THE PORT AUTHORITY OF NEW YORK & NEW JERSEY

New York City and LGA Access Traffic Conditions:

Current and Projected Assessment

October 2018

Executive Summary

This study examines vehicular traffic conditions in the New York City region, assessing recent trends and future projections to estimate travel time predictability and reliability. The report focuses on traffic conditions on the road network to and from LaGuardia Airport (LGA), mainly from Manhattan's Central Business District (CBD) – a main origin and destination of LGA air passengers. It has assumed no major changes to the transportation infrastructure, apart from those included in the New York Best Practice Model (BPM).

The analysis prepared for this study goes beyond using average travel times, as is typically done in many studies, because travel *to* an airport is different from most other trips; it is binary: you either catch your flight or you miss it. This raises the anxiety level of travelers whereby they do not just allow for average travel times but what they think is a likely "worst case." The report defines this worry as *Missing-My-Flight Anxiety (MMFA).*

Similarly, since LGA is the chosen airport of business professionals in New York City, the analysis examines trips *from* the airport differently. Many business trips have a final destination of a meeting at a set time. This creates a worry like MMFA, defined here as *Missing-My-Meeting-Anxiety* (*MMMA*).

Both MMFA and MMMA are the driving forces for travelers to mentally calculate a *"budgeted travel time."* The budgeted travel time accounts for deviations (increases in travel time) from an average trip that passengers know may occur. For that reason, the 95th percentile travel time is defined here as the budgeted travel time. In other words, one in 20 trips will be equal to or longer than the budgeted travel time. (Note: the average business traveler takes between 12 and 14 trips per year.)

With that in mind, the principal findings of the study are:

1. **Travel to and from LGA has been getting worse every year even though the number of air passengers has not changed significantly,** hovering at about 30 million a year for the past four years. The analysis was adjusted for airport construction over the past two years by discarding data from days during which on-airport traffic conditions led to unusual delays.

2. **Budgeted (95th percentile) travel time *to* LGA from Times Square increased by 18%, from 45 to 53 minutes, between 2014 and 2017**, while average travel time increased by 13%, from 31 to 35 minutes. Furthermore, the number of days with *extreme* travel times of 70

minutes or more increased from 4 in 2014, to 17 in 2017. This may result in a substantial increase to the time that passengers budget for traveling to the airport.

3. **Budgeted (95th percentile) travel time from LGA *to* Times Square jumped by 18% from 55 to 65 minutes between 2014 and 2017,** while average travel time increased from 36 to 43 minutes in the same period. The number of days with *extreme* travel time of 70 minutes or more has also increased between 2014 and 2017, from 21 to 114 days, or almost once every three days in 2017.

4. **The rapid growth of app-based, ride-hailing services, also known as Transportation Network Companies (TNCs), has greatly impacted traffic in the city as a whole and, in particular, around major hubs such as LGA.** Between 2015 and 2017, TNC ridership in New York City increased by almost 400%, reaching nearly 160 million dispatches in 2017. If TNCs simply replaced taxis, traffic volumes would not change significantly. However, TNCs have drastically altered the landscape of transportation in New York City, impacting the modal choice of travelers (more than 40% of TNC trips would have been by transit) while producing per-ride Vehicle Miles Traveled (VMT) that are 1.6 times higher than those of private cars. Annual For Hire Vehicle (FHV) pick-ups at LGA (including TNCs and other car services**,** of which TNC pick-ups are the lion's share), grew by 115% in 2016 and by 46% in 2017. In yearly volumes, the number of annual FHV pick-ups at LGA jumped by more than 1.5 million trips over two years, from 737,000 in 2015 to 2,307,800 in 2017.

5. **TNCs give a glimpse of the very likely future with Autonomous Vehicles (AVs) widely used by 2045.** Most transportation futurists predict that more people would share, rather than own AV cars, as compared to the current vehicle market, which is dominated by personal autos. The shared AV car is precisely the TNC model, sans driver. Many transportation experts foresee a significant increase in VMT in a world populated by AVs, which would make traveling by car more pleasant and convenient. Additionally, there will be far more "drivers" on the road as age, disability, and inability to get a driver's license will no longer be a factor.

   Highway capacity is expected to increase as AVs can follow each other more closely, but that does not mean they will move more people. Many AVs, either TNCs or privately-owned, will be empty cars en route to picking up a passenger or having just dropped one off. Moreover, street capacity in urban areas like Midtown Manhattan will likely go down since AVs will be constantly assessing pedestrians, conventional bicycles, e-bikes, scooters, skateboards, etc., and would travel hesitatingly through the street network.

6. **In the period between 2020 and 2045, we will see a gradual introduction of AVs mixing with conventional cars, thereby creating a period of disorder, inefficiencies, and turbulence on city streets and highways.** This is akin to the era from 1900 to 1930, when there was a mix of automobiles, horses, pedestrians, cyclists and streetcars all sharing, or trying to share, the roadway—it didn't work. The number of United States traffic fatalities, particularly pedestrians killed, exploded in that era, rising from 36 in 1900 to 31,204 by 1930. The period was marked by very slow speeds because of this turbulence. Eventually, cars, through brute force, laid claim to the roadways.

   Over the next 25 years, there will be a mix of conventionally driven cars, cars that have some autonomous features, cars that are mostly driverless but require human engagement on occasion, and fully autonomous cars (no steering wheel, accelerator or brake). Cars of the future may not even look like the cars of today. Having a variety of vehicles with multiple driving characteristics and dimensions will mean a degree of disorder that can only be handled at slower speeds in urban settings.

   The advent of AVs is expected to further increase VMT beyond the TNC-effect by inducing additional travel due to the convenience and expected low costs (no driver to pay) and by introducing privately-owned cars with no occupants on their way to pick-up or drop-off their passenger(s).

7. **Based on modeling future traffic flow, travel times to and from Manhattan's CBD by 2045 will soar *even without accounting for further growth in TNCs and the introduction of AVs.* Some examples of likely budgeted (95th percentile) travel times that do not take AVs and TNCs into account indicate:**
   a. Grand Central to LGA: going from 61 minutes today to 75 minutes
   b. LGA to Grand Central: going from 62 minutes to 104 minutes
   c. Penn Station to LGA: going from 74 minutes to 92 minutes
   d. LGA to Penn Station: going from 70 minutes to 87 minutes
   e. Financial District to LGA: going from 76 minutes to 91 minutes
   f. LGA to Financial District: going from 68 to 81 minutes

8. **By 2045, in a world of AVs and increasing TNC use, the budgeted travel time to and from LGA and Midtown Manhattan is predicted to be much longer than today (up to two hours or more).** As more people use TNCs and AVs, studies have shown VMT goes up (see bullets 4, 5 and 6 above and report text). On limited access highways, some of the increased VMT impact will be offset by added capacity. The same is not true for city streets, where turbulence created by a mix of users and increased vehicle volumes is expected to exacerbate congestion and slow travel speeds. **This study concludes that average travel time between Midtown Manhattan and LGA will reach one hour by 2045, and the budgeted travel time will be approximately two hours or more, double the budgeted travel time compared to 2017.**

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Abbreviations and Terms

AV – Autonomous Vehicle (Self-Driving Car)

The Adjusted Model – a model prepared by the Port Authority in 2017 to estimate future vehicle traffic conditions to and from LGA. The model builds on the BPM and adjusts its output by incorporating observed 2015 travel times.

BPM – (New York) Best Practice Model; the model used by NYMTC to estimate future vehicle traffic conditions in the New York Region.

BQE – Brooklyn Queens Expressway

Budgeted Travel Time – The time travelers calculate as necessary to arrive at their destination on time, accounting for potential delays.

CAV - Connected and Autonomous Vehicle

CBD – Central Business District (Manhattan South of 60th Street)

EWR – Newark Liberty Airport

FHV – For Hire Vehicle; in this study, FHVs include TNC, Black Car, Limousine and Outer Boroughs Green Taxi.

GCP – Grand Central Parkway

JFK – John F. Kennedy International Airport

LGA – LaGuardia Airport

LIE – Long Island Expressway

MMFA – Missing-My-Flight-Anxiety

MMMA – Missing-My-Meeting-Anxiety

MTA – Metropolitan Transit Authority

NYCDOT – New York City Department of Transportation

NYMTC – New York Metropolitan Transportation Council

O&D – Origins and Destinations

QMT – Queens-Midtown Tunnel

TLC – (New York City) Taxi and Limousine Commission

TNC – Transportation Network Company (Uber, Lyft, etc.)

VHT – Vehicle Hours Traveled

VMT – Vehicle Miles Traveled

VOT – Value of Time

1. Introduction

This report reviews recent traffic trends in the New York City region and projections of future conditions on the regional roadway network, with an emphasis on vehicle traffic to and from LaGuardia Airport (LGA). The goal of the analysis is to estimate the effects that projected vehicular volume changes will have on vehicle travel times in the future. The study highlights the growing variability and randomness of vehicle travel times, and the influence that this uncertainty has on travelers' trip planning.

The analysis in this study goes beyond using average travel times, as is typical in many studies, since travel to an airport is different than most other trips; it is binary, you either catch your flight or you miss it. This raises the anxiety level of travelers whereby they do not just *budget* for average travel times but rather what they think is a likely "worst case." This study defines these angsts as *Missing-My-Flight Anxiety (MMFA)* and *Missing-My-Meeting Anxiety (MMMA).* Therefore, when analyzing ground transportation *to* LGA - an airport located in a dense environment - the study uses both average and 95th percentile travel times.

The first section of the report discusses transportation network reliability and travel time predictability as two main factors that drive airport customers' travel decisions. Next, the study analyzes trends in travel speed and time in New York City and the region, as well as regional trends in population and employment. Based on the traffic and population trend analysis, and existing projections for the years 2025 and 2045, the study continues by discussing future trends in regional transportation, focusing on the repercussions on the LGA customer base. Among others, the study takes into account factors such as the future growth in the usage of Transportation Network Companies (TNCs) like Uber and Lyft, and the likely introduction of Autonomous Vehicles (AVs) into the system. The study concludes with a new analysis, projecting travel times between Midtown Manhattan and LGA in 2045, accounting for the above-mentioned factors.

LGA Passengers

The study focuses on vehicular traffic to and from LGA, an airport that as of 2017 serves 29.6 million passengers annually and is projected to serve approximately 11 million more by 2045. Based on a comprehensive 2017 survey, and similar to other airports in the New York region, visitors comprise the majority of air passengers at LGA, with 66.9% of travelers residing outside the region (**Figure 1**).

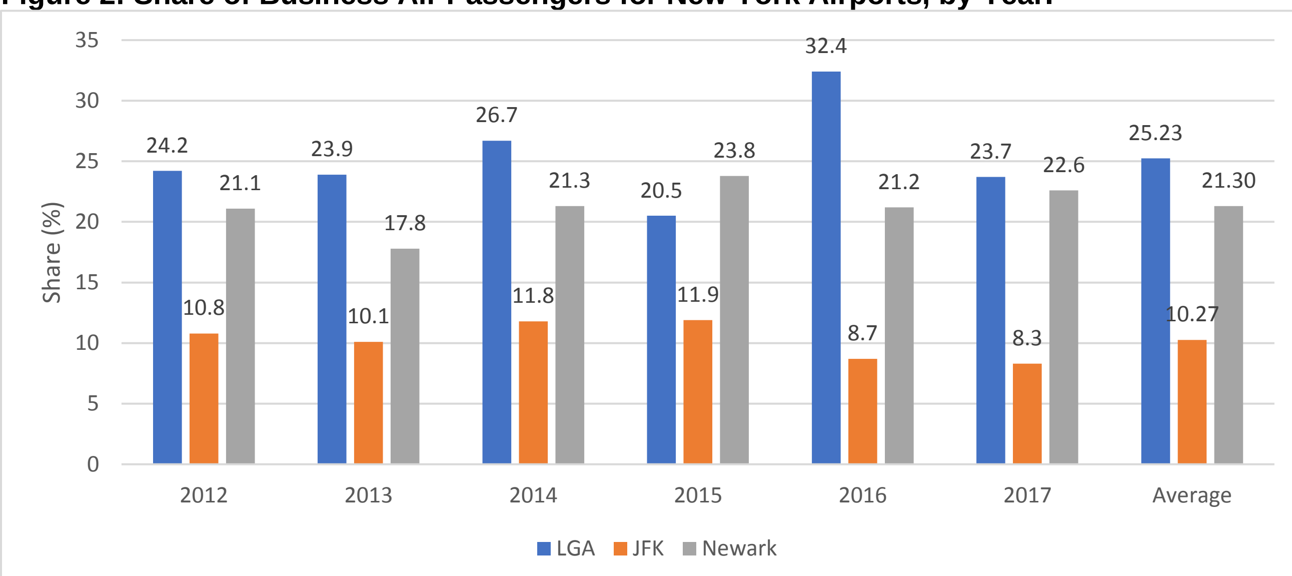
Figure 1:
LGA Air Passengers by Type

	Share of all Air Passengers
Visitors	66.9%
Locals	33.1%

Source: Port Authority of New York & New Jersey

Business air passengers in the New York region largely prefer LGA over John F. Kennedy International Airport (JFK) and Newark Liberty International Airport (EWR), the other two major airports in the region. As seen in **Figure 2**, surveys conducted between 2012 and 2017 show that the share of business travelers at LGA is greater than at EWR and JFK. In absolute numbers, about 7.5 million business travelers use LGA each year. By 2045, if business share percentages remain about the same, over 10 million business air passengers will be using LGA annually, 2.5 million more than today. This translates into approximately 10,000 more business passengers per *weekday*.

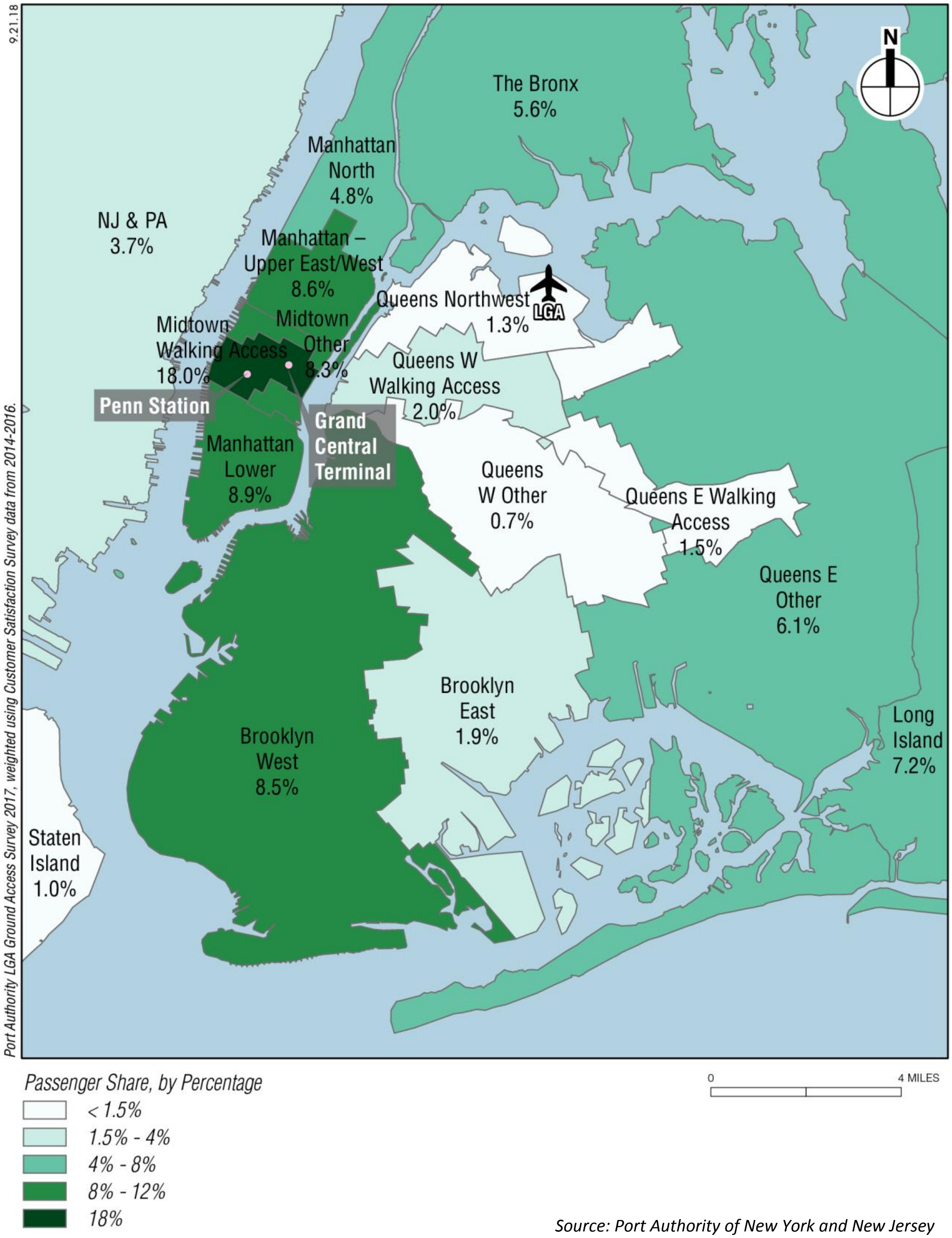
Figure 2: Share of Business Air Passengers for New York Airports, by Year.



Source: Port Authority of New York and New Jersey

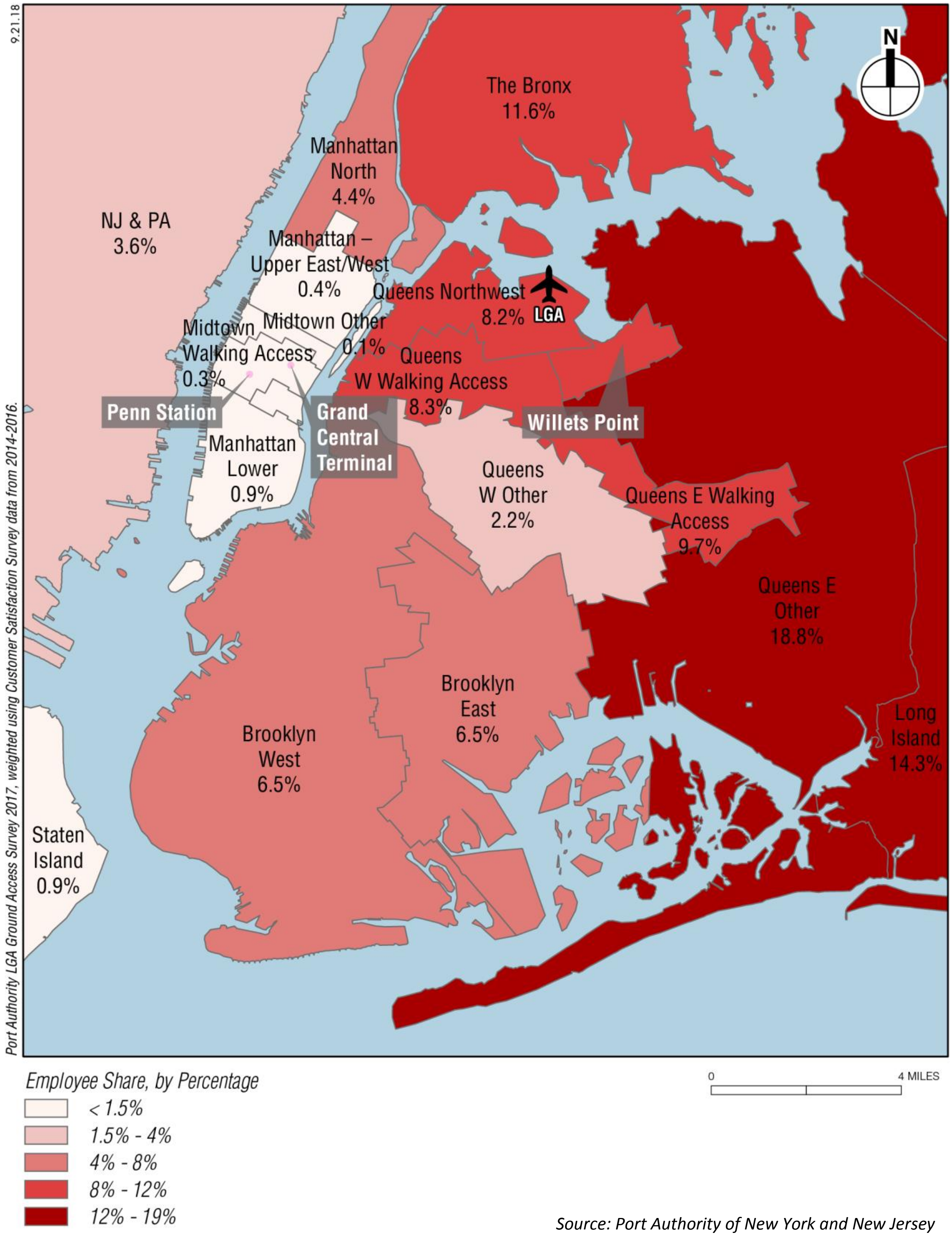
Mapping the origins and destinations (O&D) of LGA air passengers (**Figure 3** and **Figure 4**) highlights that trips to and from the airport are concentrated in specific parts of the New York region. Over 35% of passenger trips come from Manhattan south of 96th Street, and over 25% of passengers start or end their trip in Midtown Manhattan. In contrast, 43% of airport workers come from eastern Queens and Long Island, with only 1.3% coming from Manhattan south of 96th Street.

