CSC 47400 FINAL PROJECT
Visualising Bus Lane Violations Trends by NYC Neighborhood

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1. BACKGROUND

New York City is notorious for its traffic crisis. According to the New York Post, NYC is the worst ranked city in the U.S. for traffic congestion (New York Post, 2023). It is one of the leading causes of stress in NYC, and a primary contributor to this are illegal bus lane violations. Bus lanes are reserved lanes in the road dedicated for buses to move along; this ensures quick and easy flow of buses so that they can arrive at their stop. However, when these bus lanes are violated (i.e. a private vehicle parks in or next to a bus lane), it prevents buses from reaching their stop. Several assemblypeople, including Mayor-to-be Zohran Mamdani stressed the importance of keeping violations out of bus lanes: "Bus lanes make our buses faster, but double parking slows them down" (Metropolitan Transit Authority, 2024).

Many areas of NYC which are not accessible by the subway heavily rely on buses. When areas where people go to work, attend classes, or go home are difficult to reach due to bus lane violations and delays, it causes citywide stress and protests. In fact, nearly two-thirds of CUNY students have reported stress due to their commute, and the most popular solution among them is to alleviate traffic (Wolfgang, 2018). In addition, according to ABC News 7, just last year there was a protest held by Brooklyn College students to address the unreliability of buses in Flatbush (Carlo 2024).

City officials have been trying to confront this by placing fines and doing increased police patrol. However, given how costly it is to allocate these resources, it is important to know where and when to distribute enforcements against bus lane violations by priority. Data analysis and data visualizations can be used to address this.

2. DATASET OVERVIEW

In recent years, the Metropolitan Transit Authority (MTA) has partnered with the New York City Department of Transportation (NYC DOT) and the New York City Department of Finance (NYC DOF) to launch the Automated Camera Enforcement (ACE) program. This enables real-time camera detection for bus lane violations; they can record as much as the license plate, violation timestamp, exact geolocation, and bus route the violation took place. The NYC ACE dataset is available here, providing logs since 2019, and having over 4 million records. Below are the fields the dataset has:
- 'Violation ID'
- 'Vehicle ID'
- **'First Occurrence'**
- 'Last Occurrence'
- 'Violation Status'
- **'Violation Type'**
- 'Bus Route ID'

- **'Violation Latitude'**
- **'Violation Longitude'**
- 'Stop ID'
- 'Stop Name'
- 'Bus Stop Latitude'
- 'Bus Stop Longitude'
- 'Violation Georeference'
- 'Bus Stop Georeference'

3. OUR SOLUTION

This project aims to use the ACE violations dataset and combine it with NYC neighborhood geolocations to determine neighborhood-wise trends. The purpose of this is to determine where and when violations occur the most, in order to determine the priority of enforcement resource allocation. This helps the city focus enforcement on the right areas at the right times, so resources and money do not end up being wasted. The dashboards we made answer the following questions:
- Where are the worst violation hotspots?
- How have violations changed month to month?
- Which neighborhood deviates from their borough average (i.e. outliers)?
- When during the day do violations occur the most?
- What are major violation types per neighborhood?

4. TOOLS AND METHODOLOGY

Tools
The following tools were used:
- Google Colab
- pandas + geopandas
- Matplotlib
- Kepler.gl
- React + Recharts

Preliminary EDA

This project only focuses on 2025 data for now. For this reason, we used pandas to only extract them. The earliest date in the last 2.5M rows is on January 1st.

```python
import pandas as pd
path = '/content/drive/My Drive/fall 2025/CSC 474/Project/Dataset/MTA_Bus_Automated_Camera_Enforcement_Violations__Beginning_October_2019.csv'

df = pd.read_csv(path, nrows=2500000)
```

```python
df.columns
```
```
Index(['Violation ID', 'Vehicle ID', 'First Occurrence', 'Last Occurrence',
       'Violation Status', 'Violation Type', 'Bus Route ID',
       'Violation Latitude', 'Violation Longitude', 'Stop ID', 'Stop Name',
       'Bus Stop Latitude', 'Bus Stop Longitude', 'Violation Georeference',
       'Bus Stop Georeference'],
      dtype='object')
```

```python
df['First Occurrence'].min()
```
```
'01/01/2025 01:00:01 PM'
```

The dataset was then cleaned and parsed. The 'First Occurrence' field (which is a timestamp) was converted to pandas datetime format and set to New York's timezone. The additional fields Month and Day were derived.

```python
df['First Occurrence'] = pd.to_datetime(df['First Occurrence'], errors='coerce', utc=True)
```

```python
time_local = df['First Occurrence'].dt.tz_convert('America/New_York')
df['Month'] = (time_local.dt.tz_localize(None).dt.to_period('M').dt.to_timestamp())
df['Day'] = time_local.dt.floor('D')
```

