

# CITI BIKE'S NETWORK, ACCESSIBILITY AND PROSPECTS FOR EXPANSION

Is New York City's Premier Bike Sharing  
Program Accesssible to All?



How accessible is  
Citi Bike's network in  
New York City? Who  
benefits from it?

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# **Citi Bike's Network, Accessibility and Prospects for Expansion**

## **Is New York City's Premier Bike Sharing Program Accessible to All?**

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Introduction to Geographic Information Systems

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# Introduction

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Transportation systems in cities are complex, and frequently promote multimodal transportation nowadays. Cycling, a transit mode that has gained in prominence recently, is energy-efficient and environmentally friendly. As cycling is a physical activity that takes place outdoors, cyclists often discover scenic routes and explore the city.

One does not need to own a bicycle to cycle around the city. Bike sharing is one way in which cycling is made available to the general public as a transportation option. It exists in both formal and informal capacities in a large number of cities around the world.

If bike sharing programs are a way to expand cycling from a niche activity for cyclists and those who own bicycles to the general populace, then it follows that those programs should be accessible to the general public. When only a small proportion of the general populace has access to these bike sharing programs, they have less potential to make a large positive impact.

New York City's most popular bike sharing program, Citi Bike, presents an interesting case study to analyze the accessibility of these programs to the general public. The program does not exist across all of New York City yet, and has been implemented to different locations in a gradual process.

The Citi Bike network exists in a multi-modal framework, as users can connect to different transportation modes from Citi Bike. It can be utilized in conjunction with the subway or bus system as a transit option for areas with inaccessible or inconveniently located subway stations. People can also use Citi Bike alone, or for a part of their

journey and switch to the bus or subway as a matter of preference or convenience. Citi Bike has the potential to decrease car-dependency in urban areas, reduce carbon emission and promote livelihood in cities.

Analyzing where Citi Bike locates its stations in relation to age and racial demographics can be helpful in determining the program's accessibility across New York City. Citi Bike station locations in different phases of expansion could be an indicator of what Citi Bike deems important in its target demographic. They could also indicate the factors Citi Bike prioritizes in its decisions on where to locate itself, and consequently, who to provide access to.

Not all New York City residents live or work in areas close to Citi Bike locations, so it is important to ask who Citi Bike is accessible to.

Bike sharing in New York City has a very recent history. The city's first bike sharing program, called Citi Bike, launched in May 2013 and has been operating since then (Citi Bike NYC 2017a). It operates throughout the year for 24 hours a day, every day of the week. Citi Bike runs on a public-private partnership between Motivate and the New York City Department of Transportation (Citi Bike NYC, 2017a). Citi Bank is the title sponsor for Citi Bike, which is operated and managed by Motivate (Citi Bike NYC, 2017a).

Citi Bike does not exist in all parts of New York City, and this has been the case since its inception. Citi Bike has been launched in successive stages, and has now expanded from lower Manhattan to upper Manhattan, Brooklyn and Queens. The process of

expansion is still ongoing, and Citi Bike does not serve any borough in its entirety. As a result of this limited service area, Citi Bike is currently accessible to only a portion of New York City residents. Many neighborhoods, particularly those in the outer boroughs, are left out of the program (Citi Bike NYC 2017b).

Citi Bike's accessibility is also limited because of its pricing structure. All Citi Bike purchases must be made with a credit or debit card, thus excluding all people who have neither a debit nor a credit card. Citi Bike's single-ride pass costs \$4 for up to thirty minutes, and while this is the most affordable option, it is only obtainable through the Citi Bike app (Citi Bike NYC, 2017b). This makes Citi Bike even more exclusive as people without smartphones or tablets cannot access this option. Additionally, Citi Bike places a \$100 hold on the card of any casual user until the bike is returned. When you couple these factors with Citi Bike's relatively high pricing, it becomes clear that low-income New Yorkers would find it difficult to use the program.

Citi Bike's pricing is time-based, and charges can accrue as a result of this. All rides have a flat fee for the first thirty minutes and cost an extra \$4 for each additional fifteen minutes (Citi Bike NYC, 2017b). A day pass costs \$12 for unlimited thirty-minute rides and a single ride pass costs \$1.25 more than the MTA's \$2.75 bus and subway fee (Citi Bike NYC, 2017b; MTA, 2017). Citi Bike is significantly less expensive for subscribers who make an annual commitment (Citi Bike NYC, 2017b). For this type of user, the monthly pass costs \$14.95 per month and \$163 if paid in full. This is remarkably less than Metrocard subscriptions. A 30-day Metrocard costs \$121, and a 7-day Metrocard costs \$32 (MTA,

2017). This suggests that Citi Bike is targeting New York City residents who live and work in close proximity to Citi Bike stations, or use multi-modal transit options.

This pricing complicates our question about Citi Bike's accessibility in New York City. The reduced fare for annual subscribers makes it more accessible to people with a wider range of socio-economic backgrounds. On the other hand, the requirement that subscribers make an annual commitment limits this option to people with a high degree of financial stability. Moreover, this reduced fee for subscribers suggests that Citi Bike is complementing the MTA's subway and bus system rather than competing with it.

### ***How accessible is Citi Bike's network in New York City? Who benefits from this network?***

This study does not seek to answer questions about Citi Bike's users, but rather to probe whether Citi Bike's locations reproduce, exacerbate, or break from existing spatial patterns of inequity. By asking who has access to Citi Bike and what level of access is afforded to different groups of people, this study seeks to analyze Citi Bike's relationship to people and the spaces they inhabit.

To this end, an analysis of the accessibility of the Citi Bike network as well as the race and age demographics of the area it serves was done in three categories. These were areas with immediate access to Citi Bike, those with access to Citi Bike through the subway system, and those with no access to Citi Bike through either avenue.

# Methodology

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## Data

Citi Bike Station Information

2015 ACS 5-Year Estimate: Race, Age

groups and Total [by Census Tracts]

Pedestrian streets extracted from LION shapefile

Subway Stations

Subway Lines

## Network Analysis

To assess Citi Bike's accessibility, a network analysis in which we investigated the proximity of Citi Bike stations to subway stations was performed. The first step was to set up a network of pedestrian streets. Next, a half-mile was determined to be a comfortable walking distance. This distance was used throughout our analysis.

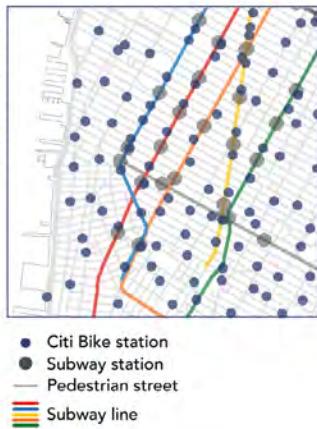
If a Citi Bike user wanted to travel using both Citi Bike and the subway, how convenient would that be? To measure that, Citi Bike stations and subway stations were located. A service area was set up around each Citi Bike station along pedestrian streets using a half-mile search radius. Finally, the number of subway stations located inside these service areas was assessed.

If a Citi Bike user docked their bike at a station, how far would they have to walk to get to the nearest subway station? To calculate this, the closest subway station to each Citi Bike station along pedestrian streets was calculated.

Finally, Citi Bike and subway networks were examined through a bi-modal transportation lens. If a Citi Bike user docked their bike at any station, which subway station

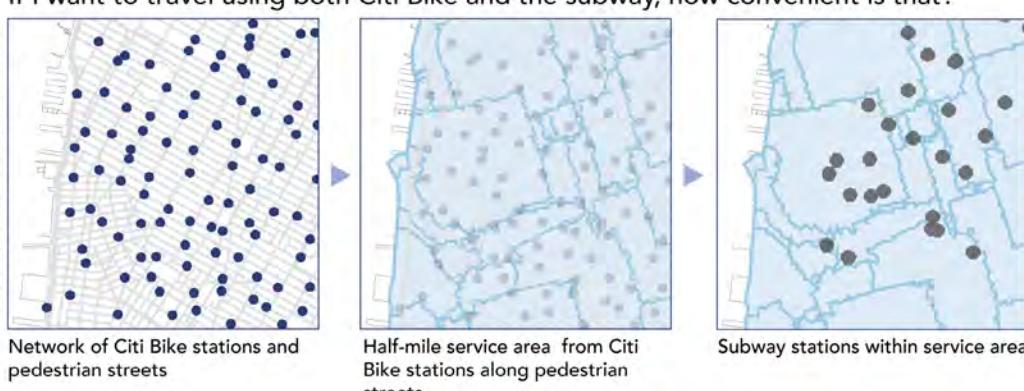
could they walk to at a comfortable distance? How far would they be able to travel along that subway line in thirty minutes? To answer this question, the distance a train travels in thirty minutes was estimated using 17mph as average speed (Johnson, 2010). A service area around subway stations was created using this distance along subway lines, and the subway stations within this service area were determined. Next, a service area of a half-mile around the subway stations accessible within a commuting time of thirty minutes along subway lines was generated using pedestrian streets. From this process, the subway stations that were accessible within thirty minutes commuting time to Citi Bike stations were assessed. Within this area, people would be able to transfer between the Citi Bike and subway networks.

## BASE LAYERS



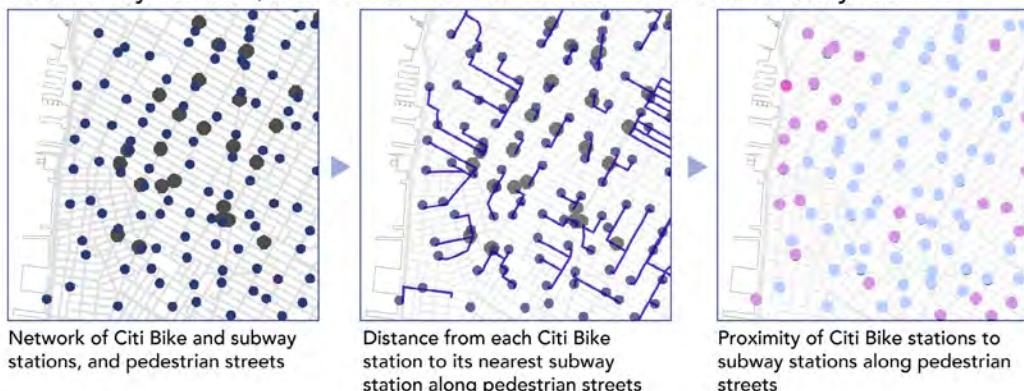
If I want to travel using both Citi Bike and the subway, how convenient is that?