Figure 3: LGA Air Passengers Distribution by Trip Origin/Destination.



Source: Port Authority of New York and New Jersey

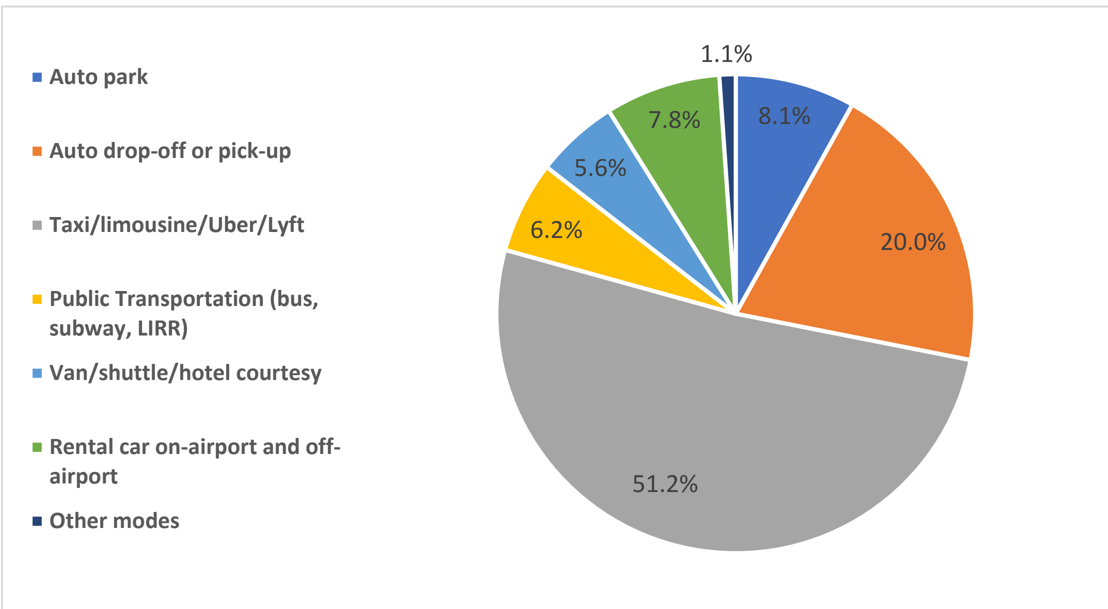
Figure 4: LGA Employees Distribution by Trip Origin/Destination.



Source: Port Authority of New York and New Jersey

Despite the prominence of trips made to and from areas that are well-served by transit, both air passengers and airport employees rely heavily on low-occupancy vehicles for their LGA trips. As can be seen in **Figure 5** and **Figure 6**, over 50% of airport employees drive to LGA and over 70% of air passengers either use taxis or For Hire Vehicles (FHVs),[1] or are dropped-off and picked-up by other drivers. It should be noted, however, that the second most popular mode of access for LGA employees is public transportation, using the bus system, accounting for 40% of the trips. On the air passenger side, just 6.2% use public transportation and another 5.6% use vans and shuttles, primarily to Manhattan, and hotel courtesy buses.

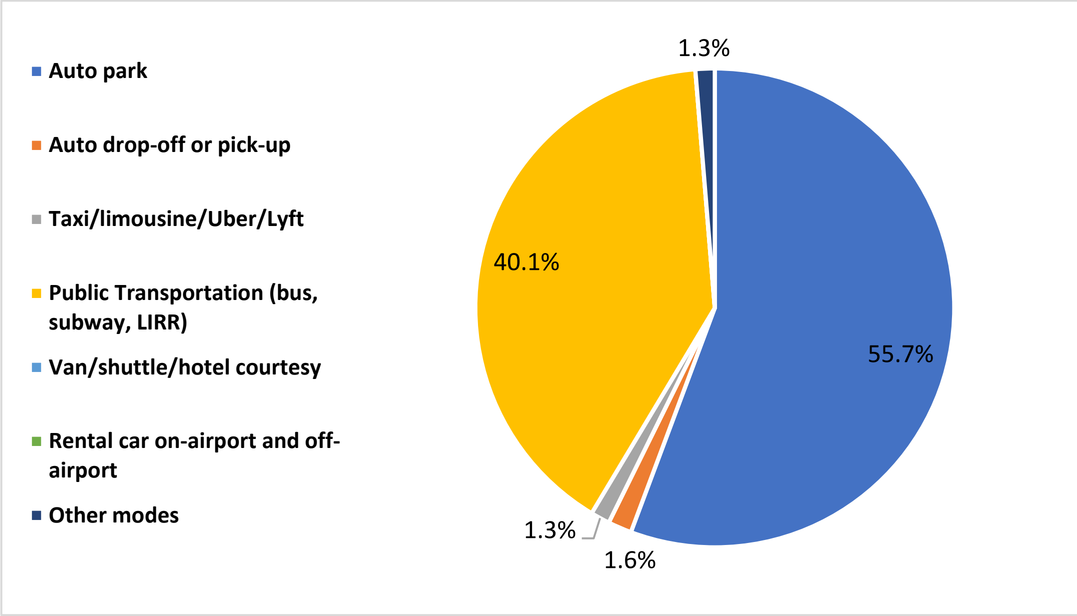
Figure 5: Air Passengers Ground Access Mode Choice at LGA, 2017.



Source: Port Authority of New York and New Jersey

[1] For the purpose of this report, and in the context of New York City, FHVs include all TNC vehicles, green taxis, black cars and limousines. Taxis refer only to yellow cabs.

Figure 6: Airport Employees Ground Access Mode Choice at LGA, 2017.



Source: Port Authority of New York and New Jersey

Figure 5 and **Figure 6** represent air passenger and employee mode splits only for 2017. It should be noted that over the past four years there have been significant modal shifts at LGA, as private vehicle use has declined and a shift from taxi to TNC vehicles has been observed (see discussion in **Section 5**).

As the majority of airport users, both passengers and employees, rely on private vehicles and FHVs, an estimate of vehicle traffic volumes and travel time predictability is critical to the understanding of future LGA access conditions. Since trips made by air passengers to and from LGA are highly concentrated in Midtown Manhattan, the analysis focuses in great part on the connection between that part of the city and LGA. Because time sensitivity and the sunken costs of arranging a trip make LGA air passengers more likely to use FHVs, trends in FHV usage is factored into this report as well. Finally, the impacts of AVs on traffic flow are projected for the longer-term future.

2. Air Passengers' Travel Choice

Generally, travel choices are made based on several factors, including travel time, reliability, cost, comfort, convenience, vehicle access, and accessibility. However, for airport trips, reliability of the ground access mode and predictability of travel times are a top concern. Passengers on their way to a flight are typically trying to avoid being late at all costs.

Many studies have found that ground access time is important in travelers' airport selection, especially for business air passengers.[2] Easy and quick access is therefore important to maintain an airport's competitiveness and ability to serve the region. As can be expected, the selection of an access mode to the airport of choice follows similar logic.[3] But selecting the right ground access mode involves more than just comparing average travel times. Air passengers are more likely than others to seek reassurance that unexpected delays will not make them miss the flight. Airline tickets and hotel accommodations are costly, and missing a flight carries a significant perceived economic loss.[4]

These circumstances, combined with the fact that trips to the airport are binary – you either catch your flight or not – trigger in many passengers a nervousness identified here as Missing-My-Flight Anxiety (MMFA). Moreover, due to the high stakes often involved in business meetings, business travelers may develop a worry closely tied to MMFA – the Missing-My-Meeting-Anxiety (MMMA). This phenomenon is more common at airports that serve major business centers, such as LGA.

The value attached to making a flight on time affects travelers' mode choice, thus they tend to select the most reliable and predictable ground access mode available. [5,6] To ensure they do not miss their flight, air passengers factor time safety margins into access mode selection and arrival time calculation, i.e., they take into account additional time in anticipation of travel uncertainty referred to in this report as *budgeted travel time*.[7] Travelers budget for longer travel time when they perceive the ground access mode to be less reliable. When users of similar ground access modes are compared, business and long-haul air passengers tend to allow longer safety margins

[2] E. Pels, P Nijkamp, and P. Rietveld, "Airport and Airline Choice in a Multiple Airport Region: An Empirical Analysis for the San Francisco Bay Area: Regional Studies: Vol 35, No 1,"; Jun Ishii, Sunyoung Jun, and Kurt Van Dender, "Air Travel Choices in Multi-Airport Markets," Working Papers (University of California-Irvine, Department of Economics, February 2006).
[3] Mei-Ling Tam, William H. K. Lam, and Hing-Po Lo, "The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice," *Journal of Choice Modelling* 4, no. 2 (January 1, 2011): 49–69, h.
[4] M. M. Pasha and M. Hickman, "Airport Ground Accessibility: Review and Assessment," 2016.
[5] Tam, Lam, and Lo, "The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice."
[6] Doohee Nam, Dongjoo Park, and Apichat Khamkongkhun, "Estimation of Value of Travel Time Reliability," *Journal of Advanced Transportation* 39, no. 1 (December 1, 2005): 39–61.
[7] Tam, Lam, and Lo, "The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice."

than other travelers, likely reflecting the greater risk they perceive to be taking when trying to make a business meeting or travel a significant distance.[8]

Furthermore, MMMA and MMFA lead to air passengers' higher willingness-to-pay for ground access trips, compared to travelers to other ground destinations. Value of Time (VOT) is a metric measuring how much a traveler would be willing to pay to save time. It expresses the trade-off between travel time and cost, with higher VOT generally translating to higher values assigned to saving time on the road and to assuring a seamless ride.

A study on VOT in the New York region, conducted in 2006 for the Port Authority, found that air passengers' VOT were significantly higher than that of other travelers in the region.[9] While business air passengers valued their time at $78.75 an hour and non-business air passengers valued their time at $52.50 an hour, other travelers in the New York region had a VOT of $19.75 an hour for commuting and $12.50 - $15.00 an hour for non-commuting trips.[10] Other studies have also found differences between business and non-business air passengers, with VOT of business air passengers being between 1.5 and 2.5 times higher than those of non-business passengers.[11]

[8] Tam, Lam, and Lo.
[9] Surabhi Gupta et al., "A Model for Joint Choice of Airport and Ground Access Mode," 2006.
[10] Gupta et al.Surabhi Gupta et al., "A Model for Joint Choice of Airport and Ground Access Mode," 2006. Note that values were adjusted to 2018 dollars.
[11] Gupta et al.; Tam, Lam, and Lo, "The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice"; Greig Harvey, "Study of Airport Access Mode Choice," *Journal of Transportation Engineering* 112, no. 5 (September 1986): 525–45.

3. **Recent Trends in New York City Traffic Conditions**

In recent years, highway traffic in the region has become more congested. In 2015, New York City was ranked by the transportation analytics company INRIX as the fifth most congested city in the United States; in 2016, it moved to second place, and stayed there in 2017.[12] In Manhattan, traffic speeds have deteriorated, and traveling to LGA has gotten steadily worse over the past five years, leading to greater variability in trip times and less predictability in trip planning.

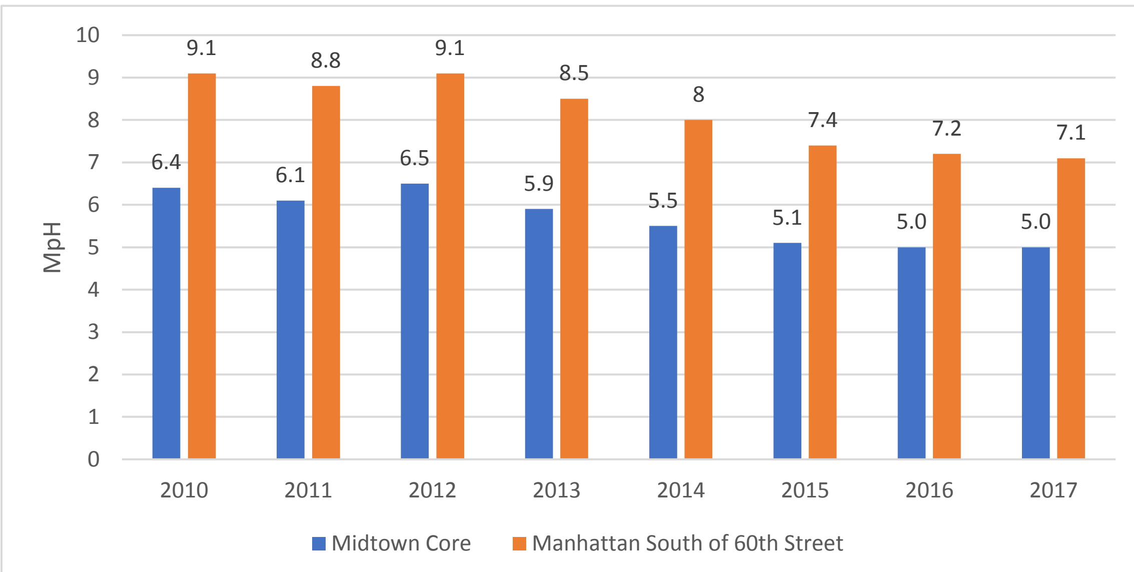
Models assigning traffic to New York City roads find that many of the highways in the city are congested during both the AM and PM peak periods.[13] With both observations and projections identifying increases in traffic, it is likely that congestion will increase on roads in New York City in general, and those leading to LGA in particular.

[12] Graham Cookson, "INRIX Global Traffic Scorecard," n.d., 44.Graham Cookson, "INRIX Global Traffic Scorecard"(2018).
[13] New York Metropolitan Transportation Council's Best Practice Model

3.1. Manhattan Travel Speeds

Average vehicle speeds in Manhattan have plummeted in recent years, and, along with them, uncertainty about travel times has soared. As shown in **Figure 7**, average travel speed in the Central Business District (CBD)[14] dropped from 9.1 to 7.1 mph between 2010 and 2017. Moreover, in the Midtown Core[15] travel speeds reached the low point of 4.7 mph in September 2017. Slightly faster than a pedestrian walking speed, this also represents a 28% drop in travel speed from the 6.5 mph recorded in 2012.[16]

Figure 7: Average Annual Weekday Travel Speed in the Midtown Core and the CBD, 2010-2017 (weekdays, 8am-6pm, excluding major holidays).



Source: NYCDOT, 2018 Mobility Report; based on Average Taxi Speed Data

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[14] In this report, the Central Business District (CBD) refers to Manhattan south of 60th Street.
[15] Midtown Core is a roughly 1.8 sq. mile area in Midtown Manhattan, bounded by East River and 9th Avenue to the east and west, and 59th and 35th Streets to the north and south. In terms of economic activity, it is the densest district in Manhattan (New York City Department of Transportation, "Mobility Report," 2018.).
[16] New York City Department of Transportation; "De Blasio's Five-Point Plan Aims to Reduce Traffic Congestion," *The New York Times*, October 22, 2017.

3.2. Road Network Traffic Conditions to and from LGA

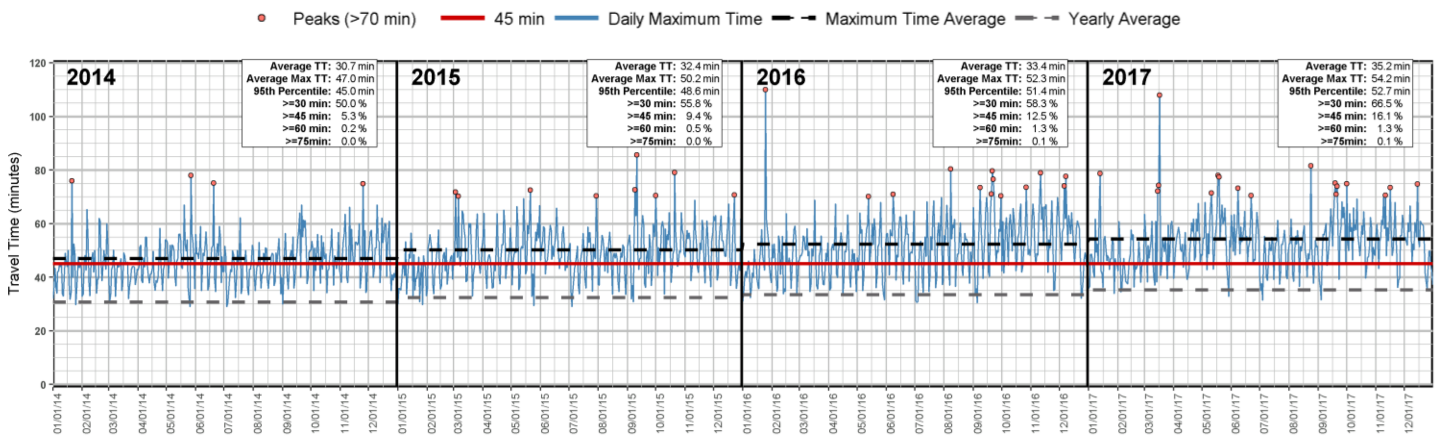
In the past few years, there have been many more instances of unpredictably long travel times on the highway system. More specifically, travel times to and from LGA have significantly increased. Focusing on Manhattan-LGA trips, the frequency of longer trips and their duration are depicted in **Figure 8** through **Figure 12**.