A geodataframe is used to store longitude and latitude coordinates of different locations as geometry objects. This way, they can be mapped later. The dataset was converted to a geodataframe.

```python
df['Violation Latitude'] = df['Violation Latitude'].astype(float)
df['Violation Longitude'] = df['Violation Longitude'].astype(float)

violations_geo = gpd.GeoDataFrame(
    df,
    geometry=gpd.points_from_xy(df['Violation Longitude'], df['Violation Latitude']), crs=4326
)
```

An **areas** geodataframe was compiled with longitude and latitude coordinates of ~30 NYC neighborhoods. A field was added to this geodataframe called **buffer** which defined a 1 kilometer buffer zone around each neighborhood's geocoordinated. All violations will be aggregated within each neighborhood's respective buffer zone.

```
areas = [
    ('Lower Manhattan / FiDi', 40.7075, -74.0113),
    ('Soho / Greenwich Village', 40.7280, -74.0000),
    ('Lower East Side', 40.7150, -73.9860),
    ('Midtown', 40.7549, -73.9840),
    ('Upper East Side', 40.7736, -73.9566),
    ('Upper West Side', 40.7870, -73.9754),
    ('Harlem', 40.8116, -73.9465),
    ('Downtown Brooklyn', 40.6925, -73.9905),
    ('Williamsburg', 40.7081, -73.9571),
    ('Bushwick', 40.6943, -73.9213),
    ('Bed-Stuy', 40.6872, -73.9418),
    ('Crown Heights', 40.6681, -73.9448),
    ('Flatbush', 40.6409, -73.9598),
    ('Bay Ridge', 40.6350, -74.0230),
    ('Coney Island', 40.5755, -73.9707),
    ('Sunnyside', 40.7451, -73.9196),
    ('Jackson Heights', 40.7557, -73.8852),
    ('Flushing', 40.7675, -73.8331),
    ('Forest Hills', 40.7187, -73.8448),
    ('Jamaica Center', 40.7027, -73.7993),
    ('Far Rockaway', 40.6054, -73.7550),
    ('South Bronx', 40.8160, -73.9070),
    ('Mott Haven', 40.8090, -73.9220),
    ('Fordham', 40.8614, -73.8903),
    ('Riverdale', 40.9030, -73.9140),
    ('Pelham Parkway', 40.8575, -73.8590),
    ('Staten Island North Shore', 40.6411, -74.0875),
    ('St. George', 40.6438, -74.0740),
    ('Mid-Island / New Dorp', 40.5735, -74.1172),
    ('Elmhurst', 40.7365, -73.8780),
    ('Astoria', 40.7644, -73.9235),
    ('Maspeth', 40.7239, -73.9120),
    ('Bushwick', 40.6943, -73.9213),
    ('Flatbush', 40.6409, -73.9598),
    ('Bayside', 40.7660, -73.7803),
    ('DUMBO', 40.7033, -73.9881),
    ('Coney Island', 40.5755, -73.9707),
    ('Howard Beach', 40.6573, -73.8448),
    ('Bensonhurst', 40.6115, -73.9970),
    ('Homecrest', 40.5932, -73.9597),
    ('Hunts Point', 40.8121, -73.8831),
    ('Rossville', 40.5517, -74.2153),
    ('Great Kills', 40.5521, -74.1516),
    ('Cypress Hills', 40.6898, -73.8718)
]

areas_geo = gpd.GeoDataFrame(
    areas,
    columns=['area', 'lat', 'lon'],
    geometry=gpd.points_from_xy([a[2] for a in areas], [a[1] for a in areas]),
    crs='EPSG:4326'
)

areas_geo['buffer'] = (areas_geo.to_crs(2263).buffer(1000 * feet_per_meter).to_crs(4326))
```

Finally, a **spatial join** was done to intersect all violations with area buffer zones. A left join was done to include as many violations as possible. This new dataframe contains all violations within the buffer zones only.

```
viol_join = gpd.sjoin(violations_geo, areas_geo.set_geometry('buffer'), how='left', predicate='within')
```

Dashboard 1 Code: Where are the worst violation hotspots?

This section aimed to look at violation hotspots by quarter of 2025. The 'Quarter' field was derived from the 'Month' field, and the spatially joined dataframe (containing buffer-zone violations) was grouped by area and quarter. Then, it was merged with areas_geo to include the specific buffer zones geometry.

```
viol_join['Quarter'] = viol_join['Month'].dt.to_period('Q').astype(str)

quarterly = viol_join.groupby(['area', 'Quarter']).size().reset_index(name='violations')
```

```
areas_quarter = quarterly.merge(
    areas_geo[['area', 'buffer']],
    on='area',
    how='left'
)

areas_quarter = gpd.GeoDataFrame(areas_quarter, geometry='buffer', crs='EPSG:4326')
```

