to address increases in taxi/TNC trips, mileage and vehicles during the day in congested parts of Manhattan. Previous attempts to limit TNC operation have met with strong resistance. However, reducing unnecessary time and mileage spent in the CBD *between* passenger trips could be very appealing. The fact that the unoccupied time between passenger trips is the fastest-growing aspect of for-hire operations in the CBD makes focusing on it particularly attractive.

Currently, over one-third of taxi/TNC vehicles in the CBD are unoccupied at any given time during weekdays. The presence of some vacant vehicles is essential to service -- some drivers need to be available for the next passengers looking for a ride. The large increase in vacant taxi/TNC vehicles over the last four years raises the question, however, of whether the number of taxis and TNCs available for the next customers is currently excessive.

This question can be addressed by examining how TNC and taxi drivers spend their time. TNCs need to be considered separately from taxis, due to important differences between TNC pre-arranged dispatch operations and yellow cab street hail operations.

Reducing unoccupied time between trips by TNCs

TNC trips that begin in the CBD take an average of 24 minutes for weekday trips. TNC drivers also spend an average of 11 minutes between dropping off one passenger and the next pick-up. Unoccupied time includes the time needed to drive to the next customer's location for pick up and time spending waiting to be dispatched. Pings on TNC APIs show that the estimated wait time for customers requesting a TNC ride is three to four minutes on average in the CBD throughout the day. Thus, of the 11 minutes (average) time spent between trips, a few minutes are required to drive to the next customer and the balance of the 11 minutes is spent waiting for a trip request. The proliferation of waiting drivers is easily seen on the Uber and Lyft apps, which show numerous drivers available for dispatch clustered near any location randomly selected in the CBD, particularly in Midtown.

If there were fewer drivers waiting for their next trip request, passengers would still receive prompt service, as shown in other parts of the city where pickups are quick even though available vehicles are more spread out than is the case in the CBD. But customers would travel faster to their destination since there would be fewer unoccupied TNC vehicles in the traffic mix.

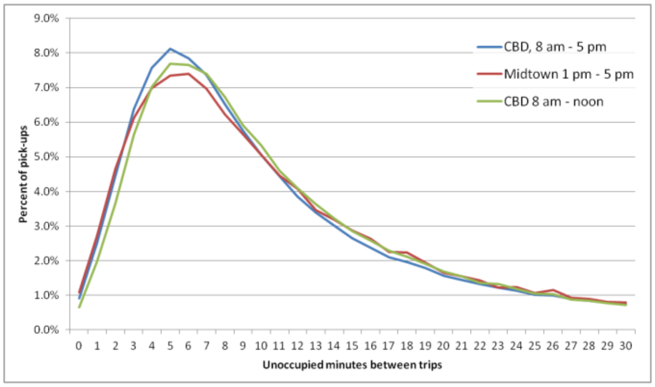
The opportunity to reduce the number of TNC vehicles in the CBD lies in the time that drivers wait for dispatch. Typically, drivers spend 3-11 minutes between trips. (See Figure 8 on the next page.) This includes the time spent driving to the pickup location (typically 2-4 minutes). The balance of time is spent waiting for a trip request.

Notably, a significant amount of the time between trips originates with drivers experiencing well over 11 minutes between trips. These most likely arise when drivers drop-off outside the CBD and then drive back into the CBD in search of their next fare.

How might unoccupied time between trips be reduced or eliminated? The answer becomes clear with an explanation of why there is so much unoccupied time between trips in the first place.

Unlike transportation services such as public transit and intercity buses, the amount of service available to potential customers is decided by drivers, not by the company operating the service. Because the main reason to drive a cab or TNC vehicle is to make money, the number of drivers on the road is highly responsive to potential earnings. Drivers work where they can make relatively good money

Figure 9. Unoccupied Time Between Trips



Source: 2016 Uber trip data.

and avoid areas where there is less money to be made. Not only where drivers work but also how much they work is highly responsive to potential revenues. Drivers spread out across the city and across the day and week to produce similar average earnings per hour geographically and temporally.

This dynamic can be seen very clearly in the TNC data. One might expect that drivers in Manhattan are much busier than drivers in the other boroughs, since the density of demand is so much higher in Manhattan. But this is not the case. Drivers spend about the same amount of unoccupied time between trips in Brooklyn and Queens, for example, as in the Manhattan CBD. Trip durations are also about the same. As a result, although there is much variation from driver to driver, average hourly fare revenue are similar no matter where in the city drivers choose to work. In economic terms, this balancing creates a market clearing equilibrium for driver wages across geographies and time of day.

This dynamic is also seen within the Manhattan CBD. Figure 9 shows the distribution of unoccupied minutes between trips for trips originating in the Manhattan CBD in selected time periods. Notably, the distribution of wait times is almost identical whether considering areas with high trip volumes and pick-ups exceeding drop-offs (Midtown in the afternoon) and situations with lower trip volumes and drop-offs exceeding pick-ups (the whole CBD in the morning). Thus, Manhattan shows the same market clearing equilibrium as the city as a whole. Through individual, largely independent decision-making, drivers are remarkably able to equalize trip flows across vastly different trip volumes and travel patterns.