## SPATIAL RELATIONSHIP



Subway stations accessible within half a mile from Citi Bike stations

If I dock my Citi Bike, how far do I have to walk to the nearest subway station?



Walking distance from each Citi Bike station to its nearest subway station

If I park my Citi Bike at any station, which subway stations can I walk to at a comfortable distance? How far can I travel along that subway line in thirty minutes?



Area accessible traveling with both Citi Bike and the subway

# Methodology

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## Demographic Analysis

To investigate who benefits from the Citi Bike service, age and racial demographics were analyzed and compared. This was done in areas where people had immediate access to Citi Bike stations, indirect access to the Citi Bike network via the subway, and no access through either. Non-white populations and population groups aged 18 to 24, 25 to 44 and 45 to 64 were analyzed in two network service areas constructed from previous network analysis. This analysis was also done in areas outside of these two network service areas.

Immediate access to the Citi Bike network was defined as a half-mile pedestrian service area around each Citi Bike station. Demographic information was aggregated by census tracts. Service areas, which intersected with the census tracts, were overlaid on top of each other. To estimate the population in these service areas, a proportional split was performed. The first step in the proportional split was calculating the area for each census tract. Next, this area was split into smaller parcels based on intersections and calculated the area in each small parcel. The proportion was calculated by dividing the area of the small parcel by that of the census tract. Using this proportion, the population in each small parcel was estimated by multiplying the proportion by the area of the parcel. Finally, the split parcels were regrouped into the service areas based on the boundary of service areas.

These steps were repeated for accessible subway network service area.

The last analyzed area was places outside both network

service areas. Similar to the above steps, the area of census tracts was calculated. The next step was to overlay the Citi Bike network service area and the accessible subway service area on all census tracts in New York City. This area was then split into smaller parcels based on intersections and the area in each small parcel was calculated. A new proportion was calculated by dividing the area of each small parcel by that of the census tract in which it was located. The demographics in each small parcel was calculated and regrouped based on the boundary of census tracts.

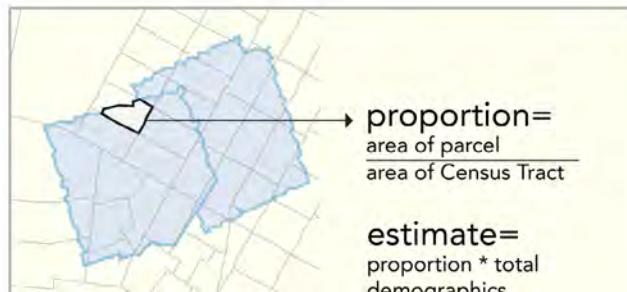
## BASE LAYERS



Half-mile service area from Citi Bike stations  
New York City census tracts



Half-mile service area from subway stations accessible to Citi Bike stations via thirty minutes on a subway line  
New York City census tracts



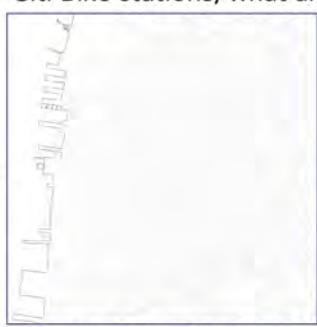
$$\text{proportion} = \frac{\text{area of parcel}}{\text{area of Census Tract}}$$

$$\text{estimate} = \text{proportion} * \text{total demographics}$$

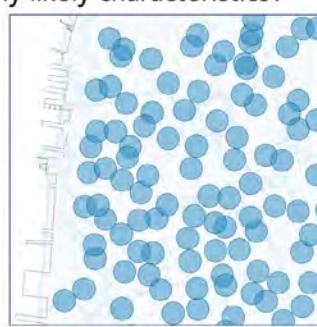
## SPATIAL RELATIONSHIP



Network of Citi Bike service area and census tracts



Union of Citi Bike service area and census tracts



Estimates of demographic characteristics in service areas

**Demographics of neighborhoods served by Citi Bike either directly or indirectly through accessible subway stations**

What if I have indirect access via subway stations?

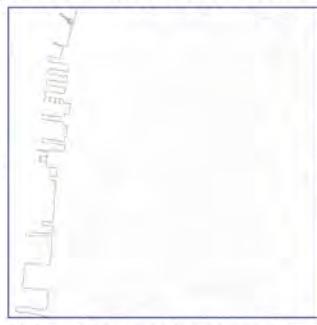
REPEAT FOR ACCESSIBLE SUBWAY SERVICE AREA

**Demographics of neighborhoods served by Citi Bike indirectly through accessible subway stations**

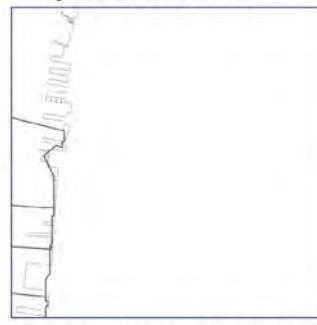
If I have no access to Citi Bike stations, what would be my likely characteristics?



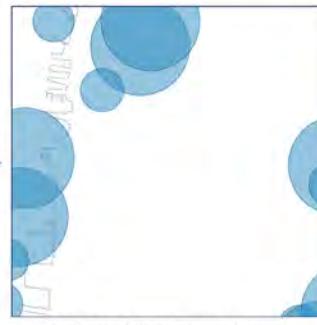
Citi Bike and accessible subway service area, and census tracts



Union of both service areas with census tracts



Extraction of areas not in either service area on census tract level



Estimation of demographic characteristics in areas not covered by Citi Bike or accessible subway

**Demographics of areas not served by Citi Bike**

# Findings: Accessibility

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The Citi Bike service area spans from midtown Manhattan to north-west Brooklyn and the southern tip of Queens in Long Island City. This is unsurprising, and correlates to the distribution of Citi Bike locations in New York City.

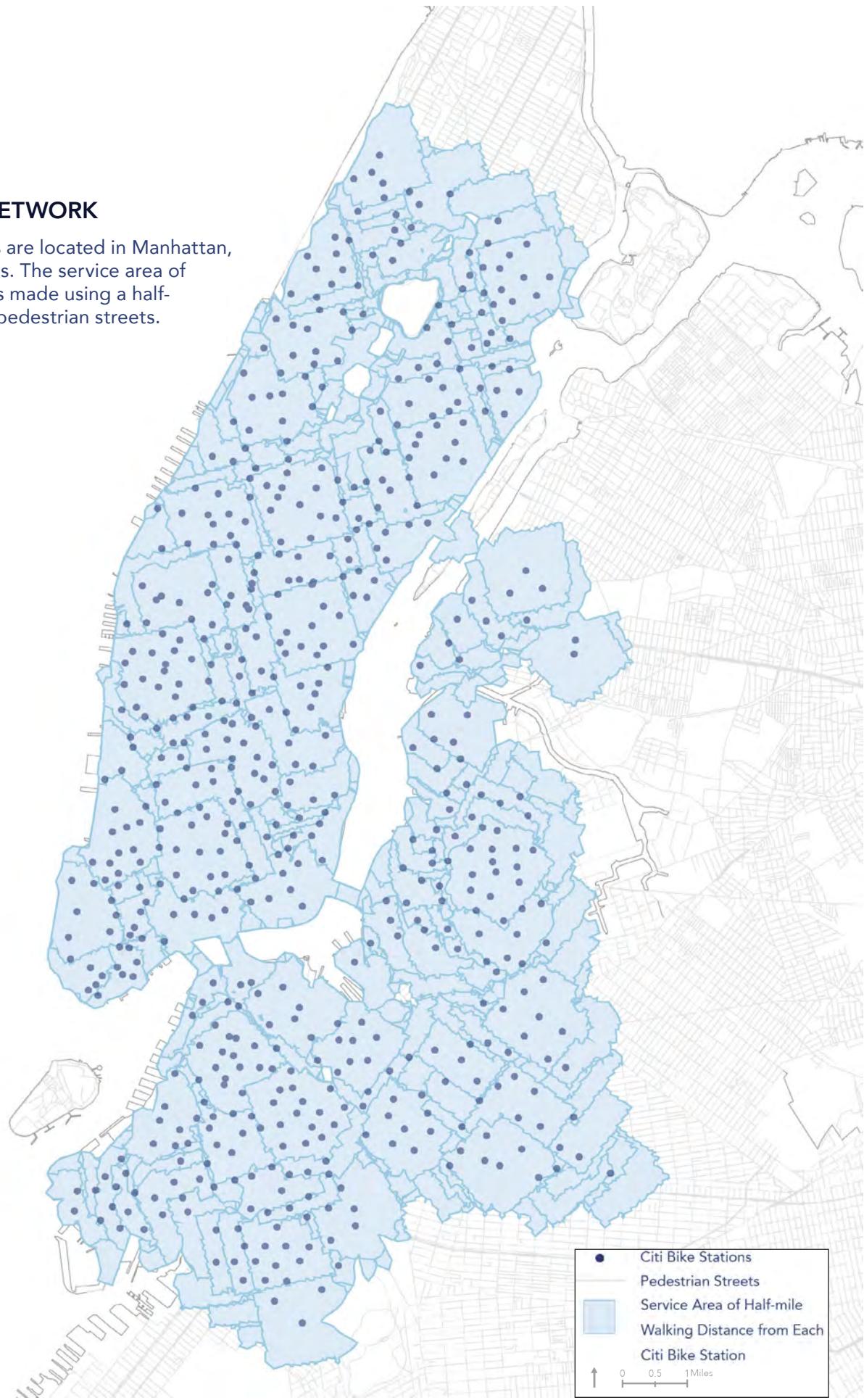
The walking distance from Citi Bike stations to subway stations varied by location. Walking distances increased towards the western and eastern parts of Manhattan and Brooklyn. This pattern was reflected in the distribution of subway stations, and a strong collocation was evident. The areas with the least walking distance from Citi Bike stations to their nearest subway stations generally had the most subway stations.