	area	Quarter	violations	buffer	lon	lat
0	Astoria	2024Q4	374	POLYGON ((-73.91166 40.76439, -73.91171 40.763...	-73.9235	40.7644
1	Astoria	2025Q1	1203	POLYGON ((-73.91166 40.76439, -73.91171 40.763...	-73.9235	40.7644
2	Astoria	2025Q2	1193	POLYGON ((-73.91166 40.76439, -73.91171 40.763...	-73.9235	40.7644
3	Astoria	2025Q3	1166	POLYGON ((-73.91166 40.76439, -73.91171 40.763...	-73.9235	40.7644
4	Astoria	2025Q4	462	POLYGON ((-73.91166 40.76439, -73.91171 40.763...	-73.9235	40.7644
...	...	...	...	...	...	...
152	Williamsburg	2024Q4	1113	POLYGON ((-73.94527 40.70809, -73.94532 40.707...	-73.9571	40.7081
153	Williamsburg	2025Q1	3368	POLYGON ((-73.94527 40.70809, -73.94532 40.707...	-73.9571	40.7081
154	Williamsburg	2025Q2	3289	POLYGON ((-73.94527 40.70809, -73.94532 40.707...	-73.9571	40.7081
155	Williamsburg	2025Q3	3173	POLYGON ((-73.94527 40.70809, -73.94532 40.707...	-73.9571	40.7081
156	Williamsburg	2025Q4	831	POLYGON ((-73.94527 40.70809, -73.94532 40.707...	-73.9571	40.7081

This was then exported to a GeoJSON file, then uploaded onto Kepler.gl to get visualizations. The resulting quarterly maps were then downloaded as HTML files to be embedded within our React frontend dashboard.

```
areas_quarter.to_file("nyc_area_quarter_polygons.geojson", driver="GeoJSON")
```

Dashboard 2 Code: How Have Violations Changed Month to Month?

A similar method was done to get monthly data. Since this is not being mapped, it was not subsequently joined again with areas_geo.

```
monthly = viol_join.groupby(['area', 'Month']).size().reset_index(name='violations')
```

To account for boroughs, they were mapped to the monthly dataframe using a python dictionary and the .map method.

```python
# add borough

area_to_borough = {
    'Astoria': 'Queens',
    'Elmhurst': 'Queens',
    'Flushing': 'Queens',
    'Howard Beach': 'Queens',
    'Jamaica Center': 'Queens',
    'Maspeth': 'Queens',
    'Bed-Stuy': 'Brooklyn',
    'Bensonhurst': 'Brooklyn',
    'Bushwick': 'Brooklyn',
    'Crown Heights': 'Brooklyn',
    'DUMBO': 'Brooklyn',
    'Downtown Brooklyn': 'Brooklyn',
    'Flatbush': 'Brooklyn',
    'Williamsburg': 'Brooklyn',
    'Fordham': 'Bronx',
    'Hunts Point': 'Bronx',
    'Mott Haven': 'Bronx',
    'Pelham Parkway': 'Bronx',
    'Riverdale': 'Bronx',
    'South Bronx': 'Bronx',
    'Harlem': 'Manhattan',
    'Lower East Side': 'Manhattan',
    'Lower Manhattan / FiDi': 'Manhattan',
    'Midtown': 'Manhattan',
    'Soho / Greenwich Village': 'Manhattan',
    'Upper East Side': 'Manhattan',
    'Upper West Side': 'Manhattan',
    'Mid-Island / New Dorp': 'Staten Island',
    'St. George': 'Staten Island',
    'Staten Island North Shore': 'Staten Island'
}

monthly['borough'] = monthly['area'].map(area_to_borough)
```

`monthly.head()`

	area	Month	violations
0	Astoria	2024-12-01	374
1	Astoria	2025-01-01	421
2	Astoria	2025-02-01	353
3	Astoria	2025-03-01	429
4	Astoria	2025-04-01	401

This dataframe has then been exported to a CSV file.

```python
monthly.to_csv('nyc_monthly_violations_per_area.csv')
```

Dashboard 3 Code: Which Neighborhoods Deviated From Their Borough Average?

These next lines of code perform something similar. To get borough-wise data, the deliverable from dashboard 1 (areas_quarter dataframe) was added the same extra 'borough' column, and then grouped by borough and Quarter. The borough average was calculated by dividing borough totals by the unique number of boroughs, then merged with the original areas_quarter data dataframe along with calculated borough totals. To calculate the deviation percentage, an additional field was added to compute the difference of each violation total per neighborhood with borough average, then divide then by the borough average.

```python
areas_quarter['borough'] = areas_quarter['area'].map(area_to_borough)

borough_totals = areas_quarter.groupby(['borough', 'Quarter'])['violations'].sum().reset_index(name='violations_borough_total')

borough_avgs = borough_totals.copy()
borough_avgs['borough_avg'] = borough_avgs['violations_borough_total'] / areas_quarter.groupby('borough')['area'].nunique().reindex(borough_avgs['borough']).values

merged = areas_quarter.merge(borough_totals, on=['borough', 'Quarter'])
merged = merged.merge(borough_avgs[['borough','Quarter','borough_avg']], on=['borough','Quarter'])

merged['deviation_pct'] = ((merged['violations'] - merged['borough_avg']) / merged['borough_avg'])
```

```python
merged.head()
```