As noted in **section 1**, both MMFA and MMMA are the driving forces for the budgeted travel time calculated by travelers. The budgeted travel time accounts for deviations (increases in travel time) from an average trip. For that reason, the 95th percentile travel time has been defined as the budgeted travel time in this report. The 95th percentile stands for the value that one in 20 trips will equal or exceed. For context, it should be noted that the average United States business traveler takes between 12 and 14 air trips per year.[17]

Based on data from the Taxi and Limousine Commission (TLC), between 2014 and 2017, the 95th percentile travel time from Times Square to LGA increased by 18%, from 45 to approximately 53 minutes.[18] In the same period, the average vehicle travel time for that trip increased by 13%, from 31 to 35 minutes. Furthermore, the number of days with extreme travel times of 70 minutes or more increased from 4 in 2014, to 17 in 2017. In the reverse direction, the data indicate an even gloomier picture: the average travel time from LGA to Times Square increased over the same period of time from 36 to 43 minutes, while the 95th percentile travel time increased by 18%, from 55 to 65 minutes. The number of days with extreme travel times of 70 minutes or more also increased between 2014 and 2017, from 21 to 114 days, or almost one of every three days that year.[19]

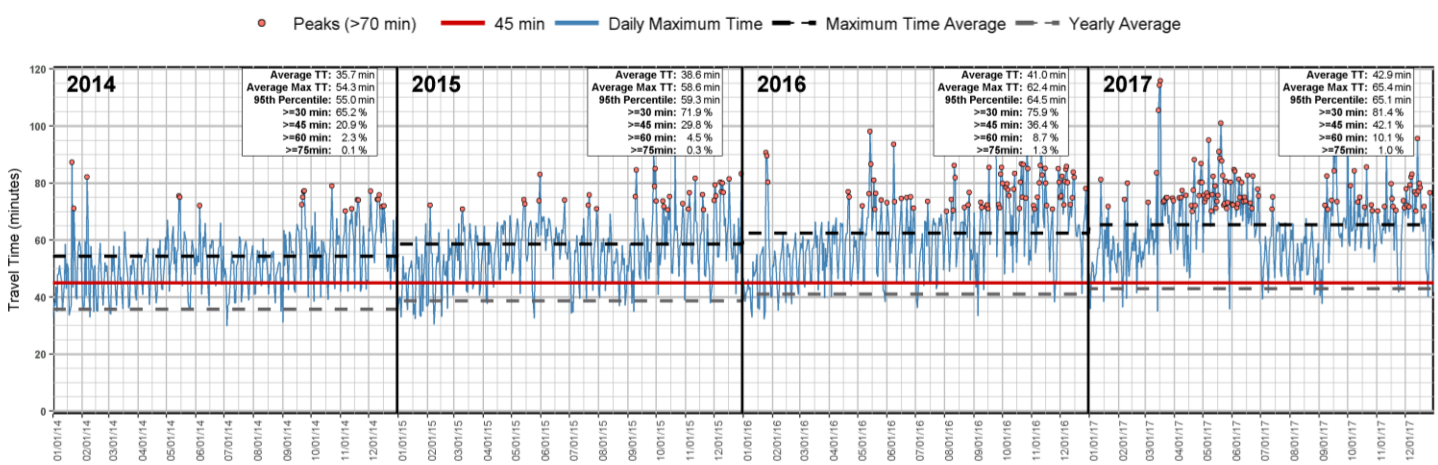
[17] Rebecca Lake, "Business Travel Statistics: 23 Speedy Facts to Know," CreditDonkey, accessed October 3, 2018, http://www.creditdonkey.com/business-travel-statistics.html
[18] "NYC Taxi & Limousine Commission - Trip Record Data," accessed October 5, 2018, http://www.nyc.gov/html/tlc/html/about/trip_record_data.shtml.
[19] Analysis excludes days during which there were extensive delays caused by on-airport construction activities at LGA.

Figure 8: Daily Maximum Vehicle Travel Time from Times Square to LGA, 2014-2017.



Note: Data cleaned to remove any days during which on-airport traffic conditions led to delays on the off-airport roadway network. Data for following dates was excluded: 08/22/16, 11/10/16, 11/18/16, 12/12/16,12/15/16, 12/16/16, 12/21/16, 01/19/17, 02/10/17, 02/08/17, 04/28/17, 12/20/17.

Figure 9: Daily Maximum Vehicle Travel Time from LGA to Times Square, 2014-2017.



Data Source: TLC Taxi GPS Data

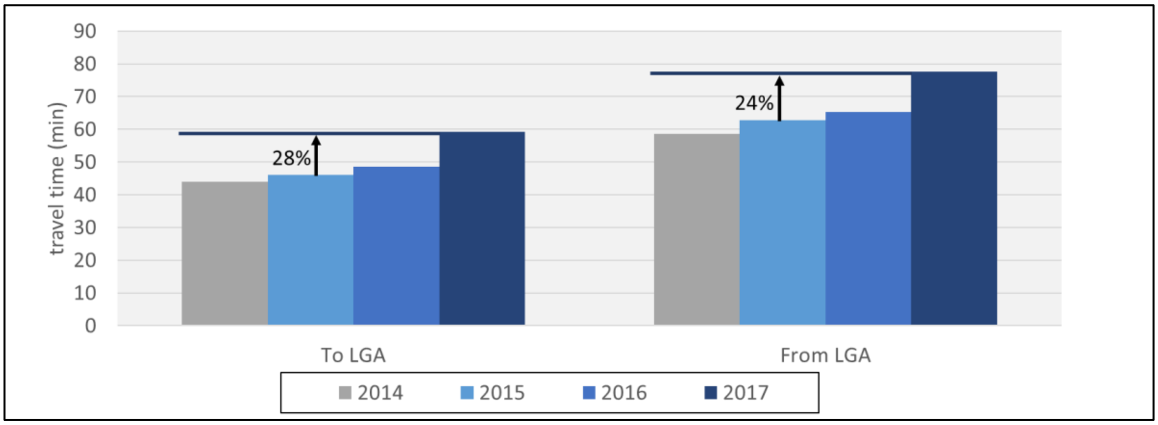
Even when excluding Manhattan congestion, travel times to and from LGA have increased significantly between 2014 and 2017. The Queens-Midtown Tunnel (QMT) is a main gateway between Queens and Midtown en route to LGA via the Long Island Expressway (LIE), Brooklyn-Queens Expressway (BQE), and Grand Central Parkway (GCP). A study based on TRANSCOM data, which focused on trips between LGA and the QMT, found that over the three-year period, 95th percentile travel time increased from 44 to 53 minutes for LGA-bound trips, and from 58 to 84 minutes in the opposite direction (**Figure 11**-**Figure 12**).[20] Overall, as seen in **Figure 10**, 95th

[20] Data source: TRANSCOM.

percentile travel times between the QMT and LGA increased by over 20% between 2014 and 2017.

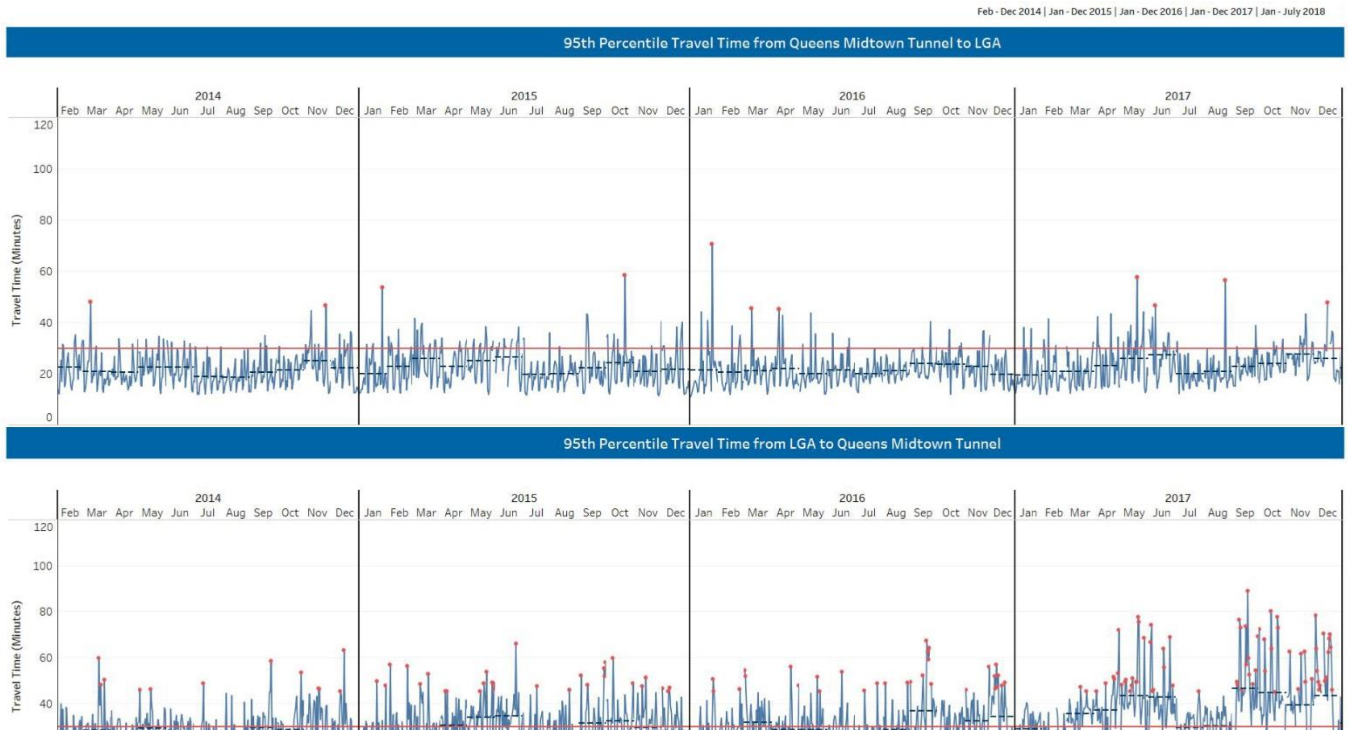
All indicators show that travel times between Midtown Manhattan and LGA are rapidly increasing. More importantly for travelers, the worst travel times are getting longer and more frequent, reducing the reliability and predictability for LGA trips.

Figure 10: 95th Percentile Vehicle Travel Times between Queens-Midtown Tunnel and LGA, 2014-2017.



Data Source: TRANSCOM

Figure 11: Daily Maximum Vehicle Travel Time between Queens Midtown Tunnel and LGA, 2014-2017.



Note: Data cleaned to remove any days during which on-airport traffic conditions led to delays on the off-airport roadway network. Data for following dates was excluded: 08/22/16, 11/10/16, 11/18/16, 12/12/16,12/15/16, 12/16/16, 12/21/16, 01/19/17, 02/10/17, 02/08/17, 04/28/17, 12/20/17

Data Source: TRANSCOM

Comparing travel times by time of day, the biggest decreases in reliability (i.e. increases in frequency of excessive travel times) occurred during the evening peak period (4 PM to 7 PM), as trips from LGA to the QMT had a greater percentage of trips with excessive delays. In 2014, only 8% of trips were in excess of 30 minutes; by 2017, 33% of trips exceeded 30 minutes. In 2014, travel times greater than 45 minutes occurred less than 1% of the time; by 2017, 9.6% of trips exceeded 45 minutes.

In the reverse direction, trips from the QMT to LGA also showed the greatest increases in excessive travel times from 4 PM to 7 PM. Between 2014 and 2017, trips in excess of 30 minutes increased from 8% to 10%; trips exceeding 45 minutes increased from 0.4% to 0.9%. One possible explanation for the disparity between excessive trips to and from LGA could be the locations where travel time data is collected by TRANSCOM, with the reader located at the Manhattan end of the tunnel, resulting in Manhattan-bound travel times including time spent in the QMT queues.

Figure 12: Vehicle Travel Times Statistics for Trips between the Queens Midtown Tunnel and LGA, 2014-2017.

Feb - Dec 2014 | Jan - Dec 2017

Travel Time Statistics for Queens Midtown Tunnel to LGA

	2014	2017
Average (Minutes)	26.60	31.74
95th Percentile (Minutes)	43.89	53.08

	6 AM - 10 AM		10 AM - 4 PM		4 PM - 7 PM		7 PM - 12 AM	
	2014	2017	2014	2017	2014	2017	2014	2017
>= 15 Minutes	45%	30%	31%	41%	71%	70%	13%	26%
>= 30 Minutes	0%	1%	1%	2%	8%	10%	0%	1%
>= 45 Minutes	0.0%	0.1%	0.0%	0.3%	0.4%	0.9%	0.0%	0.1%

Travel Time Statistics for LGA to Queens Midtown Tunnel

	2014	2017
Average (Minutes)	35.43	47.98
95th Percentile (Minutes)	57.97	83.95

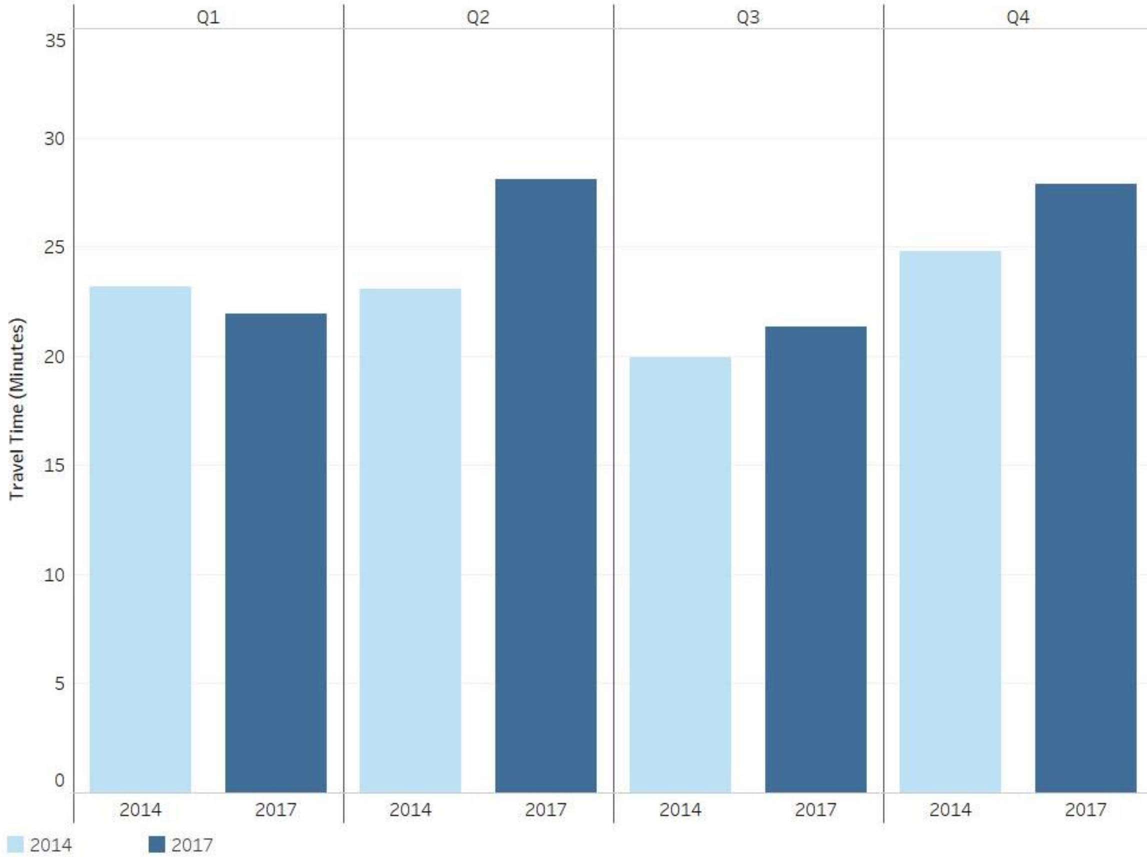
	6 AM - 10 AM		10 AM - 4 PM		4 PM - 7 PM		7 PM - 12 AM	
	2014	2017	2014	2017	2014	2017	2014	2017
>=15 Minutes	59%	66%	44%	63%	59%	74%	10%	31%
>=30 Minutes	14%	29%	8%	22%	8%	33%	1%	9%
>=45 Minutes	1.9%	5.3%	0.6%	6.3%	0.8%	9.6%	0.1%	2.5%

Data source: TRANSCOM

As seen in **Figure 13** and **Figure 14**, a quarterly view of travel times between the QMT and LGA demonstrates the rise in 95th percentile travel times between 2014 and 2017 as all quarters, except for trips to LGA in the first quarter of the year, saw a steep increase of at least 15%. It is worth noting that the first quarter of the year, from January to March, is when traffic is at its lowest volumes, specifically to and from airports, and on the roadway network in general.

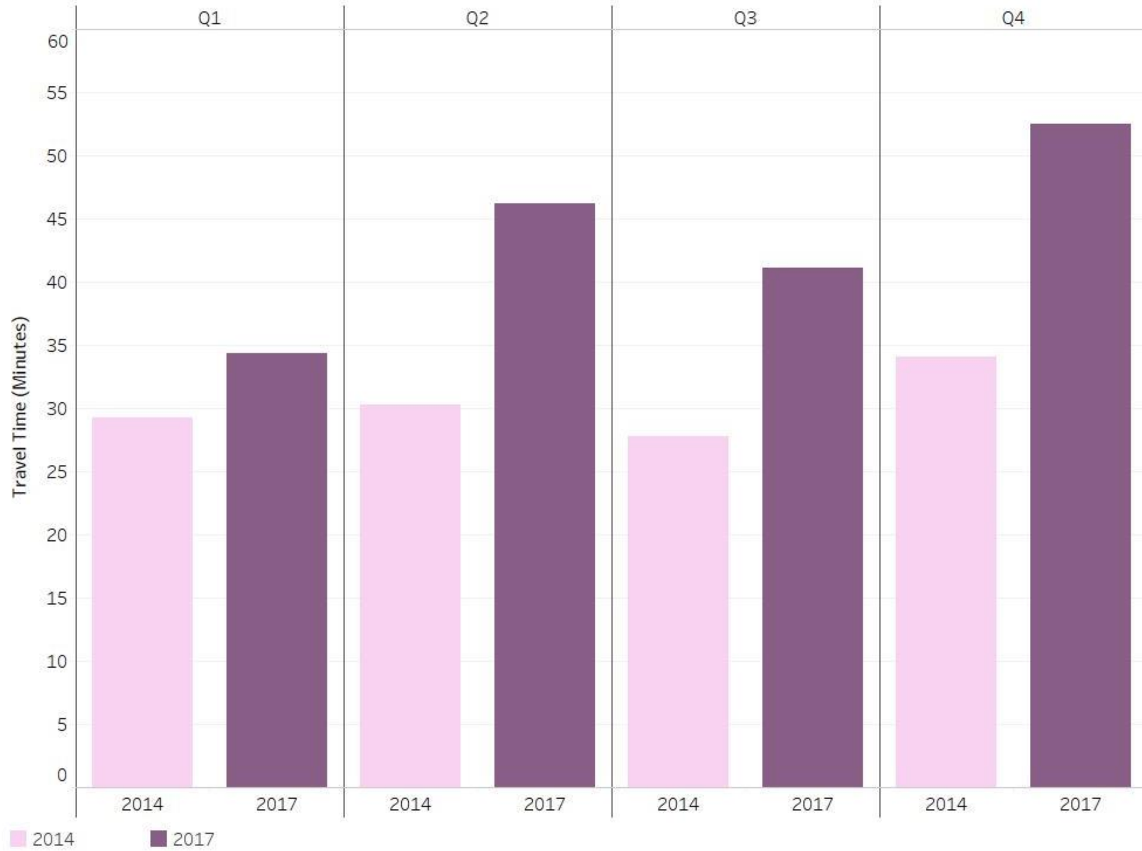
The combination of unpredictability in travel times on Manhattan streets and regional highways has impacted the trip planning of LGA air passengers. If travel speed on New York City roads continues to decrease and congestion continues to increase, the poor reliability of traffic conditions will leave air passengers and airport employees little choice but to add even more time safety margins to their trips to and from the airport.

Figure 13: 95th Percentile Vehicle Travel Times from QMT to LGA (95th Percentile), by Quarter, 2014 and 2017.



Data Source: TRANSCOM

Figure 14: 95th Percentile Vehicle Travel Times from LGA to QMT (95th Percentile), by Quarter, 2014 and 2017.