The maximum walking distance was about 1.4 miles, almost a mile further than the comfortable walking distance previously decided upon. The minimum walking distance, on the other hand, was 15 feet. The average was about 0.3 miles, which was less than the comfortable walking distance. The large range of walking distances from Citi Bike stations to subway stations indicates that the level of access from Citi Bike stations is not uniform across New York City, and the fact that some Citi Bike stations had no subway stations close to them in the service area supports this notion.

When the subway was factored in, however, accessibility to the Citi Bike network increased. The service area of Citi Bike stations contained part or all of each subway line. 39% of subway stations were within the Citi Bike service area, while a much increased 89% of New York City's subway stations were accessible from those subway stations.

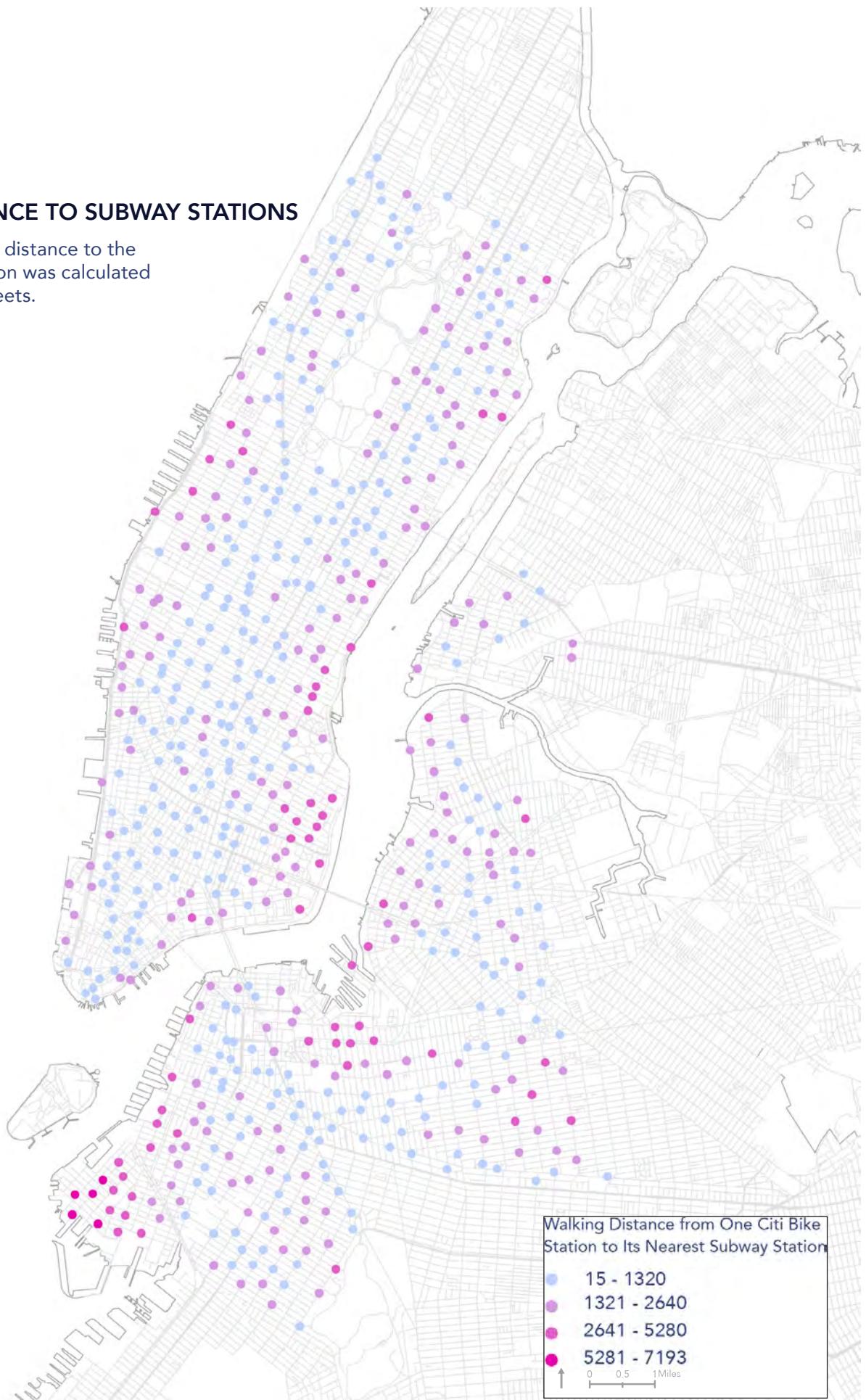
## THE CITI BIKE NETWORK

615 Citi Bike stations are located in Manhattan, Brooklyn and Queens. The service area of Citi Bike stations was made using a half-mile distance along pedestrian streets.



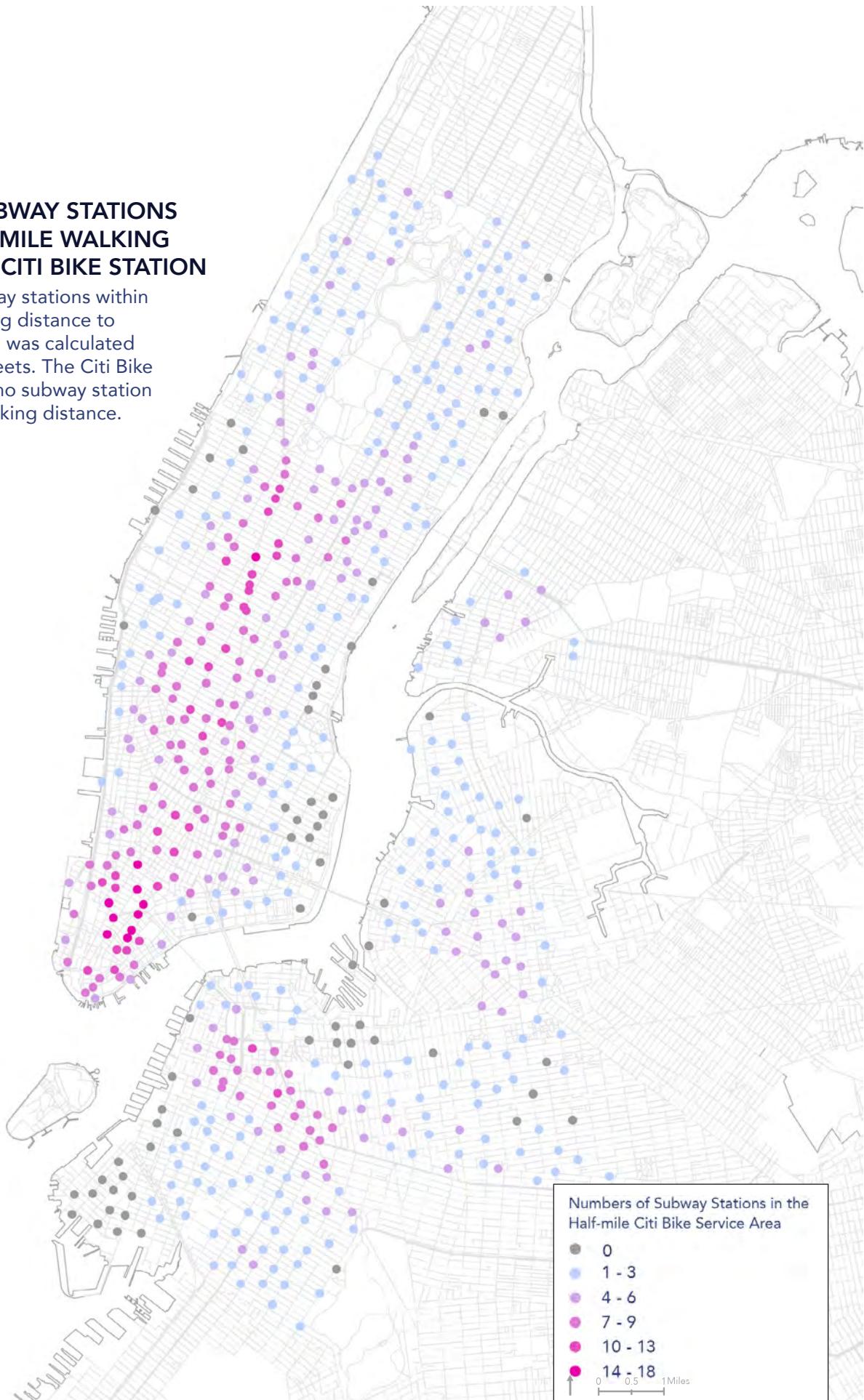
## CLOSEST DISTANCE TO SUBWAY STATIONS

The shortest walking distance to the nearest subway station was calculated along pedestrian streets.