	area	Quarter	violations	lon	lat	borough	violations_borough_total	borough_avg	deviation_pct
0	Astoria	2024Q4	374	-73.9235	40.7644	Queens	11378	1896.333333	-0.802777
1	Astoria	2025Q1	1203	-73.9235	40.7644	Queens	31231	5205.166667	-0.768883
2	Astoria	2025Q2	1193	-73.9235	40.7644	Queens	33972	5662.000000	-0.789297
3	Astoria	2025Q3	1166	-73.9235	40.7644	Queens	26386	4397.666667	-0.734859
4	Astoria	2025Q4	462	-73.9235	40.7644	Queens	7359	1226.500000	-0.623318

This was then exported to a CSV file.

```python
merged.to_csv('nyc_borough_violations.csv')
```

To visualize the exported CSV file, [include code + explanations from Recharts]. - Debasree

Dashboard 4 Code: When During the Day do Violations Occur?

To get the hourly violations and the day of the week it occurred, we simply derived new 'hour' and 'weekday' columns from the 'First Occurrence' field, then grouped the violations_geo dataframe with these new fields.

```
violations_geo['hour'] = violations_geo['First Occurrence'].dt.hour
violations_geo['weekday'] = violations_geo['First Occurrence'].dt.day_name()

time_patterns = violations_geo.groupby(['hour', 'weekday']).size().reset_index()
```

```
time_patterns.head()
```

	hour	weekday	0
0	0	Friday	3581
1	0	Monday	3181
2	0	Saturday	4818
3	0	Sunday	5468
4	0	Thursday	3405

The CSV file was then exported:

```
time_patterns.to_csv('nyc_violation_time_patterns.csv')
```

To visualize the exported CSV file, [include code + explanations from Recharts]. - Debasree

Dashboard 5 Code: What are the major violation types per neighborhood?

To get the data for this, the viol_join dataframe from earlier was grouped by 'area' and 'Violation Type.' Then, a pivot table was made from this to aggregate the total violations of each violation type by neighborhood.

```
viol_type_by_area = (
    viol_join.groupby(['area', 'Violation Type']).size().reset_index(name='count')
)
```

```
pivot_df = viol_type_by_area.pivot_table(
    index='area',
    columns='Violation Type',
    values='count',
    fill_value=0
)
```

```
pivot_df.head()
```

Violation Type	MOBILE BUS LANE	MOBILE BUS STOP	MOBILE DOUBLE PARKED
area			
Astoria	499.0	1304.0	2595.0
Bed-Stuy	217.0	5886.0	1763.0
Bensonhurst	0.0	2614.0	3707.0
Bushwick	0.0	6462.0	986.0
Crown Heights	1562.0	4298.0	466.0

This pivot table was then plotted as a stacked bar graph using matplotlib.

```python
import matplotlib.pyplot as plt

pivot_df.plot(
    kind='bar',
    stacked=True,
    figsize=(12,6),
    colormap='tab20'
)

plt.title("Violation Types by Neighborhood")
plt.ylabel("Total Violations")
plt.xlabel("Neighborhood")
plt.xticks(rotation=45, ha='right')
plt.tight_layout()
plt.show()
```
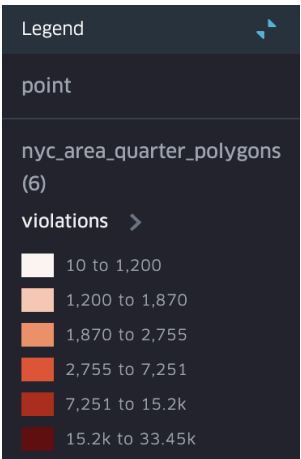
5. VISUALIZATIONS

View our interactive dashboard here.