Several approaches can be considered to reduce unoccupied time between trips. Advantages and disadvantages to each approach need to be considered. The purpose of this report is to discuss potential approaches and their pros and cons, and thus provide a basis for public discussion of policy options.

One approach currently under discussion is for the State or City to levy a tax or fee on TNC trips that traverse CBD streets. The charge might be in the range of $2 to $5. There is much precedent for taxes or fees of this kind. TNC customers already pay sales tax on rides, with revenues going to the City and State. Taxi passengers pay a 50-cent surcharge that goes to the MTA. Trip fees and taxes can generate a substantial flow of revenue. A $3 fee on every TNC and taxi ride that begins in the Manhattan core would yield about $475 million annually.[8] (This estimate is based on a charge that applies to all trips, 24/7, starting in Manhattan south of East 96 Street and West 110 Street.)

Per-trip fees are effective in raising revenue, but not so effective in combating congestion. TNC and taxi riders are generally well-off and have chosen, particularly for trips in the CBD, to take a TNC or cab instead of using public transit, biking or walking. They are thus relatively insensitive to price increases. Raising the cost of trips through a trip fee will do relatively little to reduce trip volumes or TNC (or taxi) mileage in the CBD.

Although there do not appear to be studies specific to TNCs, studies of taxi fares have found that a 10 percent increase in the fare is expected to produce a 2 percent to 2.5 percent reduction in ridership.[9] Applying these figures to TNC trips, a $3 fee would be expected to reduce TNC trip volumes (and mileage) by 3-4 percent. While not an inconsequential figure, a per-trip fee would not produce much congestion relief in the CBD.

Another approach is to more directly target unoccupied time. The City or State could require that TNC companies reduce *excessive* unoccupied time by the vehicles dispatched by them. "Excessive" could be defined as the time greater than needed for driving to the pick-up location. As the current average appears to be 3-4 minutes, unoccupied time over four minutes between trips would be subject to a penalty (most likely financial). The objective of the penalty would be to strongly incentivize TNC companies to minimize the unoccupied time of their drivers.

The advantage of this approach is that it leaves up to the companies the best way to achieve the objective of reduced unoccupied time. They have the technology to monitor drivers' time and trip patterns and adjust dispatch procedures to minimize unoccupied time between trips.

In fact, TNCs have already implemented dispatch procedures to minimize unoccupied time between trips at airports, with the same objective as being discussed here, namely, to reduce congestion.

At airports across the country, including JFK and LaGuardia airports, Uber and Lyft employ what they call "rematch." The companies' dispatch systems offer trips to drivers at airport terminals just as they drop off an arriving passenger. This avoids the driver dead-heading to the waiting area several miles away while another driver goes from the waiting area to the terminal. Rematch makes for fewer unoccupied miles on airport roadways, fewer TNC vehicles at terminal frontage, and quicker pickups for passengers.

TNCs could apply rematch to Manhattan drop-offs. Using rematch, TNC drivers could be offered a new trip just as they complete trips with CBD destinations. This would expand current TNC practices, since they already have a "pre-dispatch" procedure to book the next trip with drivers just as they finish up their current trip. For pre-dispatched trips, drivers spend virtually no time waiting for their next trip request.

During most of the day, pick-ups exceed drop-offs, so there would be a need for a few TNC drivers to "deadhead" into the CBD without a passenger. Here, the balancing dynamic discussed earlier would appear to work in favor of minimizing unoccupied time. If TNCs prioritize drivers making drop-offs in the CBD, drivers deadheading into the CBD would have to wait until no other drivers were nearby a requesting passenger before getting a trip. Only a few drivers would have the incentive to deadhead into the CBD.

While this may sound unlikely to work in practice, in fact, it already happens every hour of every day. Consider a driver who picks up in Midtown and takes a passenger to Long Island City. After dropping off the passenger, the driver can decide to stay in Queens, where he can expect to wait about 5-10 minutes for his next trip. Or he can drive back to Manhattan and wait there. Currently, some drivers deadhead into Manhattan, some stay in Long Island City, and some go elsewhere such as to LaGuardia airport. The data show drivers make a mix of decisions that have the net effect of equalizing unoccupied time across the city.

With the changes in dispatch discussed above, a driver making a drop-off in Long Island City would have the same choices he has now. Just as happens today, if "too many" drivers choose to go back into Manhattan, wait times there rise and some drivers make a different choice the next time. This is the way unoccupied times equalize across the city.

What does change in the new situation is that the threshold of "too many" falls. With drivers making drop-offs receiving priority for the next customer, drivers considering dead-heading into the CBD have less incentive to do so. As a result, there become fewer unoccupied vehicles in the CBD.

This dynamic appears to be the most likely outcome of applying rematch to Manhattan drop-offs. But this expected outcome needs to be tested in practice. Just as they began with tests of the rematch system at airports, TNCs can test applying rematch to CBD drivers, monitor the results and make adjustments as may be necessary.