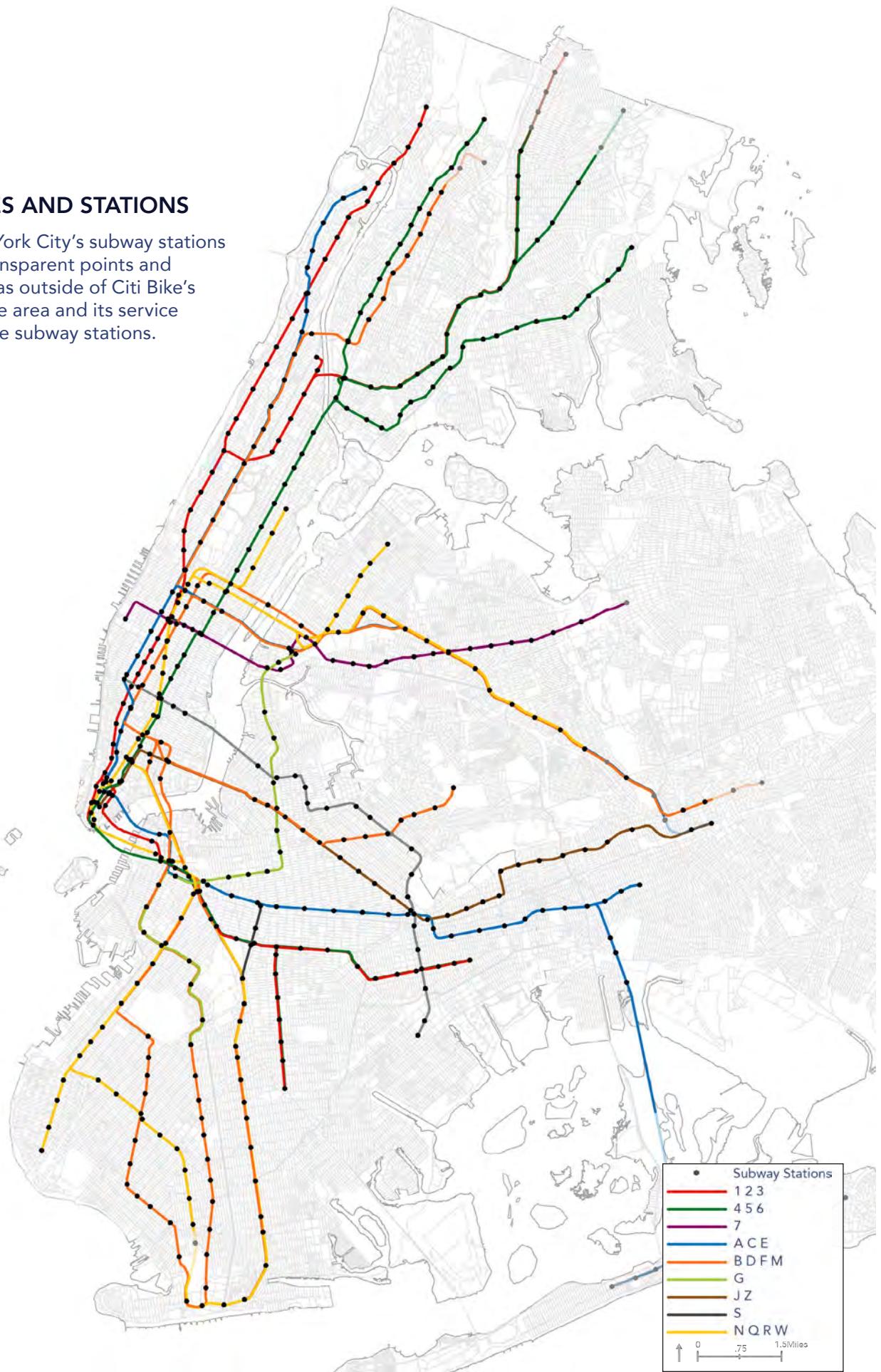
## NUMBER OF SUBWAY STATIONS WITHIN A HALF-MILE WALKING DISTANCE TO A CITI BIKE STATION

The number of subway stations within a comfortable walking distance to each Citi Bike station was calculated along pedestrian streets. The Citi Bike stations in grey had no subway station within a half-mile walking distance.



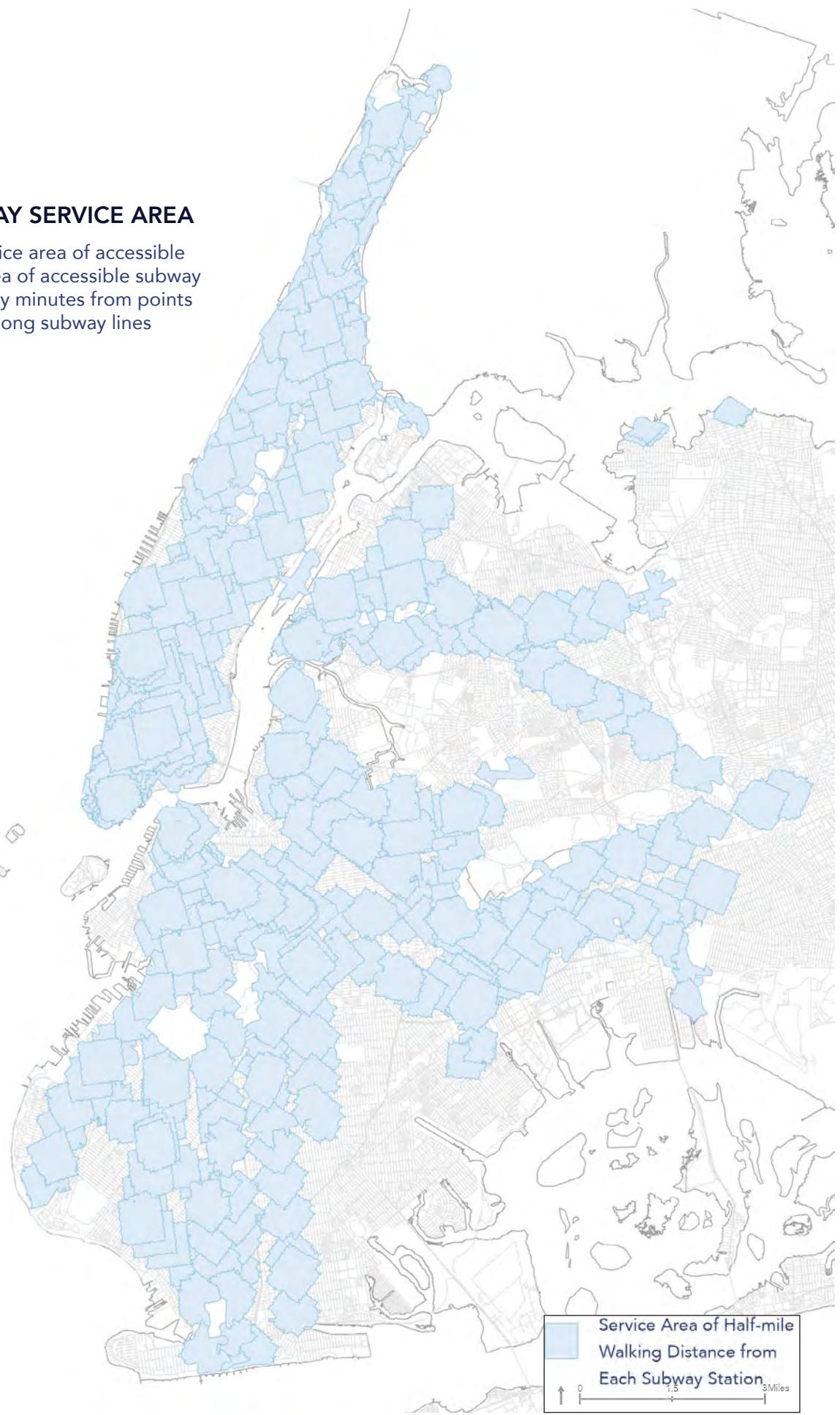
## SUBWAY LINES AND STATIONS

This shows New York City's subway stations and lines. The transparent points and lines indicate areas outside of Citi Bike's immediate service area and its service area via accessible subway stations.



## ACCESSIBLE SUBWAY SERVICE AREA

This map shows the service area of accessible subway lines. Service area of accessible subway lines i.e. lines within thirty minutes from points within the service area along subway lines



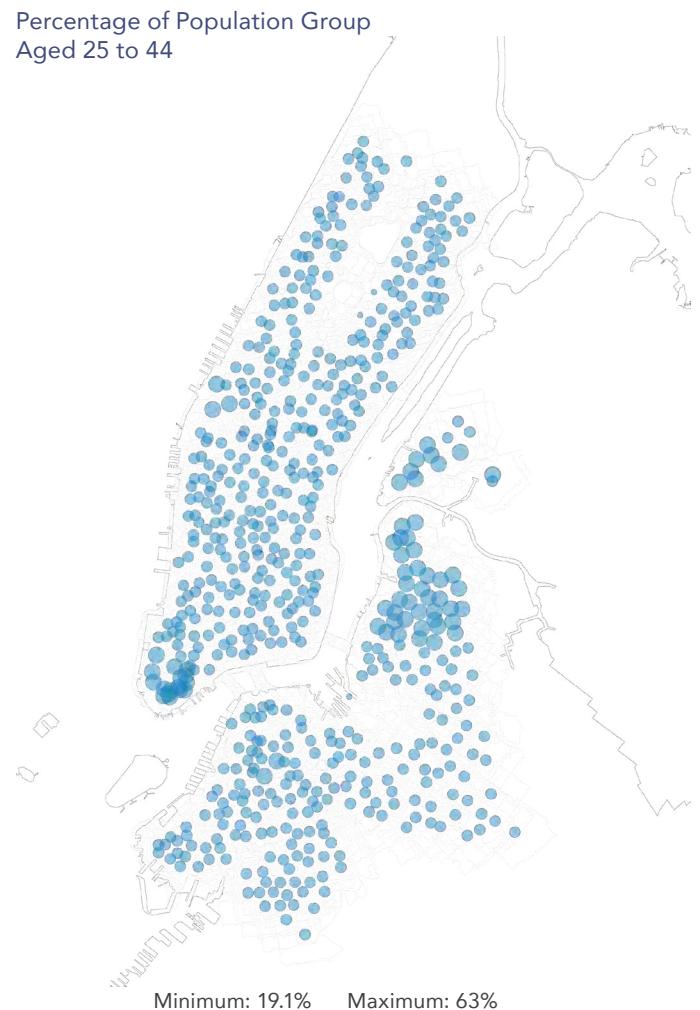
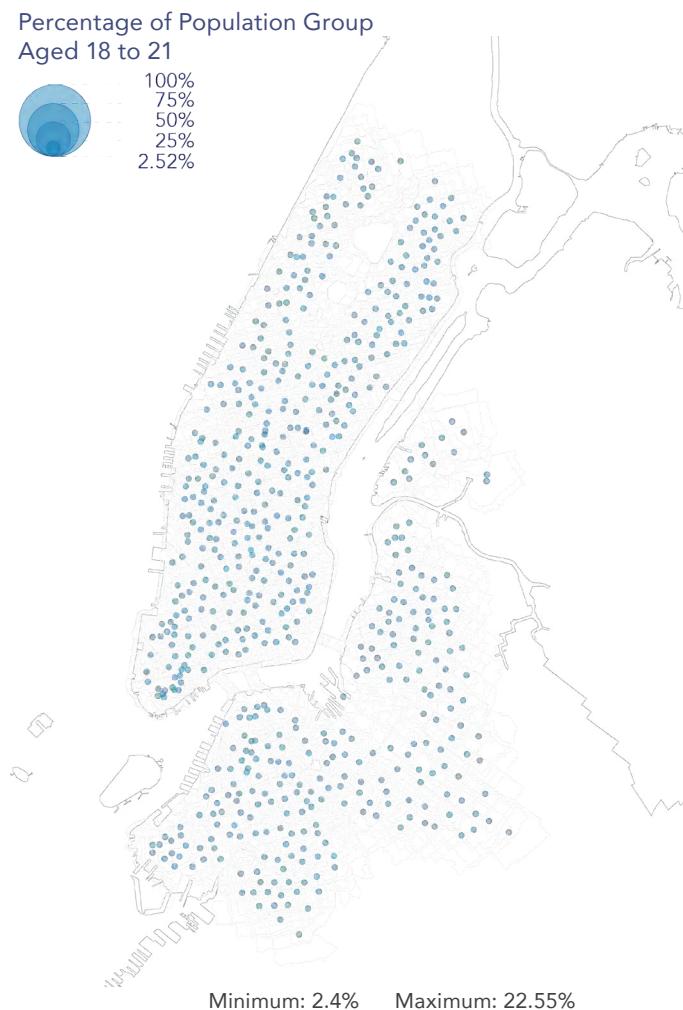
# Findings: Demographics