Where Are the Worst Violation Hotspots?
The charts below feature violation risk hotspots color coded from white to red for different boroughs within New York City. The legend beside this shows the typical range of hotspots for each colored zone. They have also been split up into 4 quarters (Q1 Jan-Mar, Q2 Apr-Jun, Q3 Jul-Sept, Q4 Oct-Dec) to easily distinguish hotspot changes over the months.
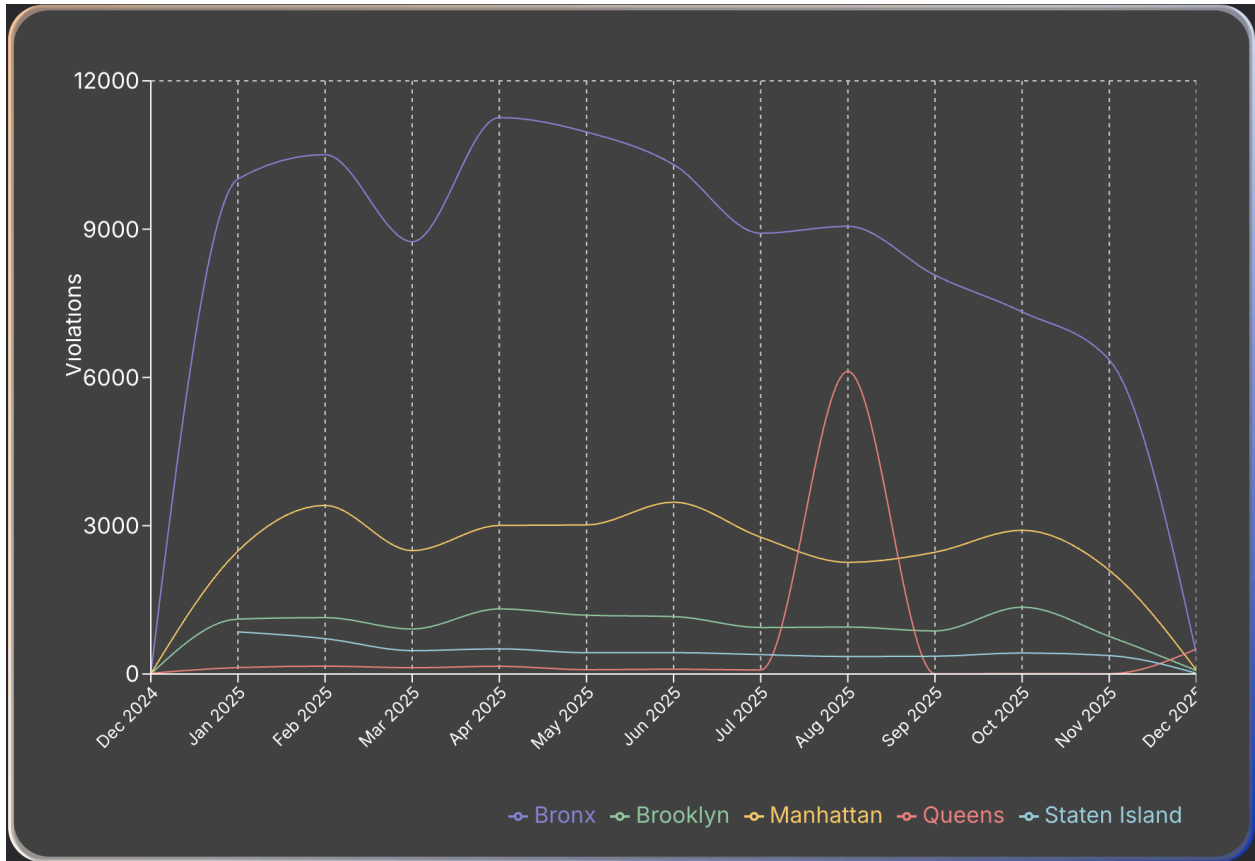
Across all quarters, the top 5 neighborhoods with the worst violation hotspots were Harlem, South Bronx, Upper East Side, Jamaica Center, and Flatbush.

From Q1 to Q2, Staten Island North Shore, Howard Beach, Lower Manhattan, and SoHo had a slight increase in violations while there was a slight decrease in Flushing. From Q2 to Q3, there was a slight increase in Williamsburg and a slight decrease in Elmhurst. Finally, from Q3 to Q4, Staten Island North Shore and Astoria had a slight increase in violations while Bushwick had a slight decrease. Thus, there weren't any drastic changes across all neighborhoods in the number of violations that occurred each quarter.

How Have Violations Changed Month-to-Month?

The figure below features the number of violations across December 2024 to December 2025, with 5 lines representing each borough of NYC. The Bronx had an overwhelming amount of around 3x more violations than the other boroughs, whereas Queens had the least amount of violations for most months with the exception of a sharp increase in August 2025.

Which Neighborhoods Deviate From Their Borough Average?
The charts below feature the number of violations per neighborhood within each borough, along with 5 lines representing each quarter across the months of December 2024 to December 2025. There is also a table below summarizing key insights from these visualizations.