Data Source: TRANSCOM

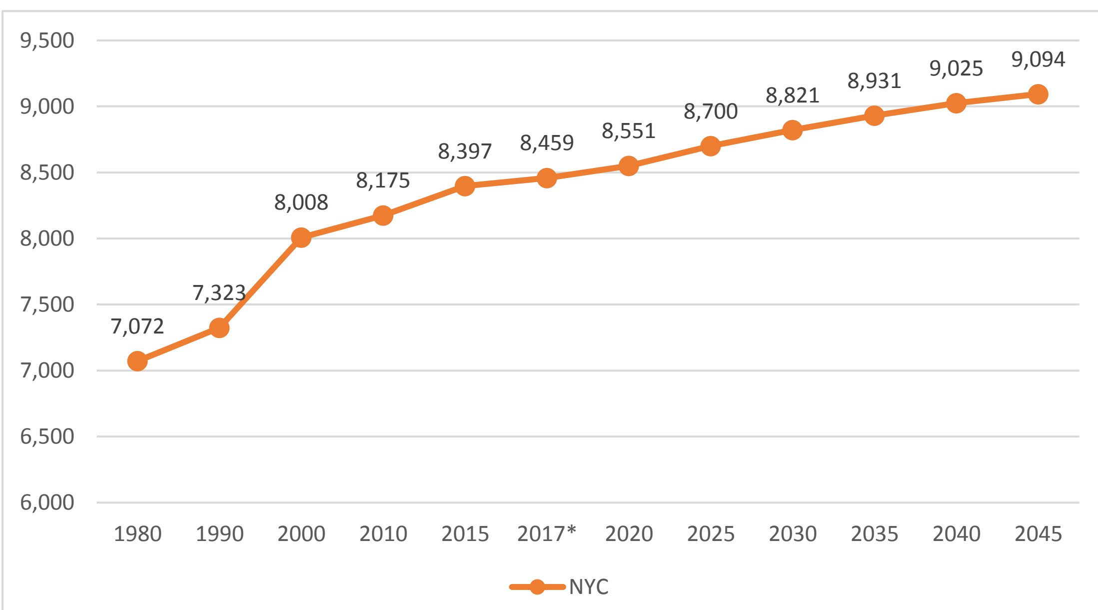
4. Future Trends in New York City

4.1. Population and Employment Trends

Over the past four decades, the New York region has consistently grown in population, jobs, and economic activity. Looking into the decades ahead, projections show the trend is likely to continue. This urban boom means that transportation infrastructure, with no significant capacity changes projected, will experience greater stress, resulting in longer travel times and lower network reliability.

Current projections by the New York Metropolitan Transportation Council (NYMTC) estimate that between 2017 and 2045, the ten-county New York region will grow by 1.3 million people, from 12.7 million to 14 million. Of the added population, 635,000 people are expected to reside in New York City alone, representing an increase in city population of 7.5% (from 8.46 million to 9.1 million, see **Figure 15**). In absolute numbers, Brooklyn is projected to grow the most, with nearly 250,000 more people expected by 2045. Relatively, however, the Bronx is expected to grow the most, adding 12% to its population by 2045. In 2010, the City of New York had projected that the population would increase by 9.5% by 2040, going from 8.24 to 9.02 million residents. As of 2017, this projection seems to be accurate, as the local population is growing at the pace projected by the City.

Figure 15: New York City Population 1980-2045 (in 000s)

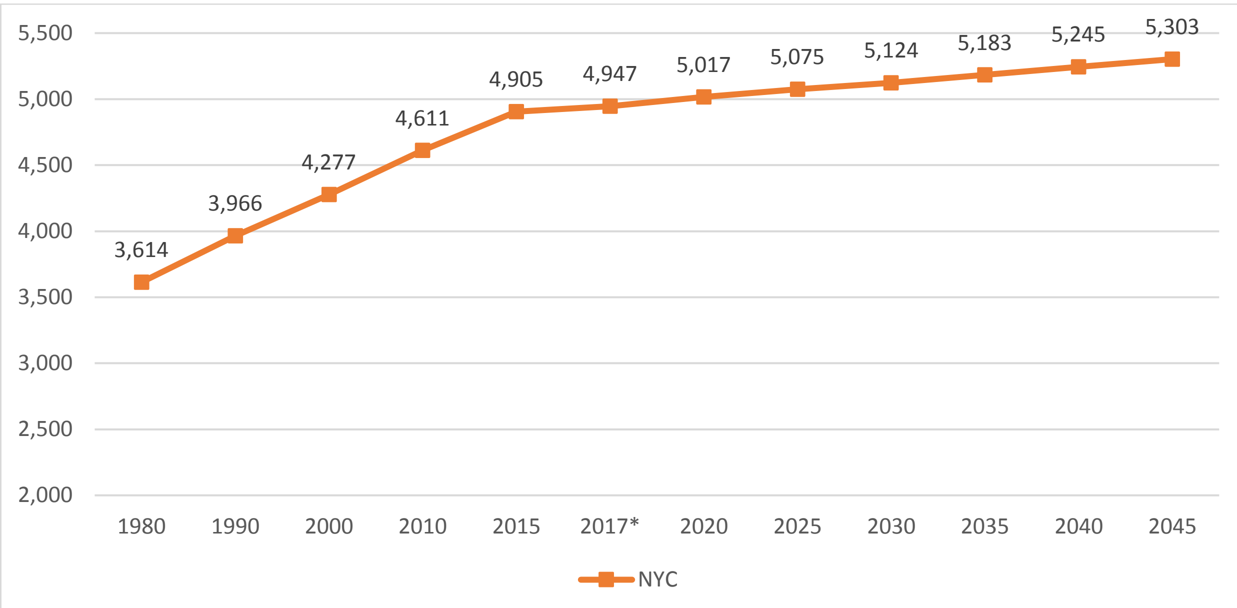


* Interpolated data

Source: NYMTC

Employment projections by NYMTC estimate that jobs in New York City will grow by 7.2% between 2017 and 2045, to approximately 5.3 million (**Figure 16**). The fastest growth rate will happen in the Bronx and Brooklyn, with jobs increasing by 9.5% and 8.5%, respectively. However, in terms of absolute numbers, Manhattan is projected to grow the most by 2045, with 196,000 additional jobs, while Brooklyn's growth projection is for 79,000 additional jobs and for the Bronx it is 40,000 jobs.

Figure 16: New York City Jobs 1980-2045 (in 000s)



*Interpolated data

Source: NYMTC

Among the areas of concentration for the new population of residents and employees will be major developments and districts rezoned for dense residential development, including:

- Greenpoint-Williamsburg
- Hudson Yards
- Sunnyside Yard
- East Midtown
- East New York
- Inwood
- East Harlem

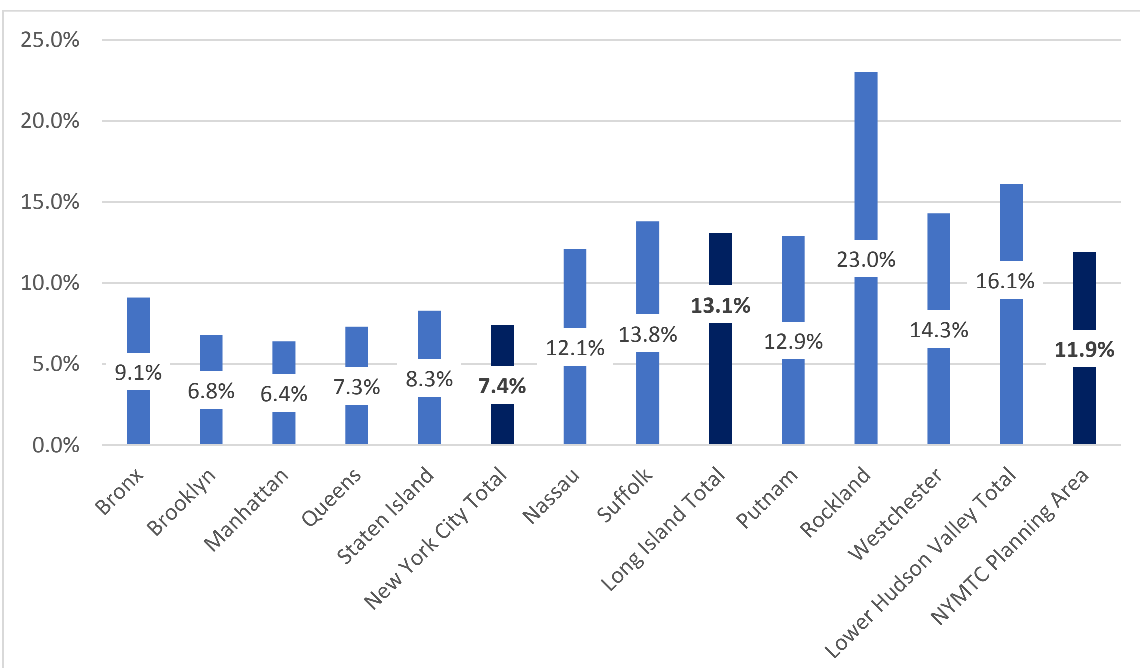
These districts, along with others, can very well shift the center of gravity in the city towards areas where transportation infrastructure may not sufficiently sustain future needs. In these areas, and citywide, growth in both population and jobs is expected to further exacerbate vehicular traffic and tax a roadway system that will see little capacity increases in the foreseeable future. It should be noted that residents and employees of nearly all these developments would use the most traffic-congested corridors considered in this study, including the western portions of the LIE, the GCP, and the northern segment of the BQE, as well as one of the over-capacity East River crossings.

4.2. Projections of Traffic Conditions

An understanding of future road conditions requires an analysis of trends in regional transportation, both those that began several years ago and those that are just beginning. The New York Best Practice Model (BPM) is used by NYMTC for projecting traffic volumes in the coming 20 to 30 years. The BPM is based on data from 2010 and therefore understandably does not capture new technologies that did not yet exist at that time. As discussed below, those technologies - namely app-based TNCs and AVs - measurably impact the way we travel today and likely will travel in the future. Layering shifts in behavior on top of the existing BPM output reveals that Vehicle Miles Traveled (VMT) in New York City are likely to increase significantly by 2045, along with congestion and unpredictability of travel patterns. Consequently, travel times will become longer and accurately planning a trip will become harder.

According to the BPM, VMT in the entire New York region will increase by 11.9% between 2017 and 2045, and by 7.4% in New York City (**Figure 17** and **Figure 18**).

Figure 17: Projected Change in Daily Vehicle Miles Traveled by 2045, the New York Region, by county.



Source: NYMTC

Figure 18: Projected Change in Daily Vehicle Miles Traveled by 2045.

County/ Borough/ Area	2017	2045	Change
Bronx	8,859,309	9,664,710	9.1%
Brooklyn	12,397,124	13,244,903	6.8%
Manhattan	8,804,886	9,368,120	6.4%
Queens	19,658,725	21,084,000	7.3%
Staten Island	5,694,788	6,170,281	8.3%
New York City Total	**55,414,832**	**59,532,014**	**7.4%**
Nassau	29,231,877	32,778,258	12.1%
Suffolk	40,983,209	46,643,771	13.8%
Long Island Total	**70,215,086**	**79,422,029**	**13.1%**
Putnam	3,484,730	3,935,760	12.9%
Rockland	8,275,831	10,180,662	23.0%
Westchester	24,679,613	28,207,148	14.3%
Lower Hudson Valley Total	**36,440,174**	**42,323,570**	**16.1%**
NYMTC Planning Area	**162,070,092**	**181,277,613**	**11.9%**

Source: NYMTC

A review of transportation infrastructure projects planned for the region in the coming decades shows that roadway capacity will most likely not grow to accommodate the higher VMT expected by 2045. In fact, major road reconstruction planned for New York City is intended to maintain current capacity and is more likely to temporarily reduce capacity on roads leading to and from LGA and other destinations in the region. These projects include maintenance and rehabilitation (but not expansion) work on the BQE, LIE, Triborough Bridge and Whitestone Bridge, among others.

According to the Bureau of Public Roads Volume-Delay Function used in the BPM, an increase of 10% in volume on an already congested road could result in a 10% to 50% increase in travel times. The actual increase of travel time within this range depends on the type of the road, number of lanes, time of day, and the existing traffic volumes. If the existing traffic volume is relatively low, then an increase in traffic volume would roughly result in a linear (or even lower than linear) increase in travel times. However, when traffic volumes reach a critical capacity level for the congested direction for all major roads, a small increase in volume can result in a highly non-linear effect on traffic.

Since the regional roadway network is already congested, and since capacity will not increase, the effects of VMT growth on travel conditions are expected to be critical. This is evident by the projection that Vehicle Hours Traveled (VHT) will rise by approximately twice the rate of VMT, reflecting the additional time travelers will spend on the road for every trip **(Figure 19**). By 2045, vehicles are expected to spend a total of 580,500 additional hours on New York City's roads, an increase of 15% from 2017. In Queens, where LGA is located, VHT is projected to increase by 15% as well (**Figure 20**), experiencing the highest nominal addition of all boroughs. Since these projections are made for full, 24-hour days, and since little change in VMT and VHT would be likely to occur in the overnight hours, it is safe to assume that the projected change will disproportionately occur during daytime hours, specifically during peak-periods.

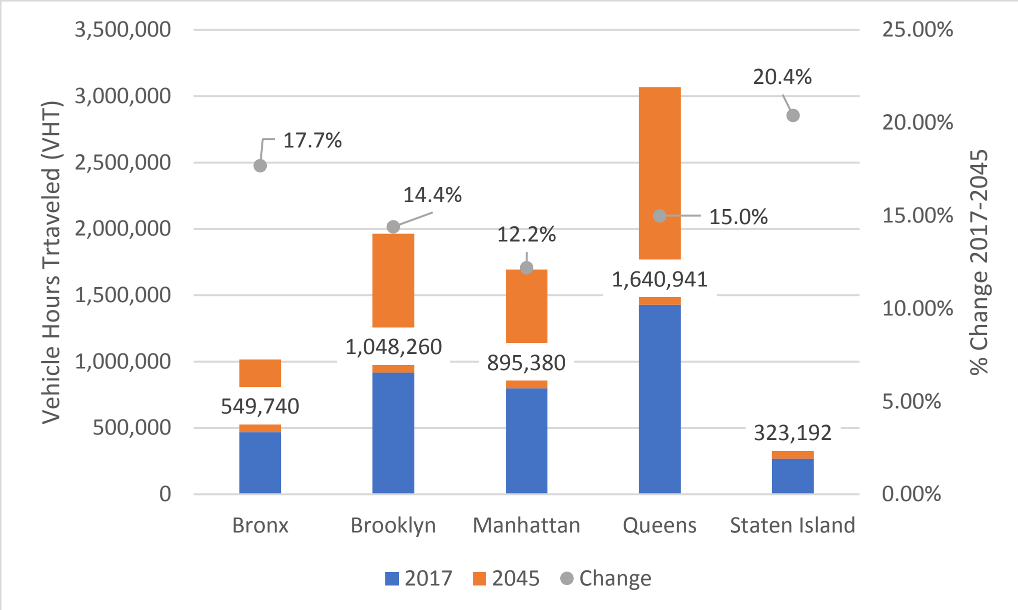
Figure 19: Travel Forecasts by Sub-Region.

	2017	2045		Percent Change 2017 to 2045
Total Daily Trips	17.01 million	18.38 million	NYC	8.0%
	6.96 million	7.85 million	LI	12.8%
	3.06 million	3.52 million	LHV	14.9%
Daily Auto Trips	7.62 million	8.00 million	NYC	5.0%
	6.69 million	7.51 million	LI	12.3%
	2.72 million	3.08 million	LHV	13.4%
Daily Transit Trips	9.39 million	10.37 million	NYC	10.5%
	0.27 million	0.34 million	LI	27.0%
	0.34 million	0.43 million	LHV	26.8%
Daily Vehicle Miles of Travel	55.41 million	59.53 million	NYC	7.4%
	70.22 million	79.42 million	LI	13.1%
	36.44 million	42.32 million	LHV	16.1%
Daily Vehicle Hours of Travel	3.88 million	4.46 million	NYC	15.0%
	2.69 million	3.39 million	LI	26.0%
	1.07 million	1.33 million	LHV	24.0%

Source: NYMTC

Note: Subregional trips include those that begin in a subregion and end anywhere (including within the same subregion), plus those that originate outside of a subregion and end in that subregion.

Figure 20: Daily Vehicles Hours Traveled by Borough.



Data Source: NYMTC

Figure 21 presents the change in auto trips between Manhattan and Queens and within both boroughs between 2017 and 2045. During the 28-year period in discussion, auto trips between Manhattan and Queens are projected to increase by over 11%, increasing the burden on the already congested bridges and tunnels that connect the two boroughs.

Figure 21: Daily Auto Trip Origins and Destinations.

	2017	2045	Percent Change
Manhattan to Manhattan	980,710	999,300	**1.9%**
Queens to Manhattan	151,859	169,173	**11.4%**
Manhattan to Queens	150,809	167,942	**11.4%**
Queens to Queens	1,419,161	1,438,906	**1.4%**

Source: NYMTC

While NYMTC's projections are the official forecasts for the region, an analysis of existing traffic conditions for trips to and from LGA implies that the BPM may be too conservative; that is, future VHT will probably be higher and congestion will likely be worse than projected. Comparing the average travel time predicted by the BPM for 2015 with actual taxi GPS data shows that travel time on almost all routes to and from LGA are, in reality, longer by at least 10% than the BPM estimated. In some cases, the discrepancy reaches 20% or 30%, with observed travel times being significantly slower than what BPM estimated (**Figure 22**).

Figure 22: Comparison of Average (observed) Taxi Travel Times to Projected BPM Times for Trips to and from LGA, 2017.

Time-of-day period	Travel time type	Trip origin/destination	Average ratio of taxi GPS time to NYBPM time
AM Peak (6am-10am) & PM Peak (4pm-8pm)	Congested Time	NY City & Long Island (LI)	109%
		NY Hudson Valley & CT	97%
		NJ	108%
	Free flow time	NY City & LI	138%
		NY & CT	116%
		NJ	139%
Midday (10am-4pm)	Congested Time	NY City & LI	118%
		NY & CT	104%
		NJ	120%
	Free flow time	NY City & LI	127%
		NY & CT	111%
		NJ	146%
Night (8pm-6am)	Congested Time	NY City & LI	125%
		NY & CT	117%
		NJ	131%
	Free flow time	NY City & LI	112%
		NY & CT	104%
		NJ	115%

Source: Port Authority of New York and New Jersey

Figure 23 displays projections yielded from a model that adjusts the BPM travel times based on observed 2015 taxi GPS data (referred to in this report as the “Adjusted Model”). The Adjusted Model was applied to forecast changes in average and 95th percentile travel times of LGA trips in 2045, as part of the 2018 LGA ridership forecast analysis. As discussed in **Section 1**, 95th percentile travel times are critical in understanding the impact that vulnerability to congestion has on airport passengers.

Figure 23: Examples of Travel Time Prediction for 2045 Based on the Adjusted Model (with LGA terminal times).

Reference location	Direction	Daypart	Average travel time (minutes)			95th percentile travel time (minutes)		
			2017	2045	% Increase	2017	2045	% Increase
Grand Central	From LGA	AM peak	44	56	26%	62	104	68%
	To LGA	PM peak	40	44	9%	61	75	23%
Penn Station	From LGA	AM peak	50	56	11%	70	87	26%
	To LGA	PM peak	48	54	11%	74	92	25%
Financial District	From LGA	AM peak	49	53	8%	68	81	19%
	To LGA	PM peak	51	55	8%	76	91	20%
Union Square	From LGA	AM peak	47	50	6%	69	79	15%
	To LGA	PM peak	46	50	8%	76	90	19%
Court St/Boro Hall, Brooklyn	From LGA	AM peak	47	52	12%	66	84	27%
	To LGA	PM peak	43	49	13%	64	84	32%
Long Island City, Queens	From LGA	AM peak	30	34	14%	42	56	33%
	To LGA	PM peak	31	37	21%	47	71	52%

Source: Port Authority of New York and New Jersey

Average travel time does not need to grow by much for predictability to worsen significantly. For example, while the average 2045 AM-peak vehicle travel time from LGA to Grand Central Terminal is projected to grow by 26%, the 95th percentile time is projected to grow by 68%. Although the average trip in 2045 is projected to take 56 minutes, one out of twenty trips is projected to take 104 minutes, an 85.7% difference.