Rematch is most beneficial to reducing congestion in the afternoon, when pick-ups exceed drop-offs and so virtually all drivers completing a trip should be able to serve their next trip nearby. In the morning, the number of drop-offs exceeds the number of pick-ups in the CBD as people come to work, but fewer are leaving the Manhattan core. As a result, there are not enough pick-ups for all drivers to quickly transition from drop-off to pick-up. Pre-dispatch would still reduce the number of unoccupied TNC vehicles, however, discouraging drivers from deadheading into the CBD as some do now.

The role for the City or State should be mandating reduced time between trips and monitoring compliance. Government should mandate the *outcome* it wants (reduced unoccupied vehicles), not the method of achieving it.

In testing rematch in the CBD, TNCs and regulatory oversight agencies should watch for possible unintended consequences. For example, do drivers resist taking passengers outside the CBD given the new priority system? The volume of TNC business throughout the city mitigates against this, but it would need to be monitored and corrective actions developed if necessary.

There is a degree of balancing involved in minimizing unoccupied time between trips without inflating customer waiting times. TNCs and regulators would need to determine how best to achieve and maintain a balance that serves the purposes of both good customer service and reduced CBD congestion.

Reducing unnecessary time between trips for taxis

Cab drivers' trips are generally shorter than is the case with TNCs, and the time between trips is also shorter. The average cab trip that starts in the CBD lasts 16 minutes. Unoccupied time between trips averages 8 minutes, primarily cruising looking for a fare-paying customer.

Unoccupied time varies between 8 and 11 minutes over the course of the day. This is substantially more than in 2013, when drivers spent an average of 5 to 9 minutes between trips, with lower figures during the afternoon rush hour.

A reasonable target for unoccupied time can be inferred from the 2013 data. During the evening rush hour, when there were reports that cabs were hard to find,[10] drivers spent an average of 5.0 to 5.5 minutes between trips. At other times during the day, they spent 6 minutes or more between trips.

A reasonable target that would minimize unoccupied time but retain good cab availability is probably 6 minutes, the point at which cab service was reasonably easy to get in 2013. Further efficiencies would likely be possible if yellow cabs also widely took trips via smartphone app, which TNC experience shows creates the potential for somewhat lower time between trips (e.g., as discussed above, 3-4 minutes on average, from accepting a trip to pick-up).

The same concept of mandating reductions in unoccupied time in the CBD can be applied to yellow cabs. However, the mechanism needs to be different. Yellow cabs obtain most of their business through street hails. Although some have apps, cabs do not generally respond to dispatch requests that are funneled through a central office.

Instead of working through central companies as with TNCs, yellow cab time in the CBD could be regulated for each taxicab. Each cab could be allocated a predetermined number of hours that it could work in the CBD during congested hours (e.g., 8 a.m. to 7 p.m.). Drivers could choose when to work in the CBD and when to work elsewhere or at other times. They would need to always have some of their allocation unused so that they could take a customer into the CBD after being picked up elsewhere. As with TNCs, there would need to be penalties for going over the allocation of CBD hours.

The technology for this system is largely in yellow cabs already, since TLC receives trip data for each trip. The system would need to be enhanced so that regulators could audit the records to prevent cheating or evasion.

A system to allocate CBD hours could be phased in over a period of months, with effectiveness monitored on an ongoing basis. As with TNCs, the objective would be to strike a balance between reducing unoccupied time and maintaining good availability of taxi service.

Drivers would benefit from this system because they would make more money while in the CBD than they do now, since there would be less unoccupied time between trips.

It should be noted that daytime CBD work is a surprisingly modest fraction of overall yellow cab activity. In June 2017, only 27 percent of all taxi trips began in the CBD on weekdays between 8 a.m. and 7 p.m. Evenings and weekends account for the large majority of taxi trip origins. While a significant change, the system discussed here would not have a major impact on overall taxi operations, nor would it subtract from industry revenues.

Table 1. Reductions of Taxi/TNC vehicles in the Manhattan CBD and vehicle mileage from reductions in unoccupied time between trips

	Scenario 1	Scenario 2
Unoccupied time between trips	4 minutes	6 minutes
Change in Taxi/TNC vehicles in CBD	-19%	-12%
Estimated reduction in vehicle mileage in CBD (all vehicles)	-11%	-7%

Results are for weekdays, 8 a.m. to 7 p.m., based on June 2017 data.

Traffic benefits

This analysis shows that there are opportunities to improve traffic flow by reducing the pool of empty cabs and TNC vehicles in the CBD. Furthermore, this can be done without compromising how long it takes to get a ride. Table 1 shows two scenarios that quantify the reduction in taxi/TNC vehicles and the potential traffic benefit.

In the first scenario, TNC and yellow cab operations are optimized and reduce time between trips to an average of four minutes. TNC drivers get their next dispatch just as they drop off the previous customer. Yellow cab operations are optimized with a combination of street hail, app usage and cab stands so that they match the efficiency of TNCs. Under the current industry structure with cabs and TNCs operating independently, four minutes between trips represents a best-case scenario.

In the second scenario, time between trips is reduced to six minutes, matching the figure seen for cabs in 2013 and allowing TNCs a couple of minutes between drop-off and acceptance of the next trip. This is probably a more realistic scenario for implementation.