Some other important noticings:
Queens - Q2 Apr-Jun had the highest number of violations except in Astoria and Elmhurst. Jamaica Center seemed to be the only neighborhood that deviated the most from the borough average.
Brooklyn - All neighborhoods had around the same levels of violations for all quarters except for Williamsburg and Flatbush. The borough average for all quarters was slightly higher than all the number of violations across all neighborhoods except for Flatbush which deviated the most.
Bronx - The borough average was slightly higher than the number of violations across all neighborhoods except for Pelham Parkway and Riverdale which were extremely lower than the borough average and the South Bronx which was even higher.
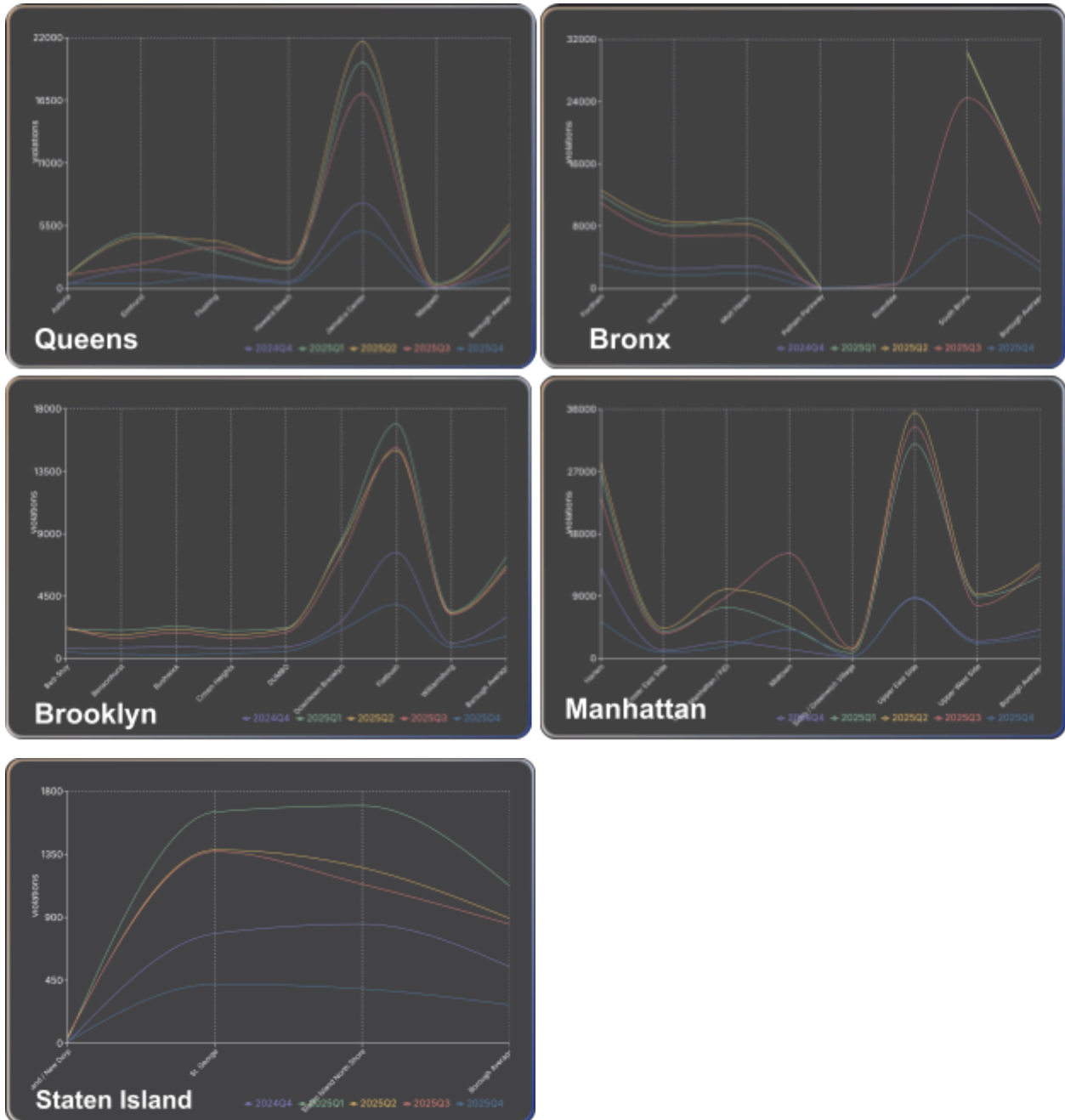
<u>Manhattan</u> - Q2 Apr-Jun had the highest number of violations except in Midtown and Greenwich Village. Harlem was slightly higher, the Upper East side was extremely higher, and the rest of the neighborhoods were slightly lower or around the same in number of violations compared to the borough average.

<u>Staten Island</u> - Mid-Island was much lower in number of violations compared to the borough average while all other neighborhoods didn't deviate much.