It should be noted that the models and analyses in this report have not assumed any major changes to the transportation infrastructure, apart from those included in the BPM, such as East Side Access and Second Avenue Subway Phases 2-4. Similarly, this study does not include any future changes in government policies or regulations that may affect travel behavior.

5. Impact of Emerging Transportation Technologies

5.1. Growth of Transportation Network Companies (TNCs)

First introduced onto New York City streets in 2012, TNCs provide on-demand and pre-arranged private ride services by connecting potential passengers to drivers through a software platform. In 2018, TNC annual ridership is projected to reach 4.2 billion nationwide, representing a 121% increase from 2016 (**Figure 24**). While overall growth in FHV ridership (which includes TNCs and other car services) has been driven by TNCs, traditional taxi ridership has sharply declined since TNCs started gaining popularity. As seen on **Figure 24**, between 2016 and 2018, annual taxi ridership in the United States decreased by 25%, reaching a nearly-30 year low (**Figure 25**).

In New York City, TNC trips increased by almost 400% between 2015 and 2017, reaching nearly 160 million dispatches in 2017.[21] As reliance on app-based technology deepens, TNC trips are expected to grow even further.

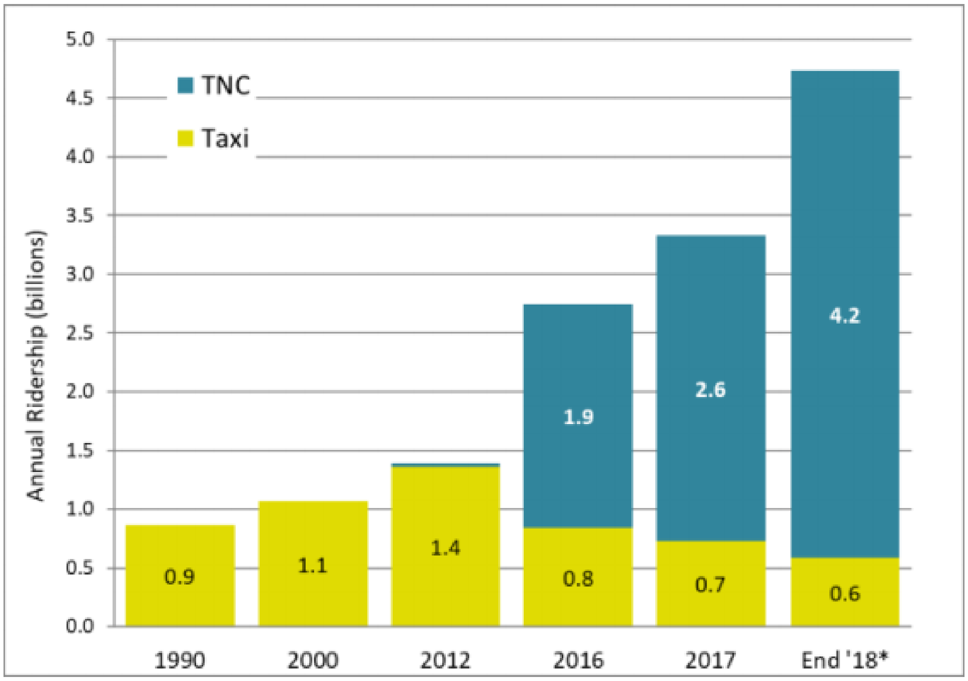
Figure 24: United States Annual Ridership for Taxis and TNCs (billions).

	2016	2017	2018	Average Annual Change	Change 2016-2018
Taxi	0.8	0.7	0.6	-13.4%	-25.0%
TNC	1.9	2.6	4.2	49.2%	121.1%

Source: Schaller, The New Automobility, 2018

[21] James A. Parrott and Michael Reich, "An Earnings Standard for New York City's App-Based Drivers: Economic Analysis and Policy Assessment," July 2018, http://irle.berkeley.edu/an-earnings-standard-for-new-york-citys-app-based-drivers/.

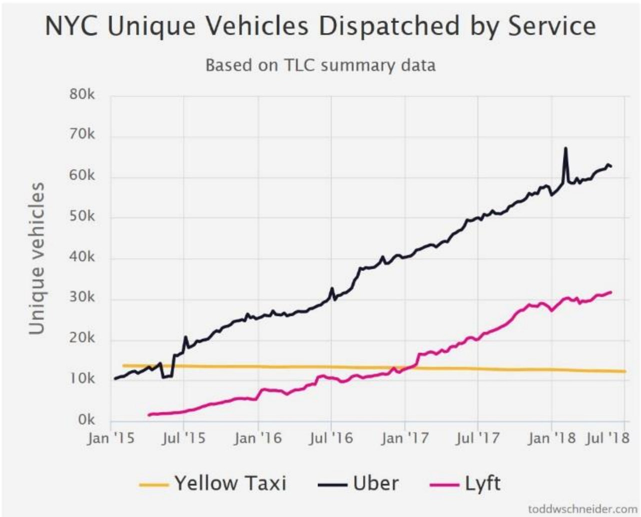
Figure 25: TNC and Taxi Ridership in the United States, 1990-2017 (Annual Ridership, in Billions).



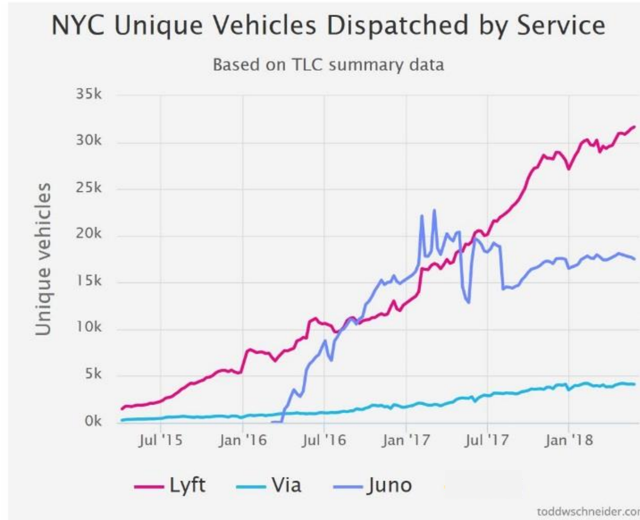
Source: Schaller, The New Automobility, 2018

In New York City, between 2015 and 2018, weekly unique dispatches of TNC vehicles steadily increased, as the use of app-based ride services has become wide-spread. For example, in May 2017, nearly 87,500 registered TNC vehicles were dispatched throughout New York City in one week; in May 2018, the numbers reached 116,000, an increase of 32.6%.

Figure 26: Weekly Unique Dispatched Vehicles in New York City – January 2015 to May 2018.



Taxis, Uber and Lyft

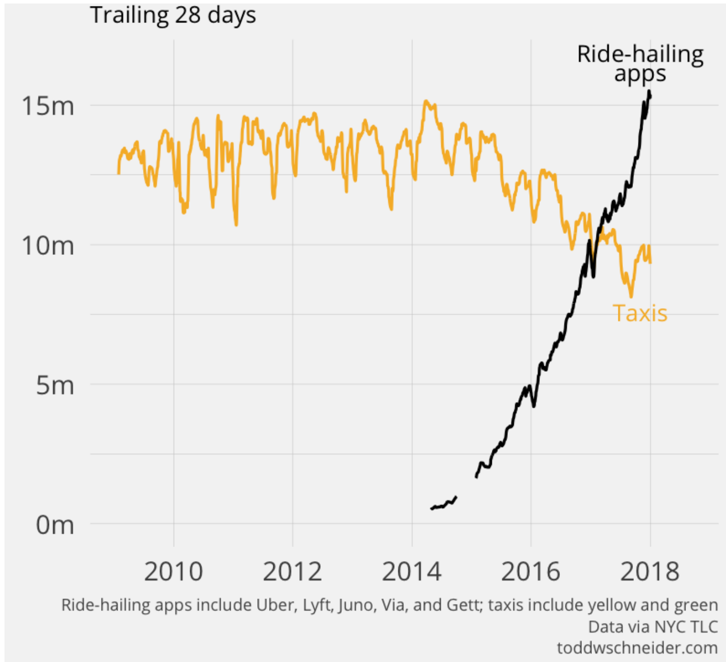


All TNCs except for Uber

Source: Todd Schneider, processed from TLC data

In February 2017, TNC ridership in New York City passed that of yellow and green taxis for the first time. Since then, app-based ride services continued to grow and in December of the same year they picked up 65% more riders than Yellow and Green taxis combined (**Figure 27**). Even within Manhattan, the borough disproportionately served by taxis and best served by public transportation, ride-hailing apps nearly equal taxis in ridership.

Figure 27: New York City Monthly Taxi and TNC Pick Ups.

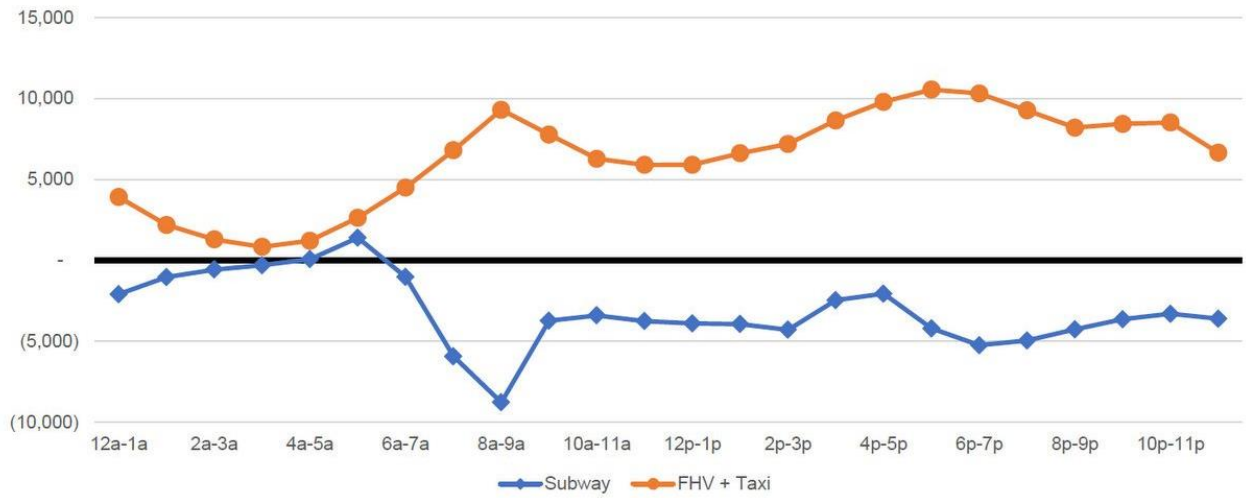


Source: Todd Schneider
Taxi data is for both yellow and green taxis

The growth in TNC ridership between 2015 and 2017 exceeded the decline in taxi and non-TNC FHV ridership.[22] From a traffic point of view, TNCs did not replace taxi trips on a one-to-one basis; instead they have added motor vehicles to the roadway network. It is likely that many TNC trips were either diverted from public transportation or generated from trips that otherwise would not have taken place. And indeed, along with taxi ridership, public transit ridership in New York City has been declining since 2015. Following a drop in ridership in 2009, and a general trend of recovery afterwards, New York City subway ridership was 1.76 billion in 2015. By 2017, ridership declined by 2% to below 1.73 billion, a decrease of 35.2 million rides. In a steeper decline, New York City bus ridership reached its peak in 2013, with 677.5 million rides per year, but then dropped by 11% (to 602.6 million rides) in 2017.[23] While a correlation between TNC's increase in ridership and the decrease of transit ridership does not necessarily mean that one is causing the other, **Figure 28** shows that increases in FHV and taxi ridership on an hourly basis appear to correlate to drops in subway ridership.

[22] Parrott and Reich.
[23] Metropolitan Transit Authority (MTA), 2018

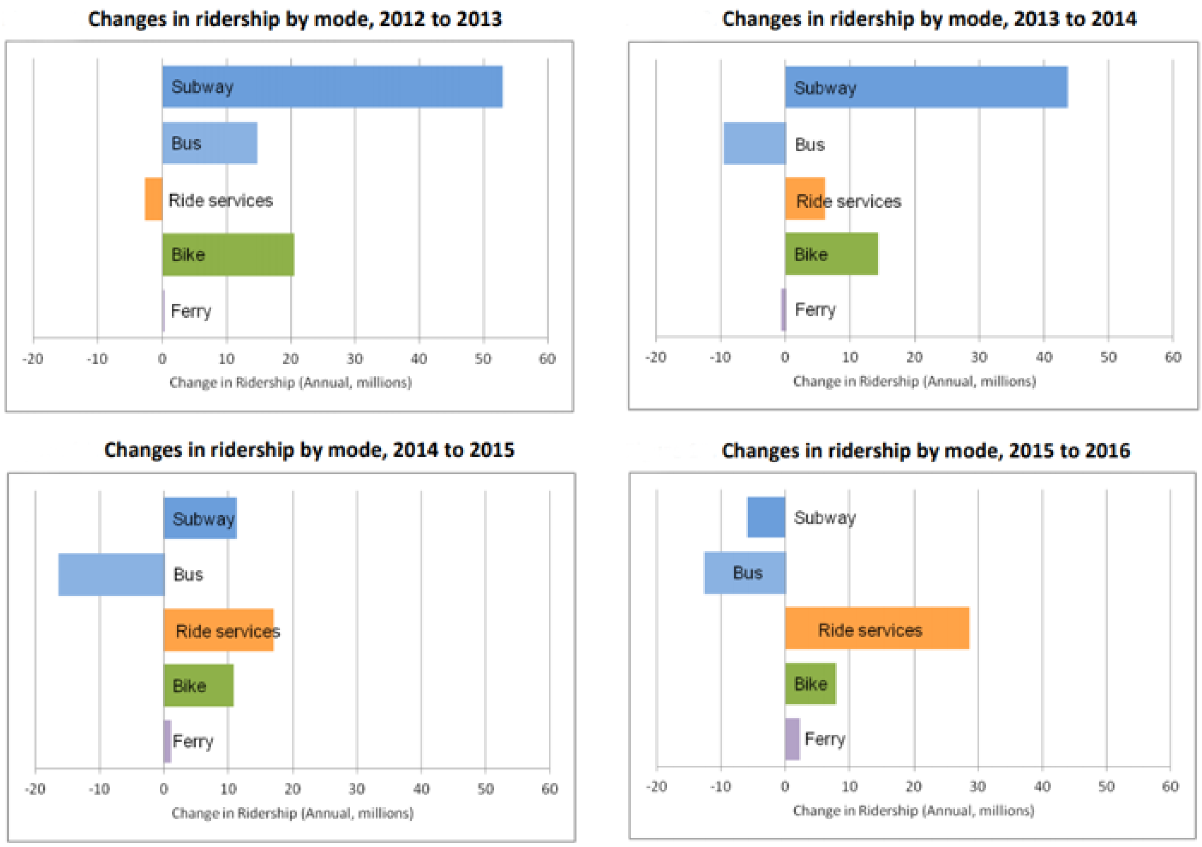
Figure 28: Changes in Subway and FHV/Taxi Weekday Ridership, 2016-2017.



Source: Schaller, 2018

Additionally, as depicted in **Figure 29**, starting in 2012, when TNCs were first introduced in New York City, the increase in subway ridership started to slow down until its decline in 2016. In a similar fashion, bus ridership started falling in 2014, following an increase between 2012 and 2013.

Figure 29: Shift in Ridership by Mode in NYC, 2012-2016.



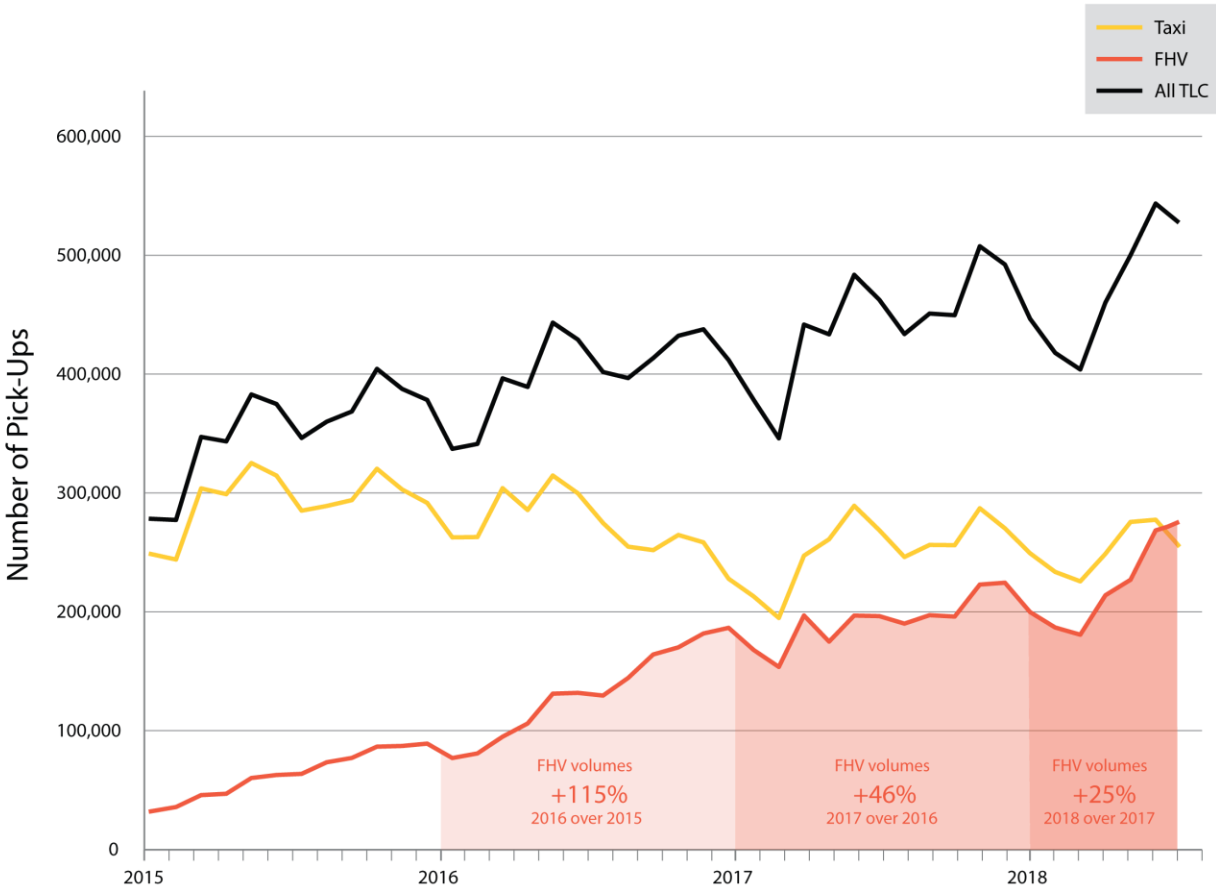
Source: Schaller, 2017

Focusing on LGA, data shows that air passengers also, increasingly, rely on TNCs. In 2016, annual FHV pick-ups (of which TNCs are the lion's share) grew by 115% compared to 2015. In 2017, they increased by 46%, compared to 2016 (see **Figure 30**). In absolute numbers, annual FHV pick-ups went from 737,000 in 2015, to 2,307,800 in 2017.

This translates to a daily increase of 2,152 pick-ups over the two-year period, or 3,000 more pick-ups on peak airport days. In May 2018, the number of pick-ups by non-taxi FHVs surpassed that of taxis and currently represents 58% of all FHV and taxi pick-ups at LGA.[24]

[24] Data is for all non-taxi FHV.

Figure 30: Monthly Taxi and For Hire Vehicle Pick Ups – LaGuardia Airport, 2015-2018.



