Traffic Congestion Analysis in Atlanta, GA

Srinivas Konreddy

Objective: The main objective of this project is to pinpoint traffic congestion hotspots in Atlanta and evaluate how effective alternative routes could be in easing traffic and improving overall flow.

Introduction: Atlanta, Georgia, consistently ranks among the most congested cities in the United States, with its traffic challenges rooted in rapid population growth and sprawling suburban development. The Atlanta metropolitan area, home to over six million residents, has experienced decades of expansion without sufficient investments in transportation infrastructure to match the rising demand. Interstate 285, the perimeter highway encircling the city, has become a focal point of congestion, often operating beyond its capacity. Originally designed as a bypass, it now functions as a primary commuter route, frequently clogged with vehicles throughout the day.

The city's heavy reliance on personal automobiles exacerbates the issue, with over 77% of residents commuting alone. Limited public transit usage—accounting for only 3.5% of daily commutes—further compounds the problem, as Atlanta's infrastructure primarily caters to car travel. Meanwhile, suburban sprawl has pushed development further from the city center, increasing the strain on the perimeter and other key roadways.

This project aims to address Atlanta's traffic woes by identifying congestion hotspots and exploring the potential for alternative routes to alleviate bottlenecks. By analyzing traffic patterns, infrastructure, and roadway networks, this study contributes valuable insights into improving mobility and reducing the economic and social costs of gridlock. The findings are expected to support data-driven strategies for enhancing traffic flow and transportation equity.

List of data sources:

1) Atlanta Shapefile: Downloaded from the Atlanta Regional Commission (ARC), this dataset provides the geographical boundaries and administrative divisions of Atlanta, including city limits and infrastructure layout.

2) Traffic Counts: Data sourced from the Georgia Department of Transportation (GDOT), detailing traffic volume and patterns for various road segments in Atlanta.

3) Roadway Network Data: Extracted from OpenStreetMap (OSM), this dataset contains information about Atlanta's road network, including attributes like road types and connectivity.

Spatial Analysis Techniques

The following spatial analysis techniques might be utilized in this project:

1. Data Preprocessing:

CRS Alignment: Ensuring all datasets use the same Coordinate Reference System to enable seamless spatial operations.

Clipping: Restricting datasets to the Atlanta city limits to focus on the area of interest.

2. Spatial Joins:

Joining Traffic Counts to Road Segments: Associating traffic volume data with corresponding road segments in the OSM network.

3. Hotspot Analysis:

Kernel Density Estimation (KDE): Identifying areas with high concentrations of traffic congestion.

Getis-Ord Gi Statistic: Pinpointing statistically significant clusters of high traffic volumes.

4. Proximity Analysis:

Buffer Creation: Analyzing the influence of infrastructure (e.g., intersections, exits) within specific distances of congested areas.

Distance Calculations: Measuring distances between key congestion points and alternative routes.

5. Network Analysis:

Shortest Path Analysis: Identifying alternative routes for diverting traffic.

Service Area Analysis: Determining the coverage of existing roadways and potential areas underserved by the current network.

6. Thematic Mapping:

Traffic Volume Maps: Visualizing Road segments with varying traffic levels.

Congestion Heatmaps: Highlighting the most impacted areas using density gradients.