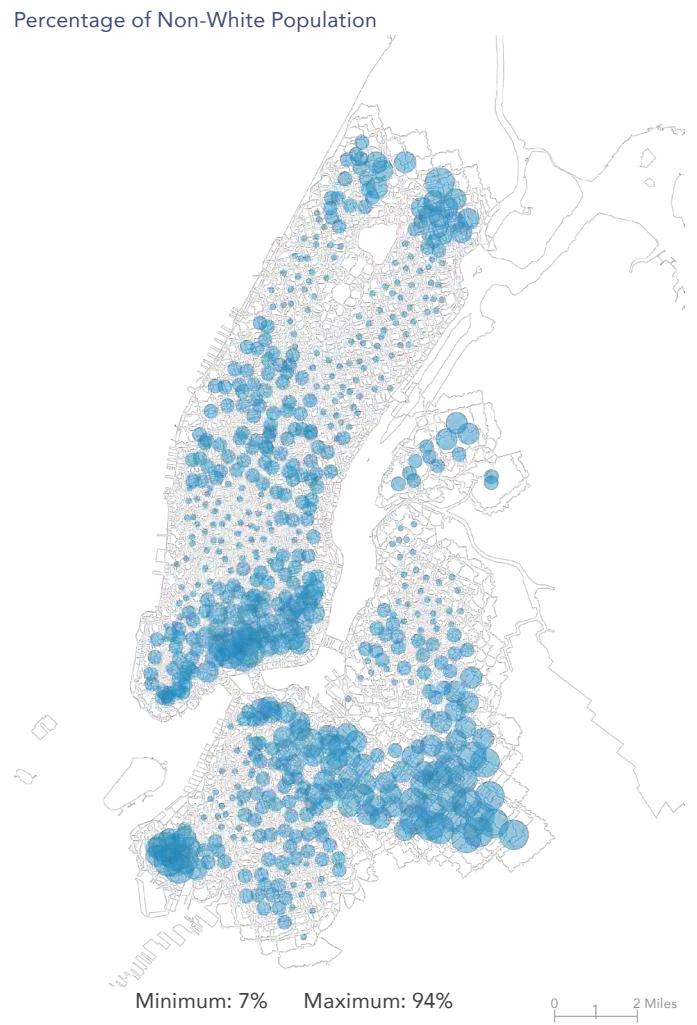
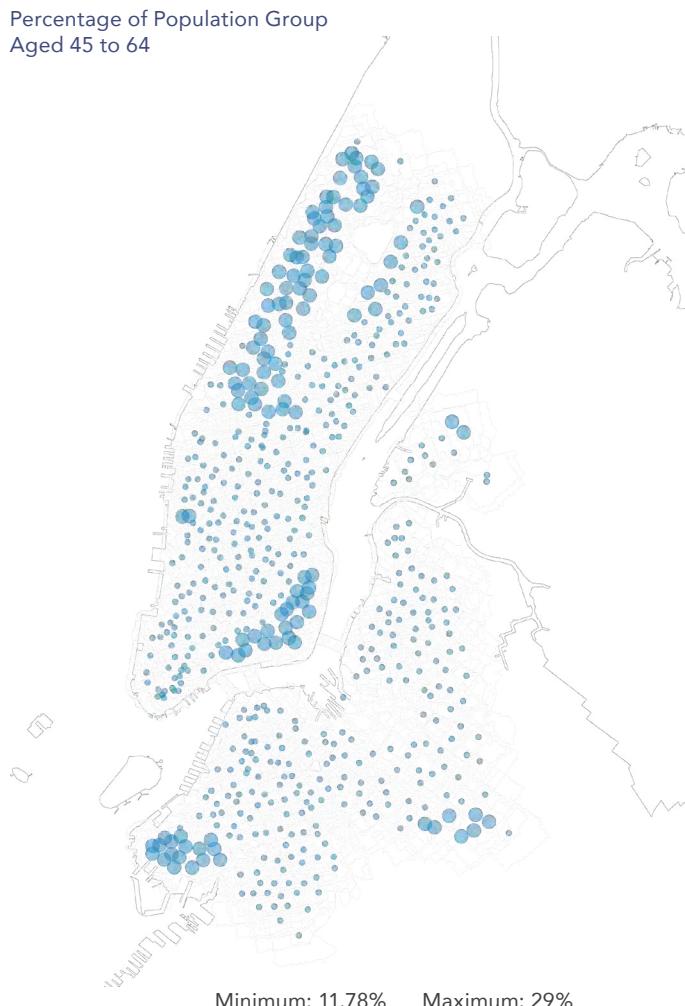
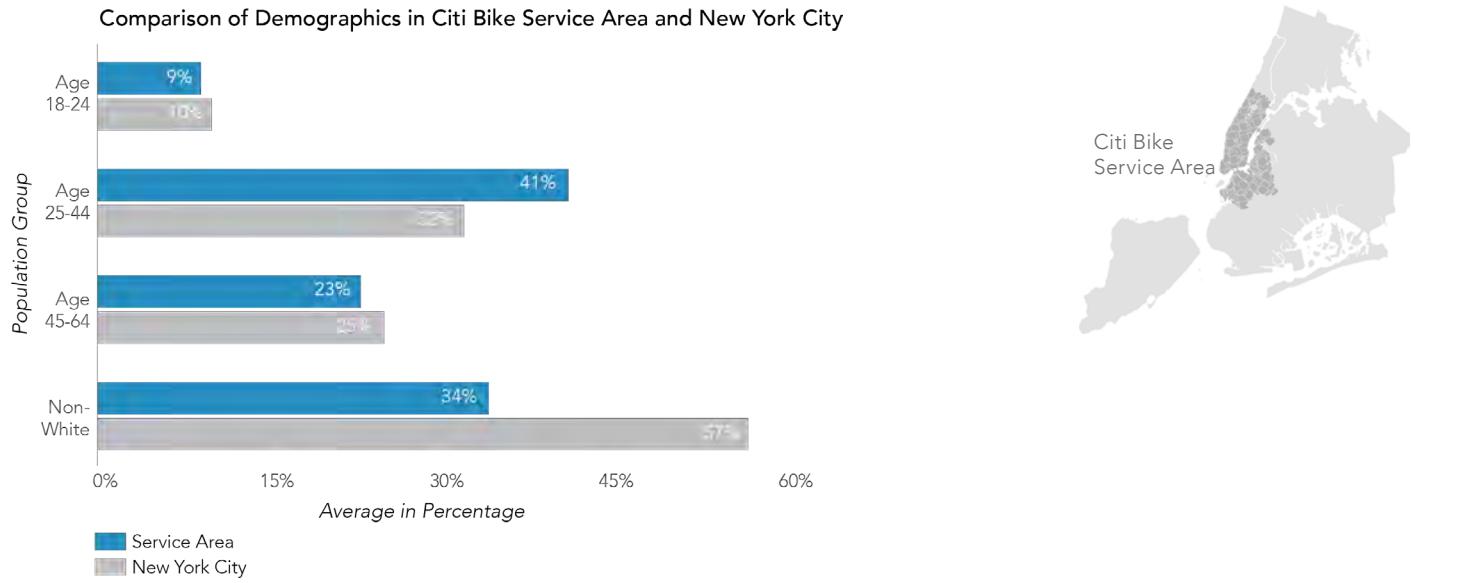
The four maps below show age and racial demographics in areas with immediate access to the Citi Bike network. Each blue dot represents the range of percentage of certain population group in the corresponding service area.

The age group with the largest population in the Citi Bike service area was people aged 25 to 44 years old with a 41% share of the population. Interestingly, the average of the 18 to 24 year old population was on par with the city-wide average, while the 45 to 64 year old population had a slightly larger

average. The 25 to 44 year old population had a slightly lower average than that of New York City.

Here, the average non-white population was 34%. This is comparatively lower than the city-wide average of 56.7%. This non-white population was concentrated in Manhattan's Chinatown and two Bridges neighborhoods, as well as Brooklyn's Crown Heights and Bedford neighborhoods. Neighborhoods further uptown in Manhattan had a significantly lower proportion of the non-white population.