As shown in Table 1, total time that taxis and TNCs spend in the CBD between 8 a.m. and 7 p.m. falls by 19 percent in scenario 1, and by 12 percent in scenario 2.

Reductions in the number of taxi and TNC vehicles in the CBD would help improve CBD traffic conditions. Taxis and TNCs combined comprise 50 percent to as much as 75 percent of all traffic in the CBD, depending on time of day.

Based on estimates of total traffic volumes, CBD traffic (including all vehicles, not just taxis and TNCs) would decline by 11 percent in scenario 1 and seven percent in scenario 2 during daytime hours. Vehicle speeds would likely increase by about the same percentage.

Daytime CBD speeds have declined by 23 percent since 2010. This one step -- reducing unnecessary driving by taxis and TNCs during the day in the CBD -- would reverse at least one-third of that decline.

The projected improvements to CBD speeds is also significant when compared with the impact of other potential measures. The 2008 Bloomberg Administration congestion pricing proposal, for example, projected that an $8 fee on vehicles entering the CBD would reduce vehicle mileage traveled (VMT) by 7 percent, with about the same increase in traffic speeds.[11]

Combining these elements could reverse most if not all of the decline in CBD speeds since 2010. A cordon congestion pricing plan, with one-way tolls a bit over $5, would potentially reduce traffic by more than the 7 percent expected from the 2008 proposal which had a one-way $8 fee, with offsets for other tolls paid on the same day (e.g., Hudson River crossings). Reducing unoccupied time would reduce overall traffic volumes by 7-11 percent, and a per-trip fee by about 2 percent. Adding these together yields close to a 20 percent reduction in traffic volumes.

Other sources of unnecessary driving

Reducing the unnecessary time between trips that taxi and TNC drivers spend in the CBD is one way to improve traffic conditions in the Manhattan CBD, but not the only one. There are other opportunities that relate to this group of vehicles as well as other frequent users of Manhattan streets. Policies to reduce unnecessary time between trips should be a first step toward addressing these other opportunities, two of which can be mentioned here.

First, the TNC trip data show that TNCs take longer to go between a given pair of origin and destination zones than do yellow cabs. Differences of three to four minutes are seen throughout origin/destination zone pairs for daytime trips in the CBD. It seems likely that TNC trips take longer than taxi trips because TNC drivers generally pick up customers at their doorstep while taxi users often walk to the nearest avenue. TNC drivers may need to go around the block to head toward the destination. The extra time for TNC trips would thus be the time required to go around the block, likely waiting at a red light after each turn.

TNCs have been experimenting with having customers walk a block or so to a designated pickup location for "pooled" (shared-ride) trips. Uber is also experimenting with advising UberX passengers that walking to a nearby corner will result in a faster overall trip. Clearly, the technology is available to combine walking and being driven, to the benefit of passengers, drivers and the efficiency of the street system. Widespread implementation of this approach should be considered.

Moving beyond TNCs and taxis, there are obvious inefficiencies in the use of street space by trucks and commercial vehicles. These vehicles often double-park and may also "block the box" at intersections. Delivery trucks can also be seen using loading zones for the entire day despite 3-hour time limits.

These inefficient uses of scarce street space are analogous to the unnecessary time between trips by taxis and TNCs. The policy objective would also be analogous -- to create efficiencies that serve to improve traffic conditions and, at the same time, benefit commercial drivers and their companies. The means would need to be derived from careful analysis of the source of inefficiencies and development of remedial steps.

Implications for Other Cities

In considering the implications for other cities, it is important to recognize that New York is in many respects quite different than other large U.S. cities. New York's density (population and employment) and extensive public transportation system need to be taken into account in thinking about how its experience translates elsewhere. While bearing in mind differences in size and density, the findings in this report are relevant to other large American cities.

Most centrally, the results in this report show the importance of the driver-driven nature of the supply of TNC service. In this respect, New York is no different than any other city, suburban or rural area. Drivers choose how much to work and where and when to drive. (TNCs tout this flexibility in recruiting drivers.) One sees in the data that at times and places that customers are plentiful, more drivers go on the road. Conversely, when and where customer demand drops, fewer drivers log onto the TNC app.

Because drivers are so responsive to customer demand, drivers make about the same amount of money in neighborhoods with low trip volumes as in neighborhoods of high trip volumes. This is seen in New York, comparing Brooklyn and Queens, for example, with Manhattan. The same dynamic is seen across the country. A recent paper by economists at Uber and New York University, using trip data from major Uber markets, found that absent a change in the rate of fare, Uber vehicle utilization (the proportion of time drivers have passengers) has remained highly consistent over time, even as the company has grown rapidly.[12] Thus, consistency in driver fare revenues is seen both across geographies and across time, despite large variations in trip volumes.

This balancing dynamic has worked to the public's advantage in important ways. TNC rides are available in many suburban and rural areas, as well as in some city neighborhoods that historically had deficiencies in taxi service availability if they had cab service at all.

But in an urban context, this dynamic means that drivers spend a considerable amount of time waiting for their next trip request, as this report shows for the Manhattan CBD and in fact, throughout the five boroughs.[13] Since customer wait times are short, drivers spend most of the time between trips simply waiting for a trip request -- and clogging the streets as they do so.