Across all boroughs, there is a common pattern of Q4 Oct-Dec 2025 being the lowest violation quarter while Q2 Apr-Jun 2025 and Q1 Jan-Mar 2025 were often highest in violations. This can be explained by many factors, such as Q4 having the lowest violations due to colder weather, more holidays which in turn causes fewer workdays, and more. Q1 having the highest violations can be explained by work, school, and regular commuting fully resuming after holidays. In this quarter, bus ridership rose sharply, especially in commuter-heavy areas like Jamaica Center, Flatbush, South Bronx, Upper East Side. Q2 also having the highest violations in some boroughs can be explained by better weather, school being in session, and more shopping, events, and tourism occurring. During these months, more bus usage naturally increases opportunities for more lane violations and obstructions near bus stops.
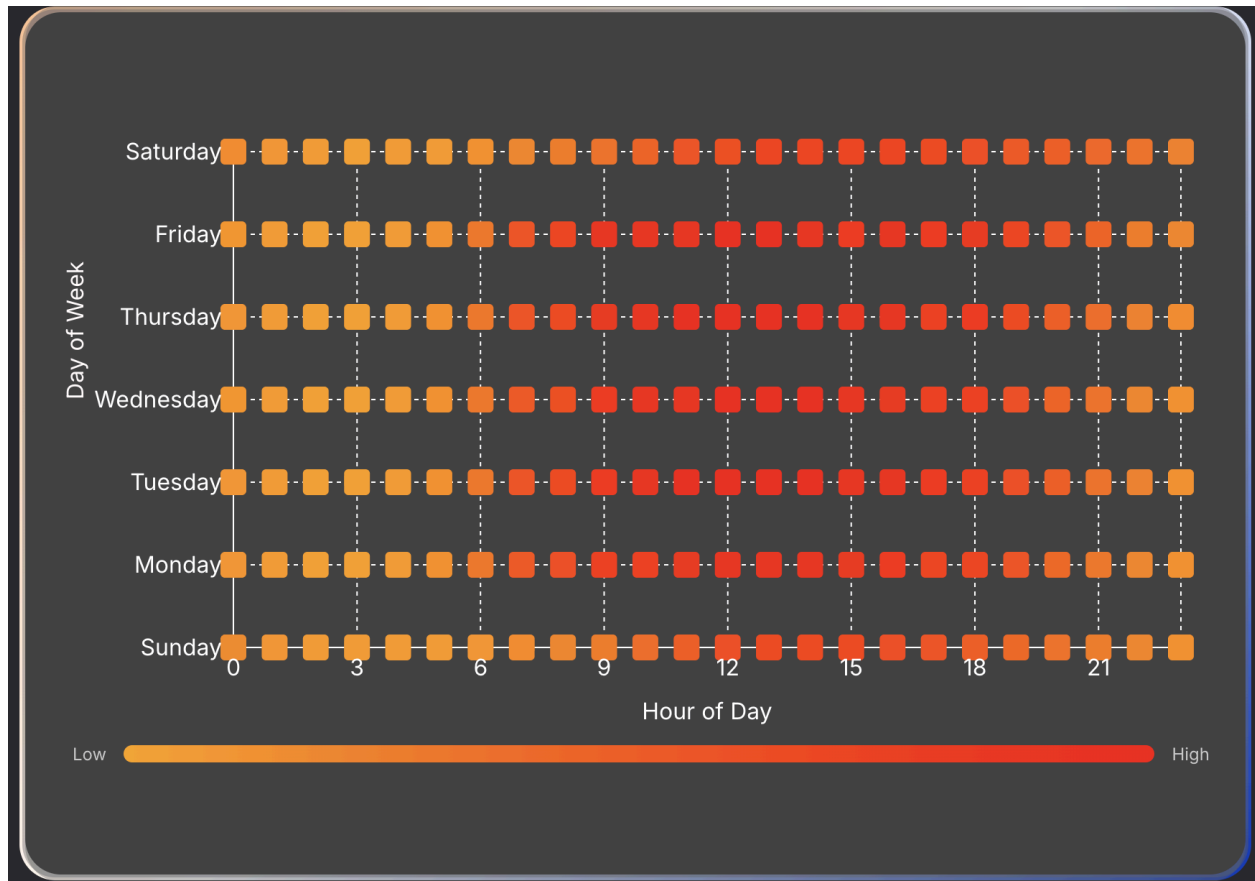
Additionally, not many neighborhoods deviated too much from the borough average and slight increases or decreases for some neighborhoods from the borough average is because of extremely low or high violation neighborhoods impacting the borough average value.

Borough	Lowest Violation Quarter	Highest Violation Quarter	Least Violations Neighborhood	Most Violations Neighborhood
Queens	Q4 Oct-Dec 2025	Q2 Apr-Jun 2025	Maspeth	Jamaica Center
Brooklyn	Q4 Oct-Dec 2025	Q1 Jan-Mar 2025	Williamsburg	Flatbush
Bronx	Q4 Oct-Dec 2025	Q1 Jan-Mar 2025, Q2 Apr-Jun 2025	Pelham Parkway, Riverdale	South Bronx
Manhattan	Q4 Oct-Dec 2024/25	Q2 Apr-Jun 2025	Greenwich Village	Upper East Side
Staten Island	Q4 Oct-Dec 2025	Q1 Jan-Mar 2025	Mid-Island	St. George, Staten Island North Shore

When During the Day Do Violations Occur?