Data Source: TLC open Data

It should be noted that in August 2018, the New York City Council placed a one-year cap on TNC license issuance, except for wheel-chair accessible vehicles; therefore, by the summer of 2019, the number of TNC vehicles will not increase dramatically (anecdotally, thousands of TNC applications were submitted in the days before the moratorium went into effect on August 14, 2018). By August 14, 2019, the City is to prepare a report with recommendations on the TNC and taxi industry.

5.1.1. **Changes in Total VMT Following the Rise in Popularity of TNCs**

TNCs often maintain that their services are filling in the gaps of existing transportation systems both temporally and geographically. While this characterization is true to some extent, TNCs are also competing for riders with the existing transit system to a great extent. Furthermore, the VMT efficiency of app-based ride hailing vehicles (that is the ratio between travel time spent with passengers and travel time spent without passengers) seems to be lower than that of private vehicles and taxis. The result of these two details is a contribution to VMT and VHT that is disproportionate to the share TNCs represent of all vehicles, a contribution that particularly effects areas of high demand for TNCs, such as LGA.

Surveys conducted nation-wide among current TNC users indicate that if app-based ride hailing services were not available, only about 20% of surveyed passengers would have used a taxi and 20% would have used a private vehicle. The rest of the passengers, or about 60%, would have taken transit or bikes, or would have walked.[25] In New York City, a 2018 New York City Department of Transportation (NYCDOT) survey found that 50% of respondents would have used public transportation if they had to replace their TNC option, and 13% would have walked. Only 2% said they would not have made the trip at all, while 43% said they would have taken a taxi and 12% would have replaced the ride-hailing trip with a private vehicle.[26] Since respondents to the survey were given the option to select multiple modes, answers do not necessarily represent an accurate distribution of TNC trips by mode they were diverted from. Normalizing the results to account for respondents' multiple answers shows that 40.5% of TNC riders would have taken public transportation had TNCs not been an option, 35% would have taken a taxi or another car service, and 13% would have walked or biked (**Figure 31)**.

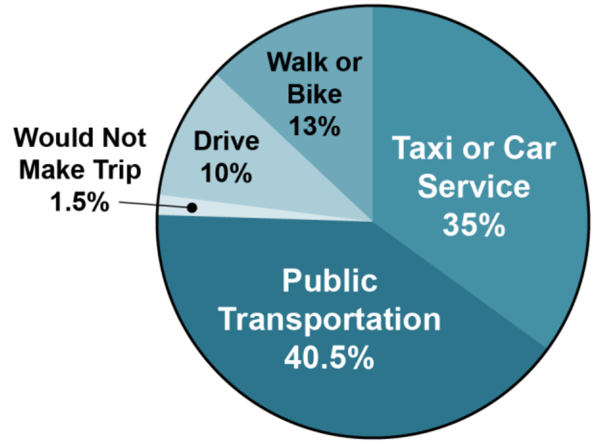
[25] Bruce Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities," 2018.
[26] The question asked by NYCDOT was: "how would you make this trip if not by ride-hail?" Respondents were given the option to select multiple modes. New York City Department of Transportation, "Mobility Report."

Figure 31: Alternative Travel Mode of Travel if TNCs Were Not Available

Respondents' Answers (multiple choices allowed)

50% Public Transportation
43% Taxi or Car Service
13% Walk
12% Drive (personal vehicle)
3% Bike
2% Would Not Make Trip

Percentages normalized to equal 100%



Data Source: NYCDOT Mobility Report 2018

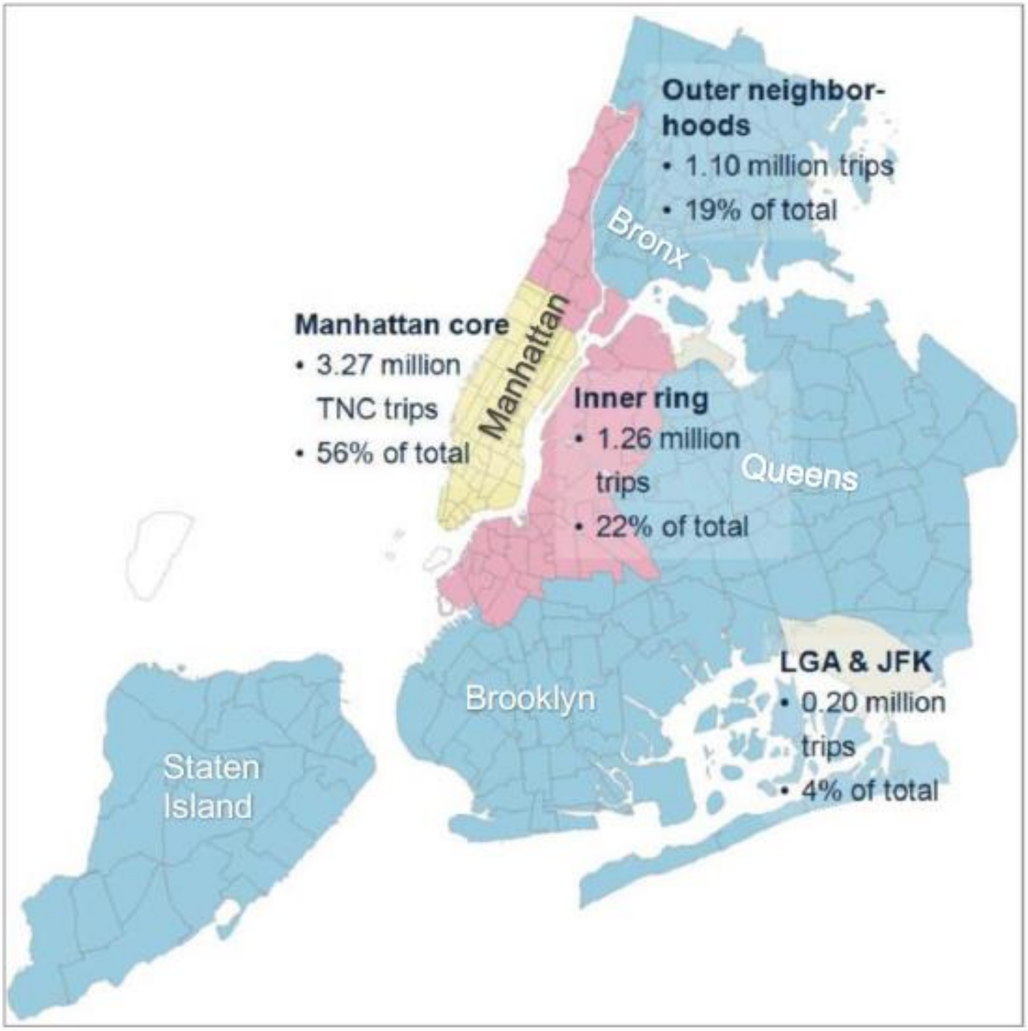
When TNC services first emerged, many transportation experts hoped they would address the first and last mile problem of connecting people to rail or subway stations that are too far for them to reach by foot. Solving this problem has been identified as a key to reducing car usage. Instead, the 2018 NYCDOT survey found that in only 0.4% of transit trips were FHVs used to connect to a station, and in only 0.9% were FHVs used to connect from a station to a final destination.[27]

Rather than serving communities with lower-quality transit service ("Transit Deserts"), TNCs are most popular where transit service, especially high capacity subway, is abundant (**Figure 32**). Not coincidentally, these are communities where traffic is already congested. These communities are also along roads such as the BQE, which air travelers are likely to use for trips between LGA and Manhattan.

Since transit is a much more efficient mode of transportation than private or shared vehicles, saving space on the road by carrying up to 40 times more people per hour, the shifting of people away from transit to ride-hailing vehicles means more vehicles on the road and more VMT are used to move the same number of people. For LGA air passengers, this shift means more vehicles will be using the roadway network leading to or from the airport.

[27] New York City Department of Transportation.

Figure 32: Share of TNC Trips by New York City Area.



Source: Schaller, 2017

Figure 33 displays the average mileage TNCs drive empty for every mile they drive with a passenger; TNCs produce more VMT than private vehicles because they must drive with only the driver on their way to pick-up passengers. Generally, for every mile driven by a private vehicle, a TNC drives 1.6 miles.[28]

While the number of TNC trips between 8 AM and 7 PM in Manhattan's CBD increased by 17% between 2013 and 2017, ride-hailing drivers had traveled 33% more vehicle miles and spent 61% more vehicle hours on the roads (**Figure 34)**.[29]

[28] Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities."
[29] Bruce Schaller, "Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City," 2017.

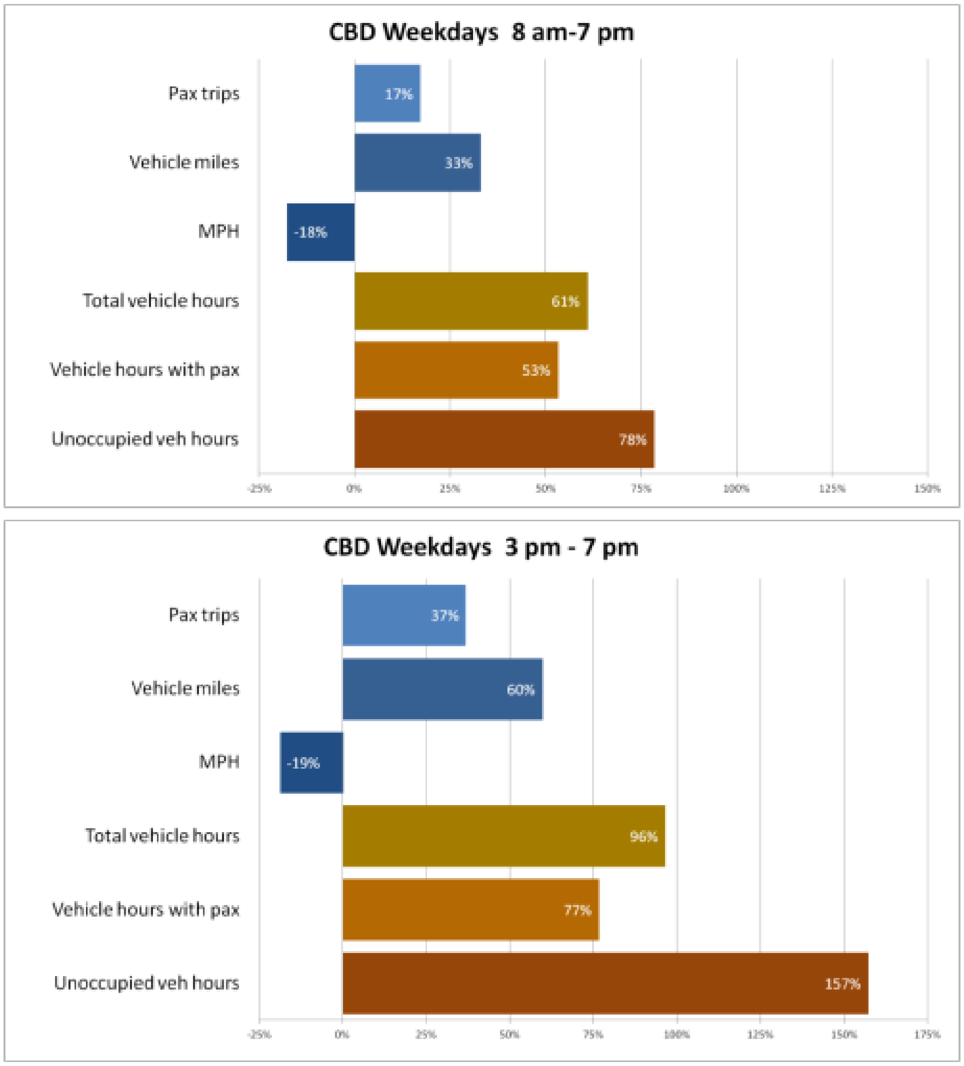
On the already burdened network of New York City, this pattern of higher VMT can have great impact on travel time and travel speed. Instead of shifting to more efficient transportation modes, the city is sliding in the other direction, consuming the most valuable resources it has to offer: road space and people's time.

Figure 33: Passenger Miles and Total Miles for TNC Trips.

	Miles Between Trips			Passenger Trip	Total Miles per Trip	% Miles with Passengers
	Waiting	Drive to Pick-Up	Total			
New York City	2.8	0.7	3.5	5.1	8.6	59%
Chicago	2.5	0.7	3.2	4.7	7.9	59%
San Francisco	1.4	0.6	2	4.1	6.1	67%
Denver Area	1.5	1.4	2.9	7	9.9	71%
Average	2.1	0.9	3	5.2	8.2	63%

Source: Schaller, 2018

Figure 34: Change in Trips, Vehicle Miles, Speeds and Vehicles in Manhattan CBD, 2013 to 2017, Selected Time Periods.



Source: Schaller, 2018

5.1.2. Changes in travel times following the rise in popularity of TNCs, including past trends and future projections

TNCs have grown at an astounding rate in New York City. While there were no TNCs in 2011, by 2017 more people were using TNCs than taxis (**Figure 35**). A number of studies have been conducted nationally, internationally, and locally regarding the effect TNCs have on VMT and travel, and in just about every study TNCs were found to be adding to VMT.[30]

A study on New York City, carried out by former NYCDOT official Bruce Schaller, examined TNCs in various scenarios of vehicle ownership, modal shifts from transit, and ride sharing. In all future scenarios examined, Schaller found that TNC growth will add VMT to the roadway network. This addition will be on top of the VMT increase projected by the BPM and the Adjusted Model discussed in **Section 4.2**, since both do not account for the regional modal shift to TNCs taking place after 2010. Moreover, due to the congested nature of the system, the addition of VMT induced by TNCs will likely be high enough to significantly impact VHT, average travel time, and reliability of trip planning. It is therefore likely that by 2045, 95th percentile AM-peak trips from LGA to Grand Central, for instance, would take more than the 104 minutes that the Adjusted Model predicts they would, and that the average trip time would be longer than 56 minutes.

As seen in **Section 4.2**, due the overburdened roadway network connecting LGA to other destinations, VMT increases in BPM and the Adjusted Model projections already lead to exponential growth in VHT and 95th percentile travel time. This scenario is more likely to materialize now, with the expansion of TNCs and their popularity among LGA travelers.

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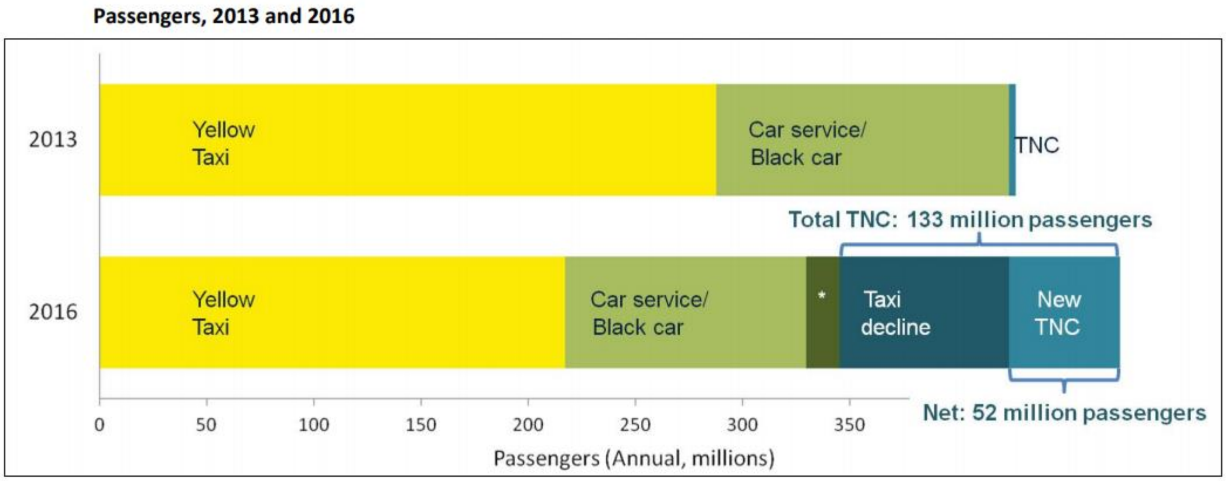
[30] Alejandro Henao, *Impacts of Ridesourcing-Lyft and Uber-on Transportation Including VMT, Mode Replacement, Parking, and Travel Behavior* (University of Colorado at Denver, 2017); Alejandro Tirachini and Andres Gomez-Lobo, *Does Ridesourcing Increase or Decrease Vehicle Kilometers Traveled (VKT)? A Simulation Approach for the Case of Santiago, Chile*, 2017; Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities"; Bruce Schaller, "Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City," 2017; "Taxi, Uber, and Lyft Usage in New York City - Todd W. Schneider," accessed September 6, 2018.

Figure 35: Shift in Passengers to TNCs in New York City, 2013 to 2016.



* Trip requests made through TNC apps and dispatched to drivers affiliated with black car and car service bases.

Source: Schaller (based on TLC data)

While accurately projecting TNC ridership in 2045 is challenging, forecasts suggest that it will increase in terms of absolute numbers, along with the industry's share in total trips. Forgoing car ownership and using TNC rides is already economically viable for many people, and per-ride costs are likely to drop further once these cars become autonomous and revenue no longer needs to be shared with a drive. Therefore, it is expected that the share of people who would transition to app-based ride services will continue to grow in the future.

In his 2018 report, Schaller estimates the excessive VMT induced by TNCs in several different scenarios, presented in **Figure 37** and summarized in **Figure 38**. In the high VMT-induction scenario, each TNC trip produces on average 160% more VMT compared to the same trip made without TNCs. This scenario assumes that 60% of those not taking an app-based ride would have taken public transportation, walked, biked, or not made the trip at all; that 20% would have taken a taxi; and that 20% would have driven themselves. In addition, it assumes that 20% of all TNC rides are shared, which is similar to the rate observed today. If the percentage of shared rides decreases or the percentage of users coming from transit increases, the addition of VMT could be even greater than 160%.

According to this scenario, if TNCs constitute 10% of all trips, VMT in the area studied would increase by 16% (i.e.one-tenth of 160%). At 30% TNC mode split, VMT would jump by 48%, and at 50%, the VMT increase will reach 80% (**Figure 36)**.

Figure 36: Increase in Total VMT by TNC Market-Penetration Scenario.

Scenario	VMT Increase per Trip	TNC Mode Share		
		10.0%	30.0%	50.0%
		Total VMT Increase (%)		
Low-end	41.0%	4.1%	12.3%	20.5%
High-end	160.0%	16.0%	48.0%	80.0%

Data Source: Schaller, 2018

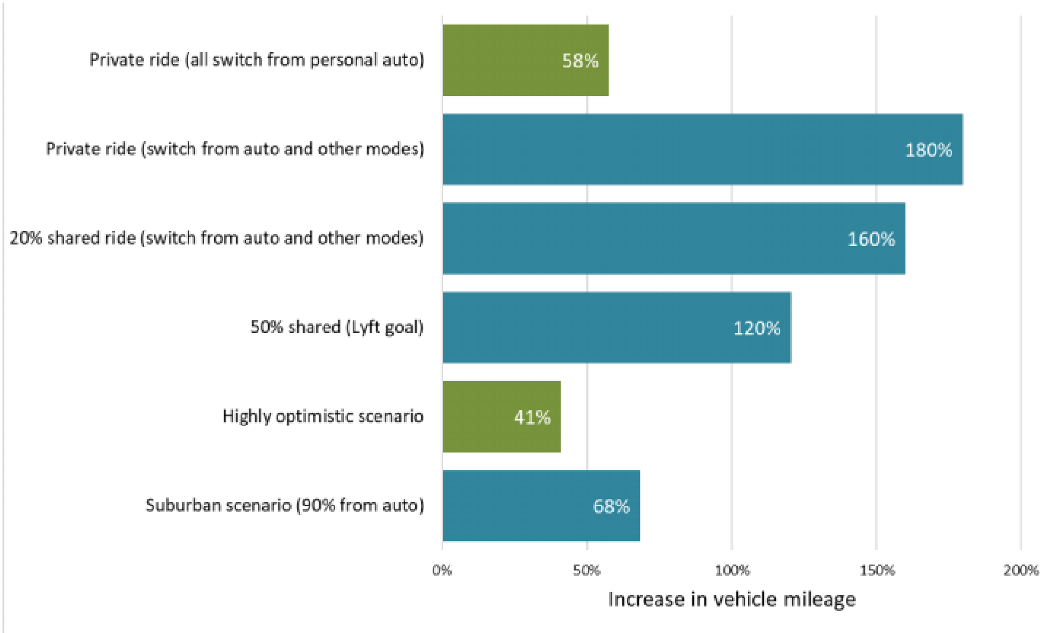
In the low VMT-induction scenario, shared rides will account for 75% of all TNC trips, and mode share of alternative modes taken if TNCs were not an option remains the same as in the high-end scenario. Despite the high rate of shared rides, VMT induced by TNCs would still be significant in the low-end scenario, with 41% more traveled miles produced by each TNC trip compared to the same trip made without a TNC service. This scenario assumes that in 38% of the trips TNC vehicles drive three or more passengers, as opposed to today's 2% rate. At this low VMT-induction scenario, a 10% TNC mode share yields a 4.1% increase in VMT. A 30% TNC share would induce 12.3% excessive VMT and a 50% TNC mode share would induce 20.5% additional VMT.