The larger and denser the city, the more time drivers spend waiting for the next trip dispatch. Thus, extra TNC vehicles are most likely to clog downtown office centers and entertainment districts with a high demand for TNC rides, compounding already existing congestion problems. This outcome is seen in New York and is likely to be found in cities across the country.

A second implication for other cities concerns opportunities for more efficient use of scarce city street space. Traffic management is often assumed to involve trade-offs between competing users. It is easy to assume that to improve traffic conditions, someone or something has to give -- drivers need to be charged a fee, or traffic and parking enforcement needs to ramp up, or trucks need to shift deliveries to off-hours. The good news from this analysis is that while those steps all have merit, there are also less painful opportunities to make traffic flow better. Reducing excess time and mileage spent by TNC drivers waiting for their next trip can improve mobility for everyone, as well as increase driver incomes.

Implications for Automated Vehicle Deployment

While TNCs have wrought major changes to how people move around cities, the transformation spawned by TNCs is likely to pale in comparison to the effects of autonomous vehicles. After years of testing with a human at the wheel to take over when needed, autonomous vehicles without a human back-up are likely to arrive in cities surprisingly soon. Google's Waymo unit recently announced the start of autonomous vehicle testing in Phoenix with an employee in the back seat instead of behind the wheel; General Motors recently announced plans to launch fleets of fully autonomous vehicles in dense urban areas in 2019.[14]

Autonomous vehicles will likely be used in ride service fleets, whether Uber, Lyft or other companies established by car manufacturers. The reason for this is cost. At the outset, autonomous vehicles will be considerably more expensive than conventional motor vehicles. To make the finances pencil out, they will have to be used intensively, with as many passengers paying as much in fares as possible. Vehicle developers have thus focused on testing autonomous vehicles in the demanding urban environments such as San Francisco, with plans in the works for testing in New York City as well.

While shared autonomous vehicles (SAVs) are likely to arrive quite soon, it is anticipated that ride service fleets like Uber and Lyft will continue to have human drivers for many years to come. Companies will be loath to depend entirely on a new technology until it is completely proven and shown to overcome operating limitations such as how well the sensing technology can "see" in heavy rainstorms and how well it can handle snow that covers lane markings.

The traffic impacts of TNC growth will be magnified as TNC fleets continue to expand and as they begin to add shared autonomous vehicles. The market-clearing dynamic discussed above means that drivers will continue to stream into dense city centers, spending excessive time waiting for their next trip, unless mitigation steps are taken. Moreover, once the costs of operating shared autonomous vehicles drops below the cost of human-driven TNC operations (taking into account higher vehicle costs but the absence of a driver in autonomous vehicles), fares are also likely to drop. Declines in fares will spur further growth, with impacts on both traffic volumes and transit ridership.

In the long run, SAVs can bring myriad benefits to cities. These range from reduced traffic injuries and fatalities to reducing the use of single-occupant vehicles, freeing parking spaces for new housing and commercial buildings, and increased use of electric vehicles.[15]

While recognizing those benefits, this report points to risks in the long transition period that precedes a fully autonomous future. These findings thus underscore the important role for public policy in managing traffic impacts as the day of shared autonomous fleets in its major urban centers approaches.

4. Conclusion

App-based ride services have established themselves as an attractive and often-used transportation option in cities large and small across the United States. Their services now rival traditional public transportation in reach and ridership. TNC patronage has grown to 75 percent of total bus ridership in New York City, and approximately 65 percent of total bus ridership nationally.[16] Offering quick, reliable and comfortable service, TNCs have built a broad base of frequent users in major cities across the country.

While clearly beneficial to urban mobility on an individual level, the growth of TNCs has raised a range of issues concerning traffic, transportation and environmental impacts as well as equity, particularly for lower-income persons and people who use wheelchairs. While these concerns have been discussed in a range of cities, there has been very little data to develop a detailed understanding of impacts or form the basis of a public policy response.

This report focuses on very fine-grained trip data available in New York City, with the purpose of understanding TNC impacts in the nation's largest and densest metropolis, and in hopes of offering insight for other large American cities.

Findings indicate that relatively modest growth in overall taxi/TNC trip-making (a 15 percent increase in the Manhattan CBD over the last four years) translates into far larger growth in miles driven and the number of taxi/TNC vehicles in the CBD during the business day. The largest growth is seen from 4 p.m. to 6 p.m., during which the number of taxi/TNCs in the Manhattan CBD more than doubled over the last four years. In the late afternoon there are nearly 10,000 taxi/TNC vehicles in the CBD; they comprise well over one-half of all traffic. These vehicles contribute to what are now the slowest traffic speeds (less than 7 mph during the day) on record in the Manhattan CBD.

In the wake of growth in TNC trips, policy-makers are presented with a dilemma. There is little appetite for limiting TNC operations given their widely-enjoyed mobility benefits. On the other hand, in highly congested urban environments such as Manhattan, TNCs are contributing to very slow traffic flow, at a cost both to their own customers and drivers as well as everyone else on the road.