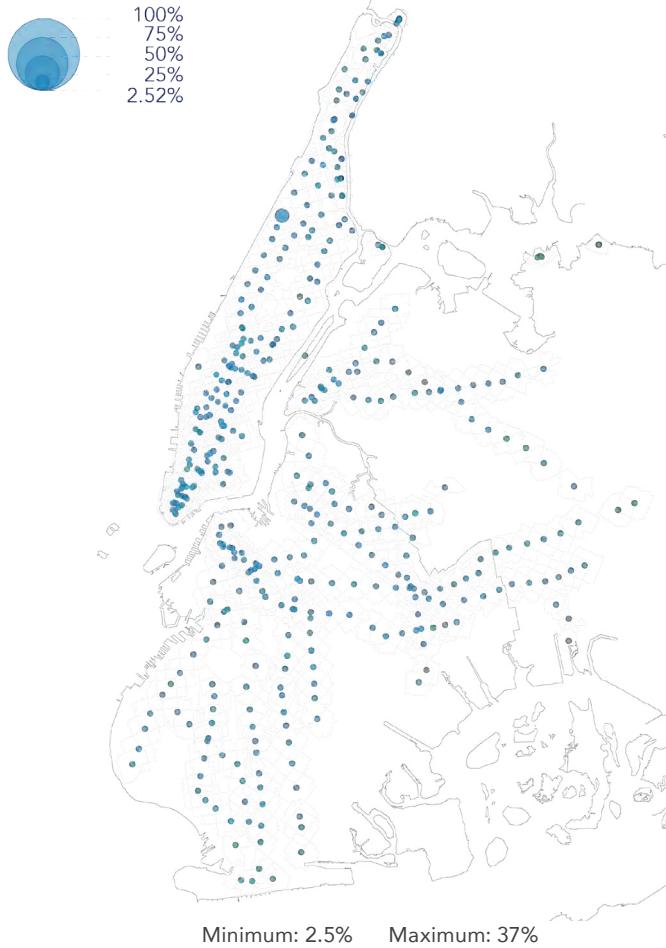


The four maps below show age and racial demographics in areas with access to the Citi Bike network through the subway system. Each blue dot represents the range of percentage of certain population group in the corresponding service area.

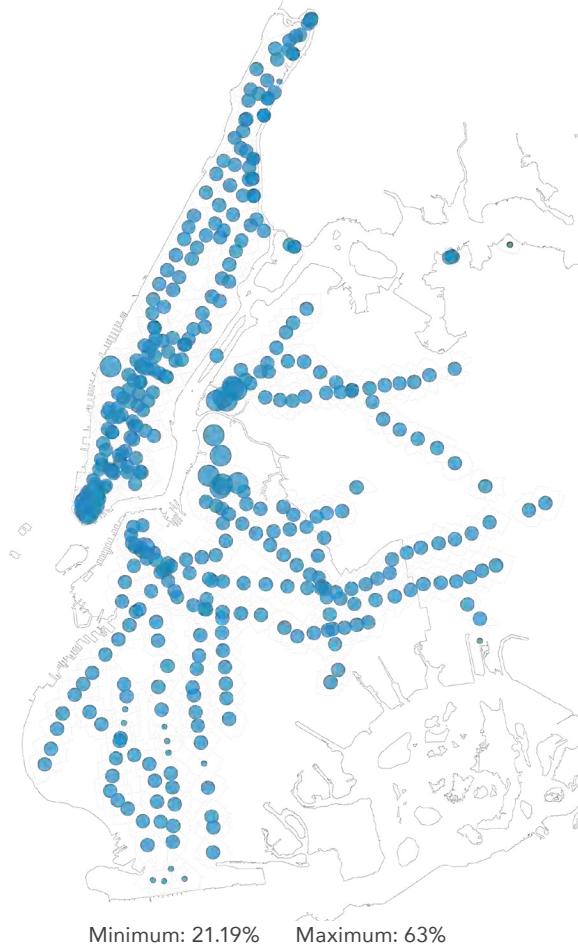
This suggests that Citi Bike's target demographic could be young, white people. Looking at areas with access to Citi Bike through the subway system provides similar findings. Here, people aged 25 to 44 years old also had the largest share of the population. While the average of non-white people

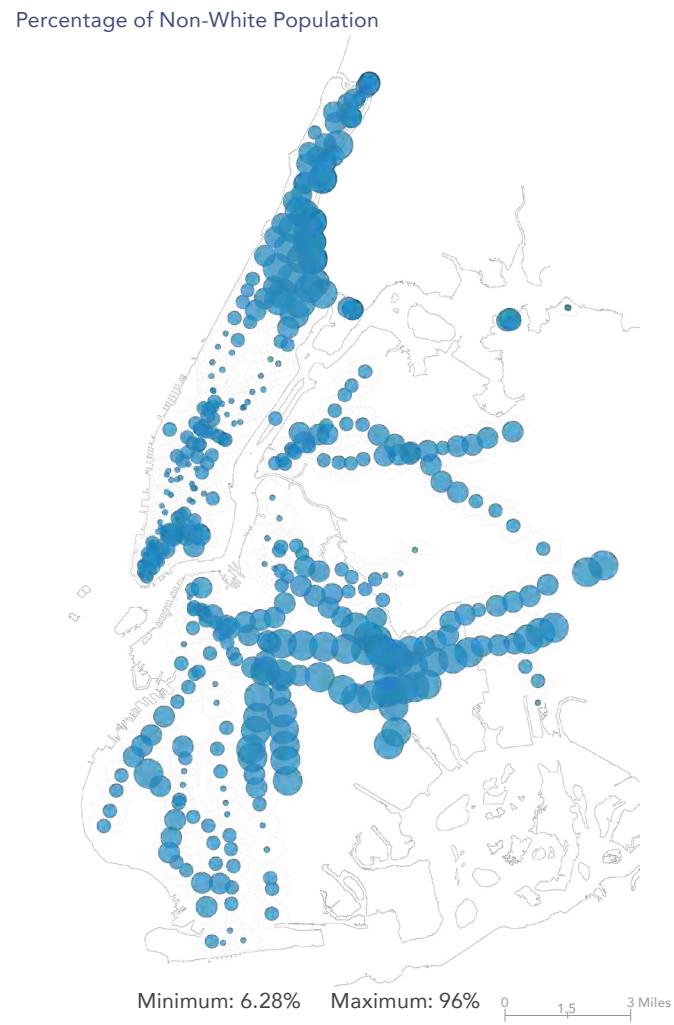
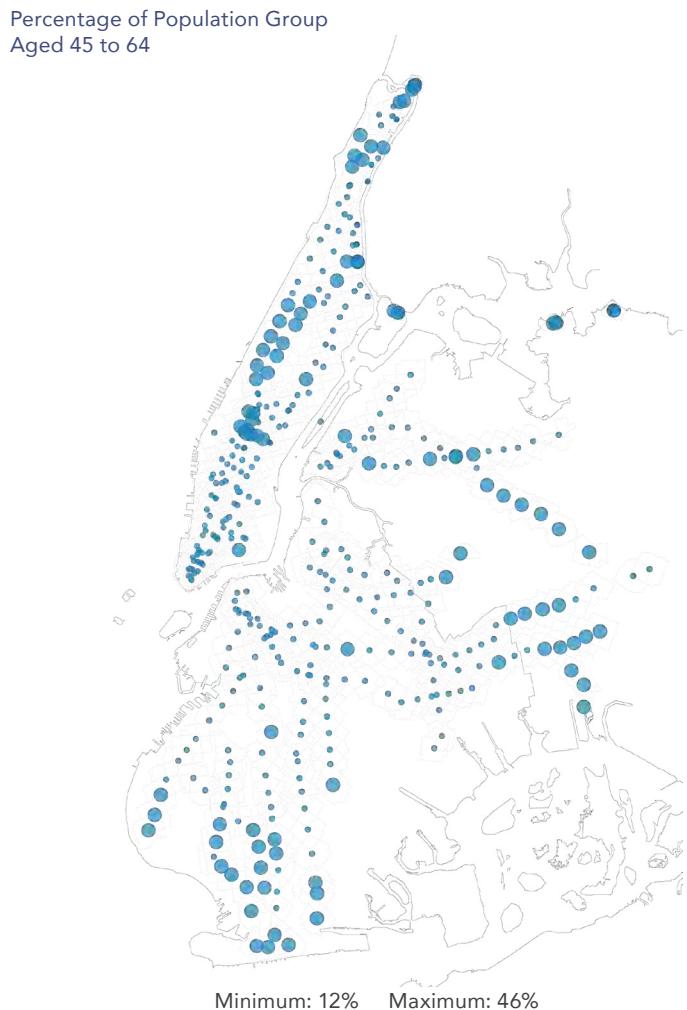
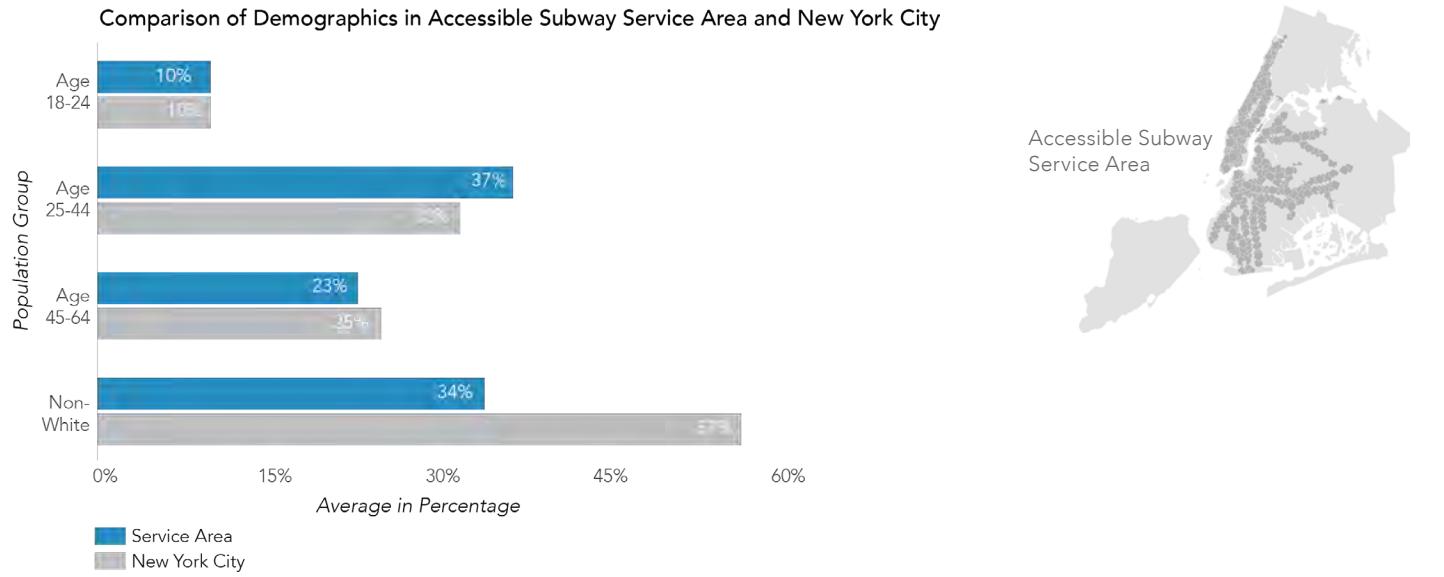
held steady at 34%, the proportion of the 25 to 44 years old population reduced from 41% to 37%.