Figure 37: Projected Change in Overall Mileage from TNC Private Ride and Shared Ride Trips.

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

Source: Schaller, 2018

Figure 38: Summary of Change in overall Mileage from TNC Private and Shared Ride Trips.



Source: Schaller, 2018

While NYMTC projects growth of 7.4% in VMT and 15% in VHT, the introduction of TNCs into New York City's transportation system will likely lead to higher than projected growth rates. Since the ratio of VHT to VMT is already at 2 to 1, it seems that the excess VMT that TNC rides produce will have a critical impact on VHT, exponentially adding time to traveler's trips and negatively impacting the predictability of traffic conditions.

Depending on the policy adopted by New York City and State, and based on the scenarios discussed above, the additional VMT induced by these rides could be as low as 41% or as high as 160% per trip. Due to the already congested nature of roads in New York City, all additional VMT will disproportionately affect VHT. This additional VHT will make trip lengths more unpredictable.

Travelers to and from LGA will probably be among the groups impacted the most from the increase in popularity of ride-hailing services. Already, LGA air passengers use TNCs more than taxis, and the growth in TNC usage is expected to continue. In addition, TNC usage along the most common routes to and from LGA is likely to grow more than the city-wide average. The neighborhoods adjacent to the QMT, Ed Koch-Queensboro Bridge, BQE, LIE, GCP and RFK Bridge are growing and are projected to continue to grow rapidly. These areas are disproportionately attracting educated millennials - precisely the demographic that uses TNCs the most.

In an already congested network, any increase in VMT can have significant effects on travel time. Growth in TNC trips and resultant VMT can increase the chances of extreme travel times becoming the norm, and of airport trips becoming less predictable. As a result, reliable airport trip planning will become harder to achieve, and air passengers will have to factor extra travel time (greater time safety margins) into their ground-access trips to make sure they do not miss their flight, leading to greater time loss than today.

5.2. Changes in Travel Behavior Following the Introduction of AVs

Fully automated, self-driving AVs will gradually become part of the transportation network in the next few decades. Knowing precisely what the future of AVs will look like is a challenging task given uncertainty around the magnitude and directionality of impact, but experts agree that as far as shared AVs go, the TNC business model provides the best insight into how the AV ride industry will operate.[31] It is likely that passengers will order AV rides on their phones in the same way they order TNC rides, with the only difference being that the car will arrive without a driver, which would decrease service costs and increase customer demand. Costs would also go down since the AV-TNCs could operate 24 hours a day with no breaks. Refueling or recharging, as well as maintenance, could be done at night when demand is low, without requiring the intervention of a driver.

The AV technology comes in varying degrees of automation. As time progresses and as the technology improves, more vehicles will incorporate higher levels of automation. However, until full automation is reached, the roadway network will host vehicles with a great range of capabilities. The traditional car has a level 0 automation and requires a driver to perform all driving tasks. At level 1, the vehicle has some form of automation to assist the driver in certain conditions. At level 2, the vehicle has automation capabilities that assist with some parts of driving while the driver continues to be fully engaged. Reaching level 3, the vehicle has ability to drive autonomously on some roads, but the driver needs to remain ready to intervene, while at level 4 the vehicle has ability to drive autonomously in certain conditions and the driver does not need to be ready to intervene. At the final level 5, the AV has the ability to perform all driving tasks autonomously in all conditions and the steering wheel is no longer necessary.[32]

AVs are frequently touted by some as the "magic pill" that will end congestion by increasing road throughput (the number of cars that can pass through a certain point within a set time). This is due to the AV technology's increased ability to communicate with other vehicles and with road infrastructure, thereby reducing crashes, and travel in platoons, which allows vehicles to drive closer together than traditional vehicles could. In less congested roadways, these technological improvements likely will speed up traffic and reduce travel times. But in highly congested urban

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[31] Samuel I. Schwartz, *No One at the Wheel: Driverless Cars and the Road of the Future* (New York, NY: PublicAffairs, 2018); B. Grush, J. Niles, and B. Schlecter, "Ontario Must Prepare for Vehicle Automation Part 2: How Skilled Governance Can Influence Its Outcome," 2017; Daniel J. Fagnant and Kara M. Kockelman, "Dynamic Ride-Sharing and Fleet Sizing for a System of Shared Autonomous Vehicles in Austin, Texas," *Transportation* 45, no. 1 (January 1, 2018): 143–58.
[32] Schwartz and Kelly, *No One at the Wheel*.Schwartz, *No One at the Wheel*.

environments like New York City, and on the roads that feed them, the capacity benefits of AVs will likely be offset by additional miles traveled by each AV.[33]

Many studies on the potential impacts of AVs conclude that VMT will increase with the expansion of AV usage. A 2016 study by the University of Leeds (UK) predicts that with the introduction of AVs, VMT will increase by as much as 60% since AVs will support a rise in productivity and a reduction in the cost of sitting in traffic, allowing people who rarely use private vehicles today to start doing so more often in the future.[34]

The potential to be productive while riding in an AV is often described as a main motive behind transitioning from current-day cars to driverless vehicles. To achieve that goal, AVs will have to be programmed to provide a smoother ride than conventional cars, which often cause motion sickness to passengers who try to read a book or fix their eyes on a screen. A study by the Imperial College in London found that in all scenarios, if AVs are designed to provide rides that facilitate work or entertainment, they will need to accelerate and decelerate more slowly than human-driven vehicles, causing travel times to increase. Consequently, AVs designed to provide a comfortable ride experience, similar to that of trains, in a dense urban street network, produce lower road capacity and cause worse congestion than human-driver scenarios. [35]

Among the studies that argue that AVs will improve travel times, many concede that these improvements will only happen when autonomous vehicles make up 70% to 90% of vehicles on the road.[36] However, before this occurs, there will likely be a tumultuous transition period when varying levels of AVs and conventional human-driven vehicles share the roads.[37] With AVs programmed to drive precisely in accordance with laws that are frequently broken by human drivers, this mix of vehicle types will likely slow down travel speeds relative to what they would otherwise be with only human drivers.[38] The car carrying capacities of city streets will likely go down not only due to the mix of cars, but also because AVs would travel hesitatingly through the streets, navigating around other road users such as pedestrians, bikes and skateboarders.

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[33]Abdul Rawoof Pinjari and Bertho Augustin, "Highway Capacity Impacts of Autonomous Vehicles : An Assessment PREPARED FOR Tampa," 2014; Schwartz, *No One at the Wheel*; Todd Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," 2018.
[34] Z Wadud, D MacKenzie, and P Leiby, "Help or Hindrance? The Travel, Energy and Carbon Impacts of Highly Automated Vehicles -," *Transportation Research Part A: Policy and Practice* 52 (2016): 1–44.
[35] Scott Le Vine, Alireza Zolfaghari, and John Polak, "Autonomous Cars: The Tension between Occupant Experience and Intersection Capacity," *Transportation Research Part C: Emerging Technologies* 52 (2015): 1–14.
[36] Jane Bierstedt et al., "Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity," *FP Think Working Group*, 2014, 10–11; S. C. Calvert et al., "Will Automated Vehicles Negatively Impact Traffic Flow?," Research article, Journal of Advanced Transportation, 2017.; Le Vine, Zolfaghari, and Polak, "Autonomous Cars."
[37] Grush, Niles, and Schlecter, "Ontario Must Prepare for Vehicle Automation Part 2."
[38] Calvert et al., "Will Automated Vehicles Negatively Impact Traffic Flow?"

While the car carrying capacity of limited access roadways could go up with AVs in use, the number of passengers moved could go down. Single occupant vehicles today are perhaps the greatest contributor to congestion. However, AVs will introduce zero occupant vehicles onto the roadways, further exacerbating vehicle inefficiency. Since parking can often be expensive and finding a spot time consuming, it is likely that after being dropped off at the destination, individual AV owners would prefer sending their vehicles to either circulate the roads or park back home until summoned for a pick up. With the expense of buying a personal AV already spent, riders to destination such as airports may prefer using the empty-car option over taxis, TNCs, or paying for a parking spot. Therefore, a large portion of AVs on the road may in fact be empty vehicles, en route to or from a fare or destination.[39]

In the same way that TNCs can divert riders from mass transit into vehicles, every transit rider who becomes an AV user will likely worsen congestion across the city, adding more unpredictability to travel times. Moreover, when compared to privately-owned cars, the additional miles that ride-hailing AVs will need to drive to complete a trip will be similar to TNCs additional miles, discussed in **Section 5.1**.

Today, a significant share of FHV fares are directed towards covering drivers' pay.[40] Since AV operational costs will not include the human factor, running a shared AV business would be less costly than FHVs, which in turn could allow the reduction of passenger fares. If AV rides will indeed cost less than traditional FHV rides, FHV services in New York City could see a rise in popularity that will exceed today's market, which is largely limited to those who can afford more than a subway fare. This could lead additional air passengers and airport commuters to choose AV/FHV rides over existing public transportation.

It should be noted that transit options that use exclusive rights-of-way would continue to provide a viable alternative for travelers, given the high reliability, efficiency and speeds that they accommodate. And despite the likely increase in the demand for AV ride services, the high capacity of mass transit during peak hours will remain an essential part of urban transportation systems like that of New York City.

And yet, while private ownership of AVs can potentially be discouraged, AVs will open the automobile market to millions who otherwise would not have access to privately owned vehicles.

[39] Pinjari and Augustin, "Highway Capacity Impacts of Autonomous Vehicles."
[40] Parrott and Reich, "An Earnings Standard for New York City's App-Based Drivers."

Among these groups are people with disabilities, elderly people and youth. According to the United States Census Bureau, about 28 million people in the US have a severe disability that could prevent them from getting behind the wheel. Similarly, by 2035, there will be 78 million people 65 years and older in the United States. Owning an AV will likely be highly popular among those who do not have access to conventional vehicles since it can support independent mobility and traveling. Nonetheless, the options the new technology provides also mean an increase in car ownership and inevitably a rise in VMT and the potential for zero-occupant vehicles.

While there is no way of knowing exactly what the future of AVs will look like, using TNCs as a proxy for how shared AV service will function and be priced, demonstrates that the new technology has the potential to further exacerbate the problems that are resulting from the growth of TNCs. Every transit user or driver that becomes an AV user, just like those who use TNCs, contributes to congestion, adds to travel times, and makes both of them less predictable.

5.3. Projections of Traffic Conditions Accounting for AVs and TNCs

As discussed in **Sections 5.1** and **5.2**, the rapidly growing app-based TNC market and the future introduction of AVs will most likely impact the average occupancy levels of vehicles, the number of trips taken and the total VMT produced by those trips. As studies show, AVs are likely to also influence roadway capacity at various degrees, depending on whether a segment is entirely on city streets, entirely on limited-access roads, or a mix of the two. By consolidating conclusions from several studies and applying them to a model relevant to trips to and from LGA, this section derives projected travel times between the airport and Midtown Manhattan in 2045, accounting for the effects of AVs, as well as for the increasing reliance on TNC services.

To produce the projections, the analysis first looks at the impact TNCs will have on 2045 travel times to and from LGA as they were projected by the Adjusted Model discussed in **Section 4.2**. To these results, it applies a multiplier that accounts for the change in travel times caused by AVs, depending on the latter's market share. Since historical data does not yet exist for AVs, or for the increasing share of TNCs in New York City by 2045, the study uses a scenario-based analysis to project the average and 95th percentile travel times between LGA and Midtown Manhattan (Grand Central Terminal and Penn Station). As results show, 95th percentile travel times from Midtown to LGA are likely to be between 100 and 122 minutes in 2045, and approximately 127 minutes for the opposite direction.

5.3.1. The TNC Growth Factor

As discussed in this report, the significant growth that TNC services have experienced since the early 2010s is expected to continue in the next decades. Due to the added VMT that TNCs produce, this growth will most likely influence travel times in 2045. Aiming to account for this influence, the analysis includes TNC growth and induced VMT in its travel time projection model.

The scenario chosen for the model consists of several factors. First, TNC market penetration rates were accounted for. For this analysis to produce conservative results, a TNC mode split of all trips in New York City was assumed to reach 50% by 2045. This share is at the mid-point of estimates by futurists, many of which believe a larger proportion of rides will be in shared vehicles. A higher TNC mode split, or market penetration rate, would further increase VMT and consequent travel times.

The rate of excessive VMT produced by TNCs was the second factor taken into account. In his 2018 report, Schaller identified several scenarios to estimate this VMT increase, ranging from 41% to 180% (see **Figure 37**).[41] To maintain a conservative approach, the low-end of the excessive VMT production range, 41%, was selected for this report. Accounting for the 50% market penetration, the increase in segment-wide VMT induced by TNCs is estimated at 20.5%:

Equation 1

41% × 0.5 = 20.5%

(TNC Induced VMT at 100% Modal Split) × (50% Modal Split) = (TNC Induced VMT at 50% Modal Split**)**

Traffic science has shown that on congested roadways, adding additional vehicles will disproportionately worsen congestion and increase travel times. As discussed in **Section 4.2**, the delay function used in the BPM shows that an increase of 10% in volume on an already congested road could result in a 10% to 50% increase in travel times. The BPM's 2045 projections found that the ratio of VMT growth to VHT growth would reach 1:2. As New York City roads linking LGA and Manhattan (LIE, BQE, GCP, QMT, RFK Bridge and Ed Koch-Queensboro Bridge) often experience severe congestion during much of the day, the conservative VMT-VHT relationship by the BPM was selected. This ratio is positioned at the low end of the exponential curve describing the volume-time relationship. Applying the selected ratio to the scenario's induced VMT, the VHT increase produced by TNCs in 2045 was set at 41%:

Equation 2

20.5% × 2 = 41%

(VMT Increase by TNCs) × (VMT/VHT Ratio) = (VHT Increase by VHT)

The Adjusted Model projections, discussed in length in **Section 4.2**, constitute the baseline travel time data for this analysis. In other words, the analysis considers the model's travel time projections as the basic input, to which the change in travel time created as a result of TNC growth is added.

Finally, the analysis assumes a linear relationship between VHT increase and travel time increase. Based on this assumption, travel times generated by the Adjusted Model should be

[41] Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities."

multiplied by 1.41 (141%) to account for the 50% TNC market share projected in 2045. That is the TNC Growth Factor, which was applied to the LGA travel times (**Figure 39**):

Equation 3

(Baseline 2045 Average Travel Time) × 1.41 = (2045 Average Travel Time Accounting for TNCs)

Figure 39: Projected 2045 Average Travel Times Acounting for TNCs

Trip	Peak Period	Baseline Projected Average Travel Time (Adjusted Model)	Projected Average Travel Time with TNCs
LGA-->GCT	AM	56	79
LGA-->Penn		56	79
GCT-->LGA	PM	44	62
Penn-->LGA		54	76

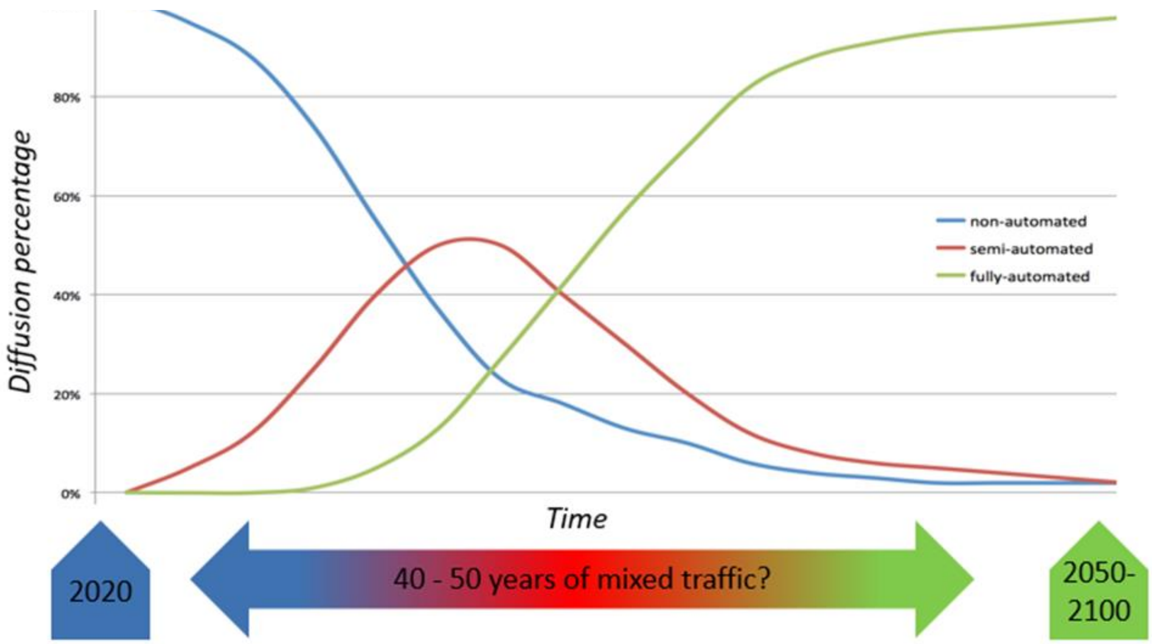
As **Figure 39** shows, peak-period travel times in 2045 from LGA to Midtown are projected to reach close to 80 minutes on average, and the trip from Penn Station to LGA would likely exceed 75 minutes. It should be noted that in 2017 existing conditions, discussed in **Section 3.2**, a 70-minute travel time is considered extreme.

5.3.2. **The AV Induction Factor**

Perhaps the most crucial element in projecting the impact AVs may have on traffic flow is the penetration rates the new technology will reach by the analysis year of 2045. As described in **Section 5.2**, the full traffic flow benefits of fully automated AVs that have no operator on board heavily rely on them dominating the roadway network and reaching a market share of close to 100%. However, as most futurists argue, the 100% market-share scenario will take many decades to come to fruition (if ever), and until that happens, the rate of AV market penetration will have a significant impact on potential headways and therefore road capacity.

Most studies provide a range of AV market share in their forecasts and, cumulatively, they predict that AVs would first become available to consumers in the mid-2020s. By 2045, fully autonomous vehicles are estimated to make up somewhere between 20% and 90% of the total automobile fleet (**Figure 40**).