A per-trip fee on taxi and TNC trips, currently part of discussions of potential congestion pricing solutions to the Manhattan traffic problem, would raise substantial revenue but only modestly reduce taxi/TNC vehicle mileage in Manhattan. This report estimates that a $3 per-trip fee, for example, would reduce taxi/TNC mileage by 3-4 percent while at the same time generating $475 million per year.

A more promising approach is to focus on the unoccupied time that taxis and TNCs spend between dropping off passengers at the end of one trip and picking up passengers for their next trip. Approaches to reducing unoccupied time are discussed in the report, with the most promising approach being a mandate on TNC companies and yellow cab owners to reduce time spent in the CBD.

The report estimates that reducing unoccupied time and mileage could reduce the number of taxi/TNC vehicles in the Manhattan CBD by 15-19 percent. This would produce an estimated 7-11 percent reduction in overall traffic in the CBD on weekdays from 8 a.m. to 7 p.m., and likely a commensurate increase in traffic speeds.

Together with congestion pricing, which was projected to reduce CBD vehicle mileage by seven percent when considered a decade ago, and a per-trip fee on taxi and TNC trips, most if not all of the 23 percent decline in CBD speeds since 2010 could be reversed.

Further development of a regulatory response to reduce unoccupied vehicles should include TNC and yellow cab companies and drivers who would be affected by a mandate to reduce unoccupied time as well as public officials responsible for adoption and implementation of such a policy.

This report also discusses the implications of the New York City experience for other large U.S. cities and for the coming advent of autonomous vehicles operating in shared fleets. Results from New York show how the business model used by TNCs affects traffic levels. The number of TNC vehicles on the road at any given time and place is set by decisions made individually by TNC drivers, each of whom decides where and when and how much to work. This dynamic is highly beneficial in making TNC service quick and generally reliable in places that never had reliable taxi service, if there was any cab service at all. But this dynamic also leads to an unnecessarily large number of unoccupied TNC vehicles throughout New York City, most notably, in congested areas of

Manhattan. The same is likely to be true in other major U.S. cities.

This dynamic will continue with introduction of autonomous vehicles. Shared autonomous vehicle (SAV) services are expected to include both autonomous vehicles and human-driven vehicles. At the same time, reduced costs from replacing drivers with autonomy in part of the fleet is likely to reduce passenger fares and spur further growth in TNC trip volumes. The end result is likely to be accelerated growth of unoccupied TNCs in mixed fleets of human-driven and autonomously operated TNC services.

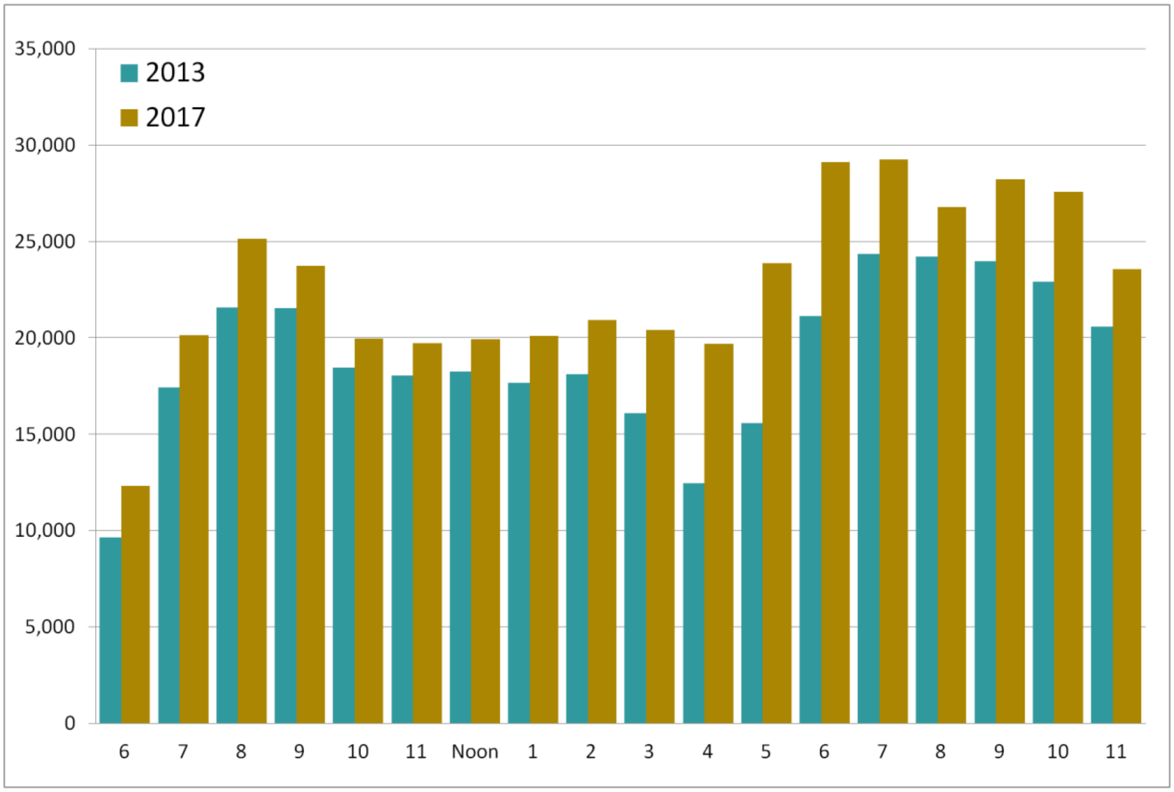
Both the current continued growth of TNCs, and accelerated rates of growth likely with autonomous vehicles, will call for public policy responses. This report is intended to help inform the development of effective policy responses that both take full advantage of the coming changes to urban transportation, and manage and mitigate the risks posed by continued proliferation of motor vehicles in the nation's largest cities.