Percentage of Population Group  
Aged 18 to 21



Percentage of Population Group  
Aged 25 to 44





The four maps below show age and racial demographics in areas with no access to the Citi Bike network either directly or through the subway system. Each blue dot represents the range of percentage of certain population group in the corresponding service area.

at 63% than that of areas with access to Citi Bike. The proportion of 25 to 44 year olds also reduced to 30%, which is slightly lower than the city-wide average. The proportion of other age groups corresponded to that of areas with access to Citi Bike.

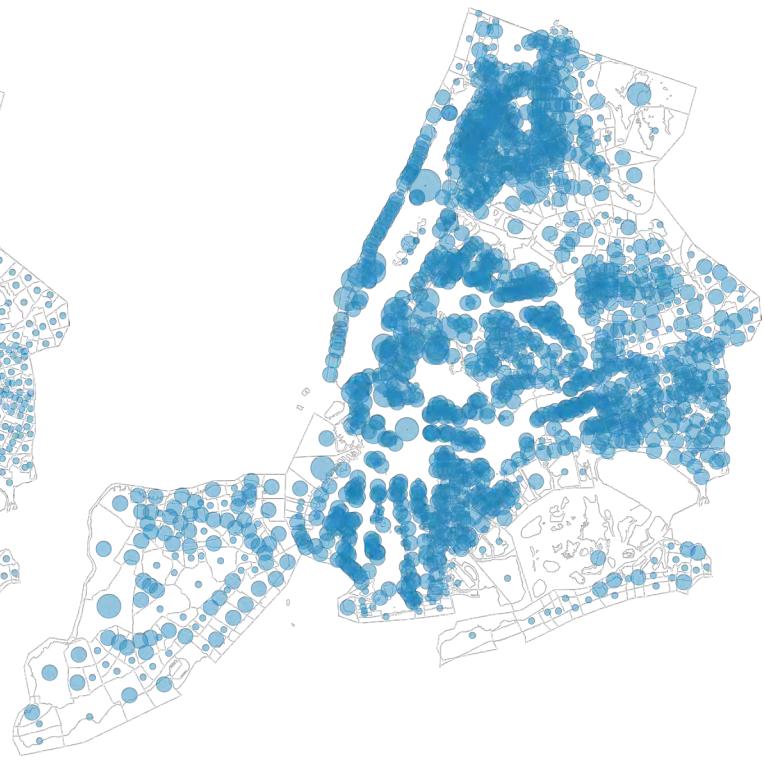
The distribution of the population in areas with no access to Citi Bike was also quite similar to areas with access to Citi Bike in terms of age. However, the non-white population was significantly higher

Percentage of Population Group  
Aged 18 to 21

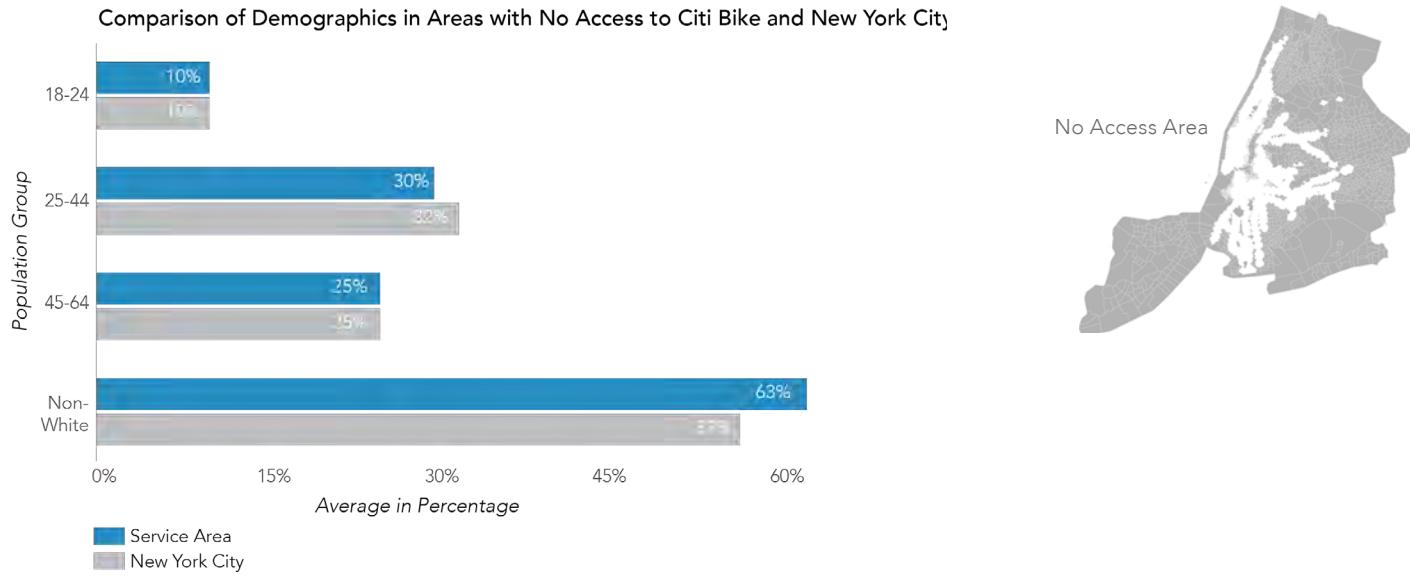


Minimum: 0% Maximum: 88%

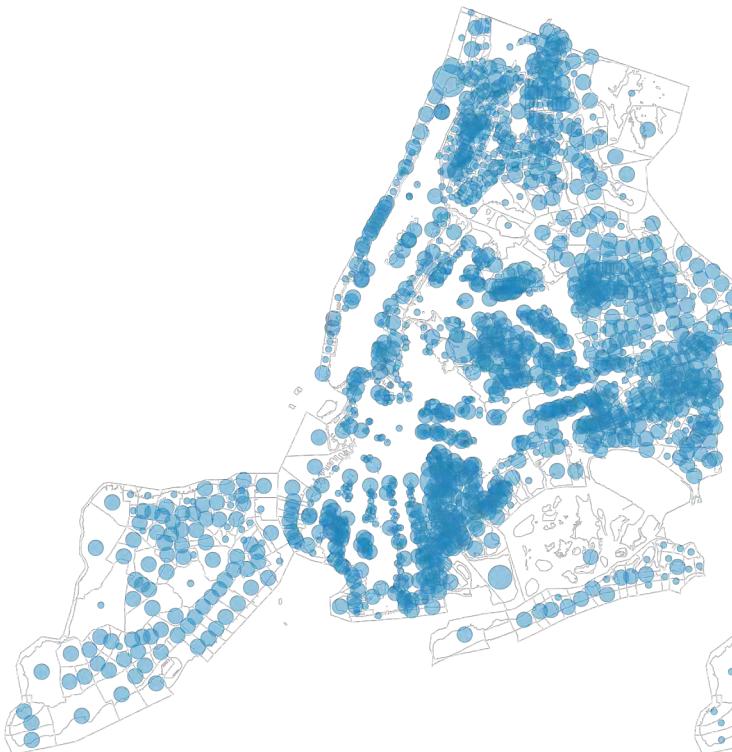
Percentage of Population Group  
Aged 25 to 44



Minimum: 0% Maximum: 100%

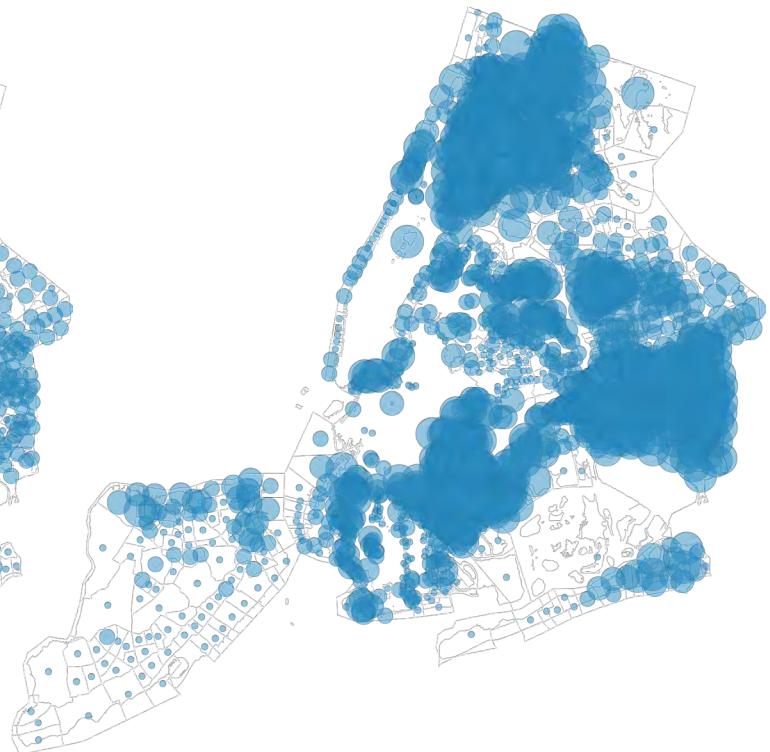


Percentage of Population Group  
Aged 45 to 64



Minimum: 12%   Maximum: 46%

Percentage of Non-White Population



Minimum: 6.28%   Maximum: 96%   0   2.5   5 Miles

# Conclusion

This analysis showed that Citi Bike's accessibility is rather robust when viewed through a bi-modal lens. This extension of the service area allowed for an analysis that took into account people without immediate access to the Citi Bike network. Yet, people in the Bronx, Staten Island, most of Queens, and a large part of Brooklyn had no access to Citi Bike even with this expanded service area.