Figure 40: Aggregate Expert Consensus Chart, Uncertain Time Scale



Source: Grush, 2017

A study prepared for the Victoria Transport Policy Institute projects that based on vehicle sales and lifecycles, 20% to 40% of vehicles will be AVs by 2045.[42] Similarly, a 2017 study accounting for consumer preferences and declining costs of autonomous technology estimates that by 2045, 50% of vehicle miles traveled will be in AVs.[43] A 2016 study predicts that AV adoption rates by 2045 will range from nearly 25% to 87%, depending on how affordable AVs become and how willing people are to pay for autonomy.[44] A 2016 survey of 33 international AV industry insiders estimates that by 2045 AVs will comprise 45%-51% of vehicles on the road.[45] Finally, a World Economic Forum report projects that, depending on neighborhood characteristics, between 26% and 53% of trips in Boston in 2045 will be taken in AVs.[46]

[42] Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning."
[43] Grush, Niles, and Schlecter, "Ontario Must Prepare for Vehicle Automation Part 2."
[44] Prateek Bansal and Kara M. Kockelman, "Forecasting Americans' Long-Term Adoption of Connected and Autonomous Vehicle Technologies," *Transportation Research Part A: Policy and Practice* 95 (January 1, 2017): 49–63, https://doi.org/10.1016/j.tra.2016.10.013.
[45] Chandra Bhat, "Travel Modeling in an Era of Connected and Automated Transportation Systems: An Investigation in the Dallas-Fort Worth Area," 2017.
[46] John Moavenzadeh and Nikolaus S. Lang, "Reshaping Urban Mobility with Autonomous Vehicles Lessons from the City of Boston" (World Economic Forum, 2018), https://www.weforum.org/reports/reshaping-urban-mobility-with-autonomous-vehicles-lessons-from-the-city-of-boston/.

Based on these studies' methodologies and range of results, it seems that by 2045, the market share of vehicles with high level AV capabilities (levels 4 and 5) will most likely range between 30% and 70%. In this report, the mid-range point of 50% was chosen as the AV penetration rate in 2045.

Several studies project the levels of VMT induced by AVs in various scenarios and market share rates (**Figure 41**). Generally, the higher the AV market share, the more VMT will be induced. This is due to the high likelihood that AVs would introduce zero occupant vehicle to roadways, open the automobile market to populations that cannot drive today, and make FHV trips less expensive.

A 2018 study on the impact of AVs in Germany and the United States estimates that at 30% market penetration, VMT would increase by 8.6%.[47] A study prepared in the University of Utah and University of Texas at Austin predicts that at 50% AV market share, the total VMT in a system would increase by 7.5%.[48] The 2018 World Economic Forum report referenced above forecasts a VMT increase of 16% resulting from an AV mode share of between 26% and 53%.[49]

Figure 41: Projected AV-Induced VMT Range by Study

Study	VMT change	Market Share
Fagnant and Kockelman (2015)	7.5%	50%
Kröger et. Al (2018)	8.6%	30%
Moavenzadeh and Lang (2018)	16%	26%-53% (mode split)

Upon review of the existing studies and their methodologies, and to maintain the conservative approach of this analysis, the VMT increase was set at the low-end value of 7.5% for an AV market share of 50%.

To complete travel time calculations, an understanding of the impacts of AVs on roadway capacity is needed. The overall themes emerging from several academic and professional traffic engineering sources include uncertainty on achievable AV headways; further uncertainty on physical separation on roadway segments and at intersections between AVs and non-AVs; and little capacity benefits from AVs in scenarios of lower market share rates.

[47] Lars Kröger, Tobias Kuhnimhof, and Stefan Trommer, "Does Context Matter? A Comparative Study Modelling Autonomous Vehicle Impact on Travel Behaviour for Germany and the USA," *Transportation Research Part A: Policy and Practice*, April 6, 2018, https://doi.org/10.1016/j.tra.2018.03.033.
[48] Daniel J. Fagnant and Kara Kockelman, "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations," *Transportation Research Part A: Policy and Practice* 77 (July 1, 2015): 167–81, https://doi.org/10.1016/j.tra.2015.04.003.
[49] Moavenzadeh and Lang, "Reshaping Urban Mobility with Autonomous Vehicles Lessons from the City of Boston."

Overall, research methodologies focus on simulations of AVs on freeways with reduced headways to replicate the closer following distances that will be possible as AV market share increases. The ranges for capacity increase due to AVs at the selected market shares are shown in **Figure 42**.

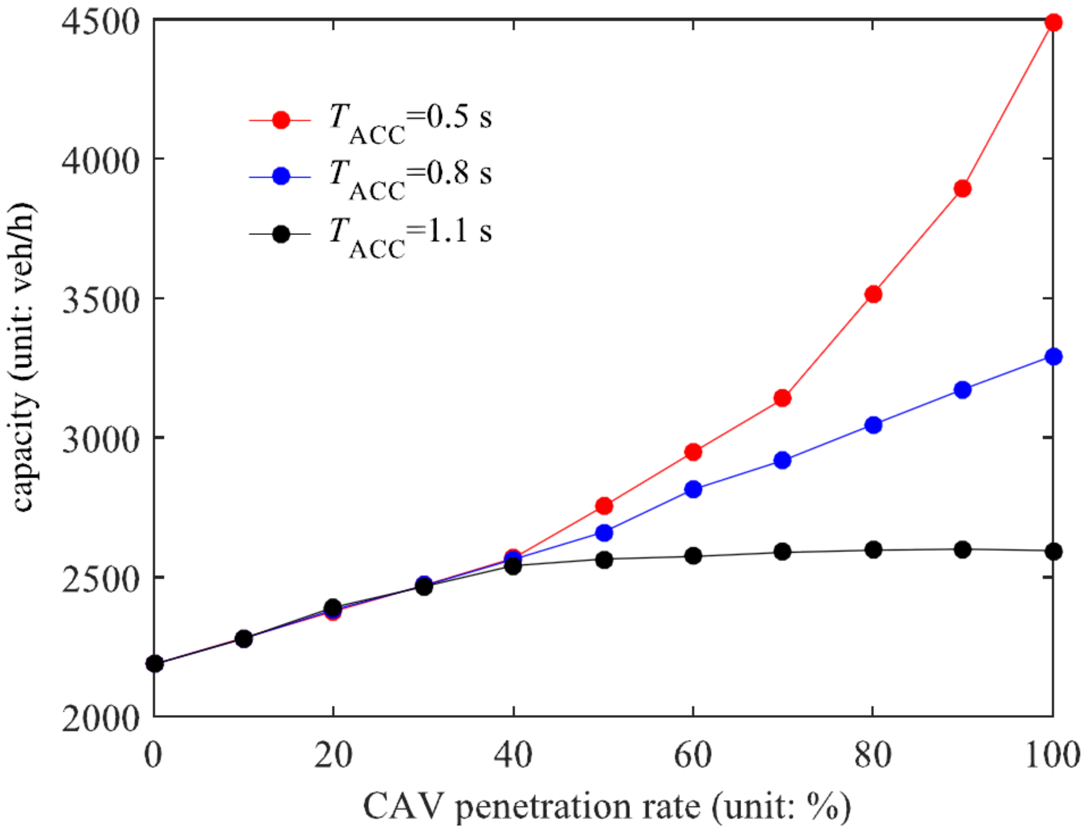
Figure 42: Projected Ranges Capacity Increases Due to AVs, from Research Papers

AV Market Share	Range in Capacity Increase
30%	5.1% - 11.4%
50%	8.0% - 33.3%

Several of the values presented in **Figure 42** are outliers due to aggressive estimates regarding AV technology, which allow for much closer vehicle following distances than what is currently contemplated. Additionally, some of the studies looked at capacity increases on both freeways and local streets. However, three of the research papers referenced to develop the ranges in **Figure 42** were especially pertinent to this travel time analysis. A 2017 Nagoya University study developed relationships between capacity and market share of AVs for three different vehicle headways: 0.5 seconds, 0.8 seconds, and 1.1 seconds. The 0.5 and 0.8 second scenarios represent more advanced Connected and Autonomous Vehicle (CAV) capabilities than what is reflected in existing technology. The authors find that with a market share of less than 30% AVs yields only a modest capacity benefit, and that for a 50% market share the capacity increase will be between 16% and 25% (**Figure 43**).[50]

[50] Lanhang Ye and Toshiyuki Yamamoto, "Modeling Connected and Autonomous Vehicles in Heterogeneous Traffic Flow," *Physica A: Statistical Mechanics and Its Applications* 490 (August 18, 2017), https://doi.org/10.1016/j.physa.2017.08.015.

Figure 43: Roadway Capacity by CAV Penetration Rate and Headway Capabilities



Source: Ye and Yamamoto

A Berkley University study based its research on simulation of autonomous vehicles in 2017 and developed relationships between capacity and market share of AVs by studying the vehicle headways achievable with different market shares. The study takes into account the different headways required for all car-following situations: AV following AV, AV following non-AV, non-AV following AV, and non-AV following non-AV. It finds that at a 50% market share, the capacity increase is expected to range between 20% and 33%.[51]

A Transportation Research Board (TRB) study performed a city-wide research of the Greater Toronto area in 2017 using modeling software. The research finds that at 50% AV market share, capacity would increase by 21%.[52]

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[51] Mohsen Ramezani et al., "Capacity and Delay Analysis of Arterials with Mixed Autonomous and Human-Driven Vehicles," in *2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)* (2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), Naples, Italy: IEEE, 2017), 280–84, https://doi.org/10.1109/MTITS.2017.8005680.

[52] Bradley Kloostra and Matthew J. Roorda, "Fully Autonomous Vehicles: Analyzing Transportation Network Performance and Operating Scenarios in the Greater Toronto Area, Canada," 2017, https://trid.trb.org/view/1437234.

Based on an examination of the methodologies and values from the papers that focused on freeway driving with less aggressive headway estimates, it was established that a 20% increase in highway capacity is reasonable for a 50% AV market share scenario.

Given the limited research and technology available that investigates capacity impacts on urban/local streets, it was assumed that there would be no capacity increase on trip segments that occur on urban/local streets. Moreover, based on the discussion in **Section 5.2**, the analysis assumes a 10% decrease in urban/local street capacity following the introduction of AVs.

Since approximately one third of the trip time between LGA and Midtown Manhattan is on urban/local roads and two thirds is on highways, the analysis applies the appropriate capacity change proportionally by roadway type, to account for the full impact AVs would have on the trip to and from the airport. Therefore, for the purpose of this study, it is estimated that the capacity of the roads connecting LGA and Midtown would increase by 10% following the introduction of AVs at 50% market share:

Equation 4

(1.2 × 0.67) + (0.9 × 0.33) = 1.1

(Highway Capacity Change) **×** (Proportion of Trip Time) + (Local Road Capacity Change) **×** (Proportion of Trip Time) = Capacity Change Multiplier

To account for the varying degrees of impacts each of the above elements has on travel time to and from LGA, the analysis employs a volume-delay function as described below in Equation 5:

Equation 5

$$t = t_f\left(1+\left(\frac{V}{C}\right)^{\beta}\right) \text{ when } \frac{V}{C} \leq 1.0 \qquad \text{(a)}$$

$$t = t_f\left(6\times\frac{V}{C}-4\right) \text{ when } \frac{V}{C} > 1.0 \qquad \text{(b)}$$

Where:

t => congested travel time
tf => uncongested (free-flow) travel time
V => traffic volume on the link
C => base capacity of the link
β => parameter (discussed in further detail)

A volume-delay function represents the relationship between the congested travel time and the volume and capacity of a segment. The difference between the volume and capacity for the analyzed segments before and after the introduction of AVs is used in this function to obtain a multiplier to average travel times in an AV-less roadway network.

While several applications of the volume-delay function exist, the most widely used is the Bureau of Public Roads functions.[53] For this analysis, the volume-delay function selected is that used in Emme, a travel demand modeling software. Emme is currently used throughout North America, including for the Seattle and Toronto metropolitan areas. Travel demand models employ volume-delay functions for the trip assignment step of the model runs.

The documentation and parameter inputs for β were taken from a 2017 study on the relationship between AVs and vehicle kilometers traveled for the Greater Toronto Area using Emme.[54] For the Greater Toronto Area, the value for β is typically 6 on freeways and 4 on other roads. These values are also used in our analysis for New York City, as the two cities share similar characteristics of dense urban areas. Of the functions described above, this analysis uses function (b), as the ratio of volume to capacity added by AVs according to the selected scenario is smaller than 1.0.

To calculate the impact AVs would have on travel time, the study derived a multiplier for the effects of AVs by dividing the results of the above function for a network with AVs by the function's results for an AV-less network.

Figure 44 displays the assumptions employed for the chosen scenario. Values for free flow travel time were assumed to be similar for both AV and AV-less networks, and since the analysis looks at ratios and not absolute values, all baseline values for the AV-less network were set at 1.

Figure 44: Research-based Scenario Assumptions

AV Market Share	Capacity Change by AVs	Induced VMT by AVs
50%	+10%	+7.5%

[53] Heinz Spiess, "Technical Note—Conical Volume-Delay Functions," *Transportation Science* 24, no. 2 (May 1, 1990): 153–58, https://doi.org/10.1287/trsc.24.2.153.
[54] Kloostra and Roorda, "Fully Autonomous Vehicles."

As seen in **Figure 45**, at a 50% market share, total capacity increase of 10% and 7.5% total excessive VMT, AVs are estimated to have a travel time impact multiplier of 0.94.

Figure 45: Multipliers for Impact of AVs on Average Travel Time

Scenario	Free flow travel time		Volume	Capacity	Beta	Congested travel time [v/c <1]	Multiplier	Congested travel time [v/c >1]	Multiplier
With AVs	1	1	1.075	1.1	5.28	1.89	**0.94**	1.86	**0.93**
Without AVs	1	1	1	1	5.28	2		2	

To project average travel times in 2045 that account for AV introduction, the AV impact multiplier was applied to projected average travel times that already account for the influence of TNCs at the analysis year, and that were calculated in section 5.3.1:

Equation 6

$$\text{(2045 Travel Time Accounting for TNCs)} \times 0.94 = \text{(2045 Travel Time with TNCs and AVs)}$$

As shown in **Figure 46**, the average travel time to and from LGA in a future scenario where AVs constitute 50% of the car fleet is projected at nearly 75 minutes, except for trips from GCT to LGA which would take approximately 58 minutes.

Figure 46: Projected Average 2045 Travel Times Following the Introduction of AVs [v/c<1]

Trip	Peak Period	Baseline Projected Travel Time (Adjusted BPM)	Projected Average Travel Time with TNCs	Average 2045 Travel Times with TNC + AVs	Percent Change from no TNC & no AV Condition
LGA-->GCT	AM	56	79	**74**	33%
LGA-->Penn		56	79	**74**	33%
GCT-->LGA	PM	44	62	**58**	33%
Penn-->LGA		54	76	**72**	33%

Since travelers to and from LGA are most likely to use extensive buffers to budget their travel time, the next step of the analysis was to find the relationship between average travel times in 2045 and the 95th percentile travel time that same year. To achieve that, a multiplier was calculated based on the Adjusted Model results by dividing the 95th percentile travel time by average travel time for all legs between Midtown and LGA, and then averaging the results. This way, the effect of any potential outlying leg would have on the final multiplier was normalized, setting the final multiplier used in the analysis at 1.705:

Equation 7

(a) $$\frac{\textbf{Adjusted Model 95th Percentile Travel Time}}{\textbf{Adjusted Model Average Travel Time}} = \text{Budgeted Travel Time Multiplier}$$

(b) $$\frac{\textbf{Sum of all Budgeted Travel Time Multipliers}}{\textbf{Number of Legs}} = \text{Average Budgeted Travel Time Multiplier}$$

Figure 47: 2045 Budgeted (95th Percentile) Travel Time Multiplier Based on the Adjusted Model

Trip	Peak Period	Average Travel Time	Budgeted (95th Percentile) Travel Time	Budgeted Travel Time Multipliers	Average Budgeted Travel Time Multiplier
LGA-->GCT	AM	56	104	1.86	**1.705**
LGA-->Penn		56	87	1.55	
GCT-->LGA	PM	44	75	1.70	
Penn-->LGA		54	92	1.70	

To extrapolate th budgeted travel times, i.e. the 95thpercentile travel times, with AVs for trips between Midtown Manhattan and LGA, theAverage Budgeted Time Multiplier presented in **Figure 47** was applied to the 2045 projected average travel times that account for AVs, shown in **Figure 46**.

Equation 8

(2045 Average Travel Time Accounting for TNCs and AVs) × 1.705 =
(2045 Budgeted Travel Time Accounting for TNCs and AVs)

As seen in **Figure 48**, the 95th percentile travel times in 2045 are projected to be between 22% and 46% higher than the equivalent figures had TNCs and AVs not been introduced into New York City's roadways, reaching approximately two hours for the majority of legs examined.

Figure 48: Projected 2045 Average and Budgeted (95th Percentile) Travel Times Following the Introduction of AVs [V/C < 1]

Trip	Peak Period	Baseline Budgeted (95th Percentile) Travel Time	Average 2045 Travel Times with TNC + AVs	Budgeted (95th Percentile) 2045 Travel Times with TNC + AVs	Percent Change from 2045 Baseline Budgeted (95th Percentile) Travel Time
LGA-->GCT	AM	104	74	**127**	22%
LGA-->Penn		87	74	**127**	46%
GCT-->LGA	PM	75	58	**100**	33%
Penn-->LGA		92	72	**122**	33%

6. Conclusion

Traffic in New York City has gotten worse in recent years. In Midtown Manhattan, travel speeds dropped 28% between 2012 and late 2017, reaching a 4.7 mph low point – not much faster than the average pedestrian walking speed. Looking into the decades ahead, projections show the trend is likely to continue, especially with limited ability to expand roadway capacity. This will result in longer travel times and lower network reliability.

Along with higher traffic volumes came longer travel times and lower predictability in trip planning. Particularly crucial to air passengers trying to make it to a flight, or from a flight to a meeting, unpredictability in travel time manifests itself in greater safety margins they factor into their ground access trips when planning a trip to and from the airport. Therefore, the 95th percentile travel time, referred here as the budgeted travel time, is essential in this study.

As can be expected by the increase in vehicular volumes, budgeted travel times have risen between 2014 and 2017. For instance, the budgeted travel time between Times Square and LGA increased by 18%, in both directions. Trips originating or ending at the QMT in 2017 saw budgeted travel times that are higher by 20% for LGA-bound trips, and by 45% for the opposite direction, compared to 2014.

Projections for the following decades imply that traffic conditions will only get worse, with VMT increases exponentially impacting VHT and travel times. The regional model used for these projections (BPM) is somewhat conservative, as the observed travel times in 2015 actually being 10%-30% longer than projected. Moreover, trips to and from LGA have been found to be even less predictable than projected.

Further, neither the modal shift to TNC usage nor for the introduction of AVs were on the horizon when the current BPM was “built” in 2010. Since the model does not account for them and since TNCs and AVs produce more VMT than traditional privately-owned cars, VMT will increase even further than the Adjusted Model projects. Based on a conservative analysis, if in the future TNCs constitute 10% of the traveler mode share, ride-hailing services could lead to a total VMT increase of at least 4.1%. At 20% TNC share, total VMT would jump by at least 8.2%, and at 50% TNC share the VMT would increase by 20.5% or more. While actual data for VMT increases pursuant the introduction of AVs does not yet exist, it is projected that the effect of AVs on traffic volumes will be even greater than that of TNCs, due to the high likelihood of a rise in car ownership and of driverless cars circulating the roads empty.

The travel time projection analysis developed for this study used a 50% mode split for TNC and a 50% market share for AVs in 2045. The analysis projects that average travel times between LGA and Midtown will reach nearly 75 minutes, with budgeted travel time for LGA air passengers approximating two hours.

If current trends continue, if AVs indeed become prevalent, and if there are no significant infrastructure changes, passengers trying to get to LGA in the future will face much greater difficulties than today in accurately planning their ground access trip. The evolving conditions described in this report will force LGA air passengers to factor in even larger time safety margins for trips to and from the airport.