Appendix. Results by Time of Day

	Total		Average per hour			
	24 hours	8 a.m.- 7 p.m.	8 a.m.- 7 p.m.	8 a.m.- 3 p.m.	3 p.m.- 7 p.m.	7 p.m. midnight
Taxi 2013						
Trips	378,166	198,948	18,086	19,096	16,319	19,553
Mileage	1,053,021	489,496	44,500	47,025	40,080	51,203
Total hours	103,404	59,446	5,404	5,805	4,703	5,404
Occupied hours	69,256	41,390	3,763	3,888	3,544	3,704
Unoccupied hours	34,148	18,056	1,641	1,917	1,159	1,700
Pct occupied	67%	70%	70%	67%	75%	69%
Taxi 2017						
Trips	249,767	136,851	12,441	12,479	12,374	13,044
Mileage	695,545	326,834	29,712	29,352	30,342	33,595
Total hours	81,087	48,178	4,380	4,382	4,377	4,235
Occupied hours	52,546	33,149	3,014	2,967	3,095	2,837
Unoccupied hours	28,541	15,029	1,366	1,415	1,281	1,398
Pct occupied	65%	69%	69%	68%	71%	67%
TNC 2017						
Trips	202,262	105,779	9,616	8,879	10,906	10,379
Mileage	802,135	353,964	32,179	29,538	36,800	38,194
Total hours	91,608	51,929	4,721	4,386	5,307	4,743
Occupied hours	55,069	33,155	3,014	2,762	3,456	2,912
Unoccupied hours	36,539	18,774	1,707	1,624	1,851	1,831
Pct occupied	60%	64%	64%	63%	65%	61%
Total Taxi+TNC 2017						
Trips	452,029	242,630	22,057	21,358	23,281	23,423
Mileage	1,497,680	680,798	61,891	58,890	67,141	71,789
Total hours	172,695	100,107	9,101	8,768	9,683	8,979
Occupied hours	107,615	66,304	6,028	5,729	6,551	5,749
Unoccupied hours	65,080	33,802	3,073	3,039	3,132	3,229
Pct occupied	62%	66%	66%	65%	68%	64%
Change 2013 to 2017*						
Trips	56,045	34,528	3,138	1,465	6,067	2,958
Mileage	378,464	161,843	14,763	9,377	24,194	17,436
Total hours	61,900	36,463	3,322	2,605	4,577	3,193
Occupied hours	33,844	22,199	2,023	1,613	2,740	1,807
Unoccupied hours	28,056	14,263	1,299	992	1,837	1,386
Pct change: Trips	15%	17%	17%	8%	37%	15%
Pct change: Mileage	36%	33%	33%	20%	60%	34%
Pct change: Total hours	59%	61%	61%	44%	96%	59%
Pct change: Occupied hrs.	48%	53%	53%	41%	77%	48%
Pct change: Unoccup. hrs.	81%	78%	78%	51%	157%	81%