The figure below shows a violation heatmap by hours of the day for each day within a week. The density of violations is color coded from yellow to red representing low to high number of violations. Violations have occurred the most between 9 AM - 4 PM from Monday - Friday which makes sense since this includes rush hour times for many people who go to work and school, and weekdays tend to be busiest days of the week.
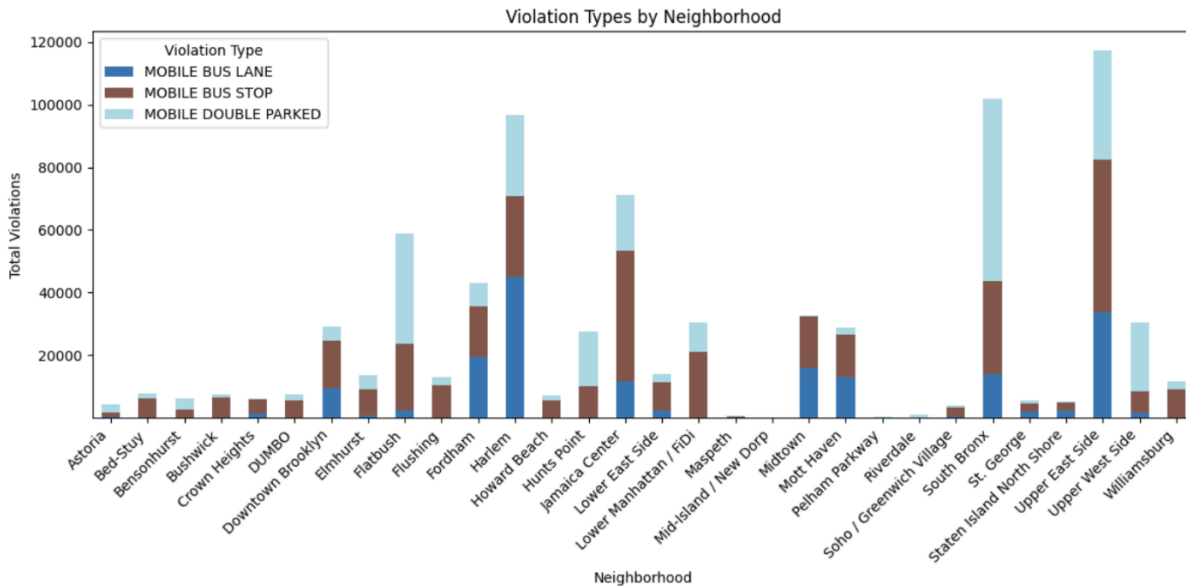
What Are The Major Violation Types Per Neighborhood?

The figure below shows the total number of violations per neighborhood in all boroughs alongside color coded sections of different violation types such as mobile bus lane, mobile bus stop, and mobile double parked. Identifying major violation types by neighborhood reveals the underlying causes of bus interference, provides possible targeted and equitable enforcement strategies, and highlights how land use and curbside design, not just driver behavior, shape transit reliability across NYC.

For each major violation type, these were the neighborhoods that had the most violations:
1. <u>Top Mobile Bus Lane Offenders</u>: Harlem, Upper East Side
2. <u>Top Mobile Bus Stop Offenders</u>: Upper West Side, Lower East Side, South Bronx
3. <u>Top Double Parking Offenders</u>: South Bronx, Upper East Side, Flatbush

For these specific areas, mobile bus lane offenders could be reduced with further bus lane camera enforcement, bus stop lanes could be redesigned for bus stop offenders and reducing congested areas, and for double parking offenders, the commercial loading infrastructure could be expanded on since these types of vehicles also receive many violations and block roads.

Violation Types by Neighborhood

6. CONCLUSION

MTA bus violations across New York City follow consistent spatial and temporal patterns. A small group of neighborhoods, Harlem, South Bronx, Upper East Side, Jamaica Center, and Flatbush, consistently emerged as the most severe violation hotspots, indicating long-standing structural issues related to high transit volumes and curbside demand. Violations were generally highest in quarters Q1 and Q2 and lowest in Q4, reflecting seasonal commuting patterns, school schedules, weather conditions, holiday-related slowdowns, and other factors contributing to these trends.

Most neighborhoods closely followed their borough averages, with deviations largely driven by a few extreme high or low violation areas that disproportionately influenced borough-wide trends. Violations were also concentrated on weekdays between 9 AM and 4 PM, aligning with peak work and school travel hours. Differences in dominant violation types across neighborhoods further highlighted the role of land use and street design in shaping bus interference. By identifying when and where bus lane violations are most concentrated, this analysis directly addresses one of the root contributors to New York City's traffic congestion and commuter stress. Citywide officials could focus more on targeted, neighborhood-specific interventions, such as enhanced bus lane enforcement, improved bus stop design, and expanded loading infrastructure in improving bus reliability and reducing violations.

7. REFERENCES

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