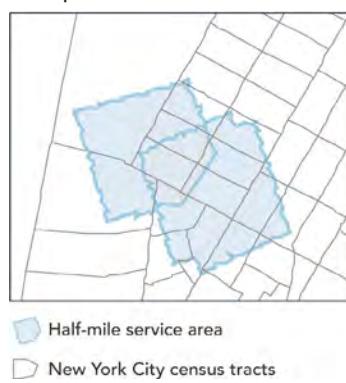
Evaluating the demographics in areas with varying access to Citi Bike demonstrated that access to the Citi Bike network is, in fact, related to race but not to age. Citi Bike's level of access to younger people is unsurprising given New York City's relatively young population. Minority populations are less likely to have access than white populations.

For a more comprehensive analysis, the scope of our research question could be expanded to include considerations of income, commercial and residential area, and Citi Bike trip data like travel direction and distance. Our analysis would be bolstered by incorporating data on the proportion of Citi Bike trips that were docked or initiated close to subway stations. It would also be more robust if it explored the relationship between income and accessibility to Citi Bike stations. Our analysis focused on accessibility as it related to residential demographics, but it would gain an additional layer of depth if demographics in business and work areas were also considered. The analysis done here could be factored into a study on the viability of different New York City locations for Citi Bike stations. Finally, this project has the potential to be expanded into an inquiry on how Citi Bike decides where to locate its stations.

Our search radius for the network analysis was based on an assumption that half a mile was a comfortable walking distance for people. As a result, the search radius did not take the effect of important factors such as incline and disability into account. Our analysis would have been more thorough if we had included these factors in it.

Finally, we used an average subway speed to calculate the distance along a subway line. This did not account for changes in speed between express trains, which skip certain stations, and local trains which make all stops. Additionally, we did not factor differences in speed between subway lines into our analysis. If we were able to account for the various speeds along different subway lines and between express and local trains, our analysis would have been more comprehensive.

The Modifiable Areal Unit problem was a challenge we had to reckon with in our demographic analysis. The service area and census tract boundaries did not align, and as a result, we could not use the population values in the census tracts directly in our analysis. We estimated the population in our service areas by calculating the proportion of service areas in the census tract(s) they intersected with. This process limited the accuracy of our results.



# Appendix

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## Data Sources

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Retrieved 27 April 2017, from <https://gwwash.org/view/4524/average-schedule-speed-how-does-metro-compare>

	Why	Step-by-step	Filename in GIS
<b>1. Demographics</b>	An understanding of the demographics around Citi Bike locations will give an indication of the characteristics of Citi Bike users  racial minority only interested in young population and working-age population	<ol style="list-style-type: none"> <li>Download 2015 ACS 5-year Estimate by census tracts - "SELECTED CHARACTERISTICS OF THE TOTAL AND NATIVE POPULATIONS IN THE UNITED STATES ", "COMMUTING CHARACTERISTICS BY SEX", "RACE"</li> <li>Clean dataset in excel               <ol style="list-style-type: none"> <li>non-white</li> <li>age group 18-24</li> <li>age group 25-44</li> <li>age group 45-64</li> <li>median income</li> </ol> </li> <li>Table join demographics data to 2015 census tracts shapefile</li> <li>Calculate average citywide demographics               <ol style="list-style-type: none"> <li>non-white</li> <li>age group 18-24</li> <li>age group 25-44</li> <li>age group 45-64</li> </ol> </li> </ol>	
			56.70671338 9.895009258 31.51973426 24.606304
<b>2. Base Layers</b>		<ol style="list-style-type: none"> <li>Create a geodatabase for base layers</li> <li>Download lion shapefile</li> <li>Select pedestrian-accessible streets</li> <li>Export data</li> </ol>	Base_layer lion pedestrian_network
a) nyc streets		<ol style="list-style-type: none"> <li>Download nyc borough boundary shapefile</li> </ol>	Boroughs_2016
b) nyc borough boundary		<ol style="list-style-type: none"> <li>Download nyc greenspaces shapefile</li> </ol>	NYC_Greenspace
c) nyc greenspaces			
d) nyc census tracts boundary		<ol style="list-style-type: none"> <li>Download 2015 census tract shapefile from U.S. Census Bureau</li> <li>Select the counties in NYC - Kings County, Richmond County, Queens County, Bronx County, New York County</li> <li>Export data</li> </ol>	NYC_CTs_2015
<b>3. Network Analysis</b>	Where is citibike accessible to by walking?	<ol style="list-style-type: none"> <li>Download Citi Bike station data</li> <li>Export NYC citibike stations from dataset</li> <li>Network analysis to calculate service area of each Citi Bike station for up to 1/2 mile (using Citi Bike docking stations and pedestrian-only streets)</li> </ol>	Citibike_Stations CitibikeStations_NYOnly CBS_ServiceAreas_All
b) subway stations		<ol style="list-style-type: none"> <li>Download subway station data &amp; project it</li> </ol>	SS_Projected
<b>4. Spatial Relationship</b>	Where is citi bike located in relation to subway stops? Where do service areas of Citi Bike and subway overlap? This helps with seeing if people can switch between transportation modes		
a) Walking distance between a citi bike station and its nearest subway station		<ol style="list-style-type: none"> <li>"Make Closest Facilities Layer" to calculate distance to the closest subway from Citi Bike stations</li> <li>Table join CBStoSS_ClosestFacilityWalkingDistance to CitibikeStations_NYOnly</li> </ol>	CBStoSS_ClosestFacilityWalkingDistance CBS_WalkingDistanceToNearestSS
b) Numbers of subway stations within 1/2 mile walking distance to a citi bike station		<ol style="list-style-type: none"> <li>"Spatial Join" - point to polygon</li> </ol>	SS_CServicearea_Spatialjoin

Why	Step-by-step	Filename in GIS
	2. Table join SS_CBSERVICEAREA_Spatialjoin to CitiBikeStations_NYConly	CBS_NumberSS_withinServiceArea
c) Subway stations along the same subway line within 30-min commuting time to a citibike station	<p>Download Subway Lines &amp; Project to NAD83</p> <p>Clean Subway lines</p> <ol style="list-style-type: none"> <li>1. "Select by location" to select SS points that are within CBS_ServiceAreas_ALL and export data</li> <li>2. Get subway travel speed</li> <li>3. Calculate length of subway line that are within 30-mins commuting time</li> <li>4. Perform network analysis to create service areas of SS that are within distance along the subway network</li> <li>5. "Select by location" to select SS points that are within SS_CBS_polygons</li> <li>6. Perform network analysis to create service areas of SS_CBS_alongSL that are within 1/2 mile walking distances</li> </ol>	SubwayLines_Projected. SubwayLines_CleanedCorrected_Final SS_CBS_points 17 miles per hour 8.5 miles = 44880 ft SS_CBS_polygons SS_CBS_alongSL SS_CBS_ServiceArea
5. Demographics Comparison	An understanding of the demographics New York City-wide will give a basis for comparing or understanding Citi Bike's population demographics	
a) Network of Citi bike station: Proportional Split	<p>CBS_AGE</p> <ol style="list-style-type: none"> <li>1. Table Join age demographics table to CTs</li> <li>2. Export data and save</li> <li>3. Add a new field and calculate the area of census tracts</li> <li>4. "Union" Age_CTs_NYC and census tracts to split the service area into small parcels</li> <li>5. Add new fields Total_Pop_Partial, Age_18to24_Pop_Partial, Age_25to44_Pop_Partial, Age_45to64_Pop_Partial</li> <li>6. Calculate population for above fields</li> <li>7. Dissolved based on FID for service areas</li> <li>8. Calculate percentage of population for age 18 to 24, age 25 to 44 and age 45 to 64.</li> <li>9. Symbolizes by Proportional Density</li> </ol> <p>CBS_Race</p> <p>Repeat the steps with racial demographic</p> <p>SS_CBS_AGE</p> <ol style="list-style-type: none"> <li>1. Table Join age demographics table to CTs</li> <li>2. Export data and save</li> <li>3. Add a new field and calculate the area of census tracts</li> <li>4. "Union" Race_CTs_NYC and census tracts to split the service area into small parcels</li> <li>5. Add new fields Total_Pop_Partial, Age_18to24_Pop_Partial, Age_25to44_Pop_Partial, Age_45to64_Pop_Partial</li> <li>6. Calculate population for above fields</li> <li>7. Dissolved based on FID for service areas</li> <li>8. Calculate percentage of population for non_white</li> <li>9. Symbolizes by Proportional Density</li> </ol>	Age_CTs_NYC Area_Acres CBS_CTs_Union Area_Partial Proportion Age_18to24_Per, Age_25to44_Per, Age_45to64_Per