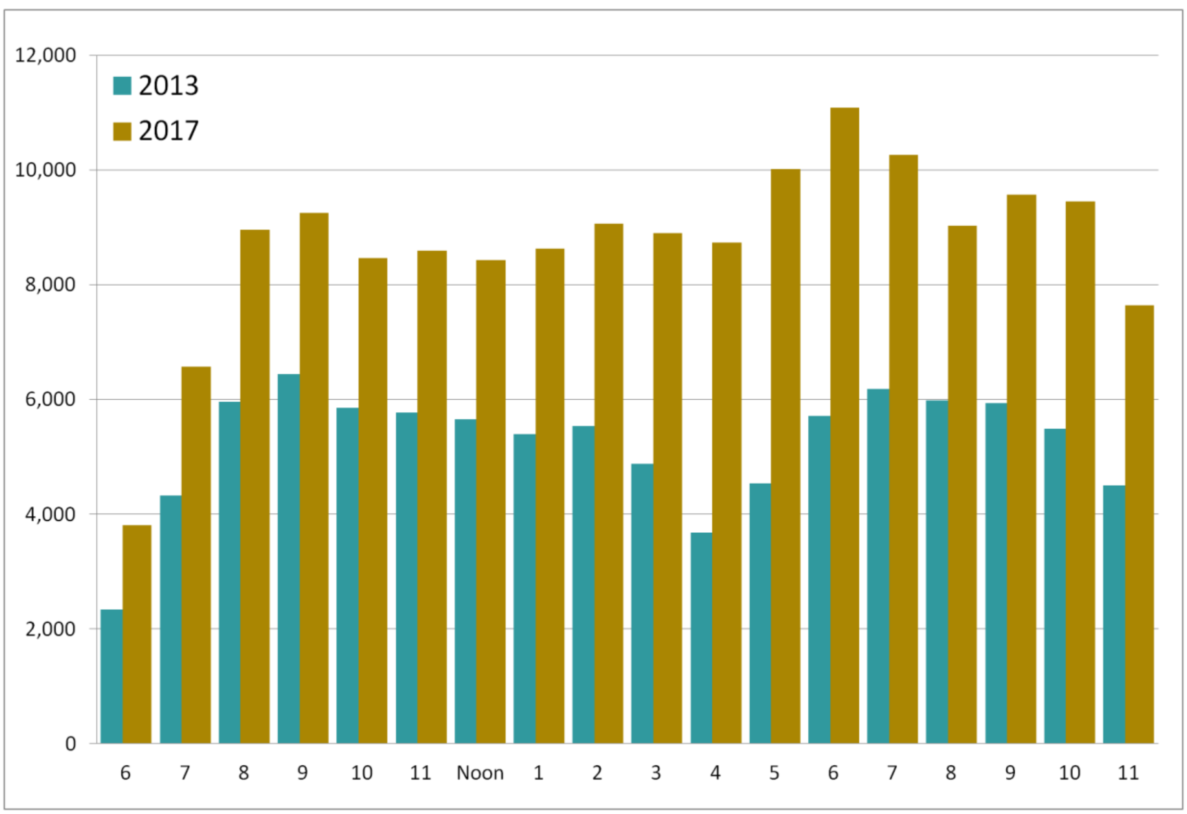
Change from 2013 to 2017 accounts for small number of Uber trips in 2013 (estimated as 1% of taxi trips) and trips dispatched by TNCs to black cars.
Data are for June weekdays in 2013 and 2017, for trips starting and/or ending in Manhattan below 60th Street (CBD).

Trips by Hour: Total taxi/TNC trips in the CBD, by hour, weekdays June 2013 and June 2017



Trips beginning and/or ending in the CBD, average weekday in June 2013 and June 2017.

Vehicles by Hour: Total Taxi/TNC vehicles in the CBD, by hour, weekdays June 2013 and June 2017



Endnotes

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[1] Marc Santora, "Cuomo Calls Manhattan Traffic Plan an Idea 'Whose Time Has Come,'" New York Times, August 13, 2017.

[2] Office of Governor Andrew Cuomo, " Governor Cuomo Announces "Fix NYC" Advisory Panel," press release, October 5, 2017.

[3] Office of Mayor Bill de Blasio, " Mayor de Blasio Announces Initiatives To Help Ease Congestion," press release, October 22, 2017.

[4] Schaller Consulting, "Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City," February 2017.

[5] Based on the number of Uber vehicles licensed in June 2013, Uber trip volumes were about 1 percent of those for taxis. Uber was the only TNC operating in New York City at that time.

[6] For taxis, late March and early April 2013 and April 2017; for TNCs, March to June 2016.

[7] Jonathan V. Hall, John J. Horton and Daniel T. Knoepe, "Labor Market Equilibration: Evidence from Uber," October 11, 2017. Available: http://john-joseph-horton.com/papers/uber_price.pdf

[8] Although beyond the scope of this report, it should be noted that the full spectrum of trip fees and taxes need to be addressed when considering the per-trip fee discussed here. TNCs currently pay a sales tax that goes to State, City and MTA coffers on each trip, whereas yellow cab riders are charged a 50-cent per trip fee that is dedicated to the MTA. Changes to the existing tax/fee structure should standardize the charges across all vehicles working for-hire in Manhattan, so as not to advantage yellow cabs or TNCs, or vice versa.

[9] Bruce Schaller, "Elasticities for Taxicab Fares and Service Availability," *Transportation*, Vol. 26, August 1999.

[10] New York City Taxi and Limousine Commission, "Taxi Medallion Increase, Final Environmental Impact Statement," October 2013.

[11] New York State Traffic Congestion Mitigation Commission, "Commission Recommendation," January 31, 2008.

[12] Note that utilization does change when the fare changes. Uber's fare reductions have led to higher utilization with the result, according to the modeling of trip data reported in this paper, that driver incomes stabilize after a fare cut at about the same level as prior to the fare reduction.

[13] Although this report focuses on the Manhattan CBD, notably, unoccupied time and customer wait times are about the same throughout the five boroughs of New York City. There are thus excessive number of drivers waiting for customers in Queens and Brooklyn, for example, just as in Manhattan. This report focuses on Manhattan, however, as the center of the city's congestion problem.

[14] Tom Krisher, "Waymo rolls out autonomous vans without human backup drivers," *Denver Post*, November 12, 2017; and Alexandria Sage, Paul Lienert, " GM plans large-scale launch of self-driving cars in U.S. cities in 2019," Reuters, November 30, 2017.

[15] International Transport Forum, *Shared Mobility: Innovation for Livable Cities.*

[16] Comparison of taxi/TNC and bus ridership is based on TLC trip data and MTA bus ridership for New York City. National figure is based on and published estimates of Lyft ridership and market share and national bus ridership from the American Public Transportation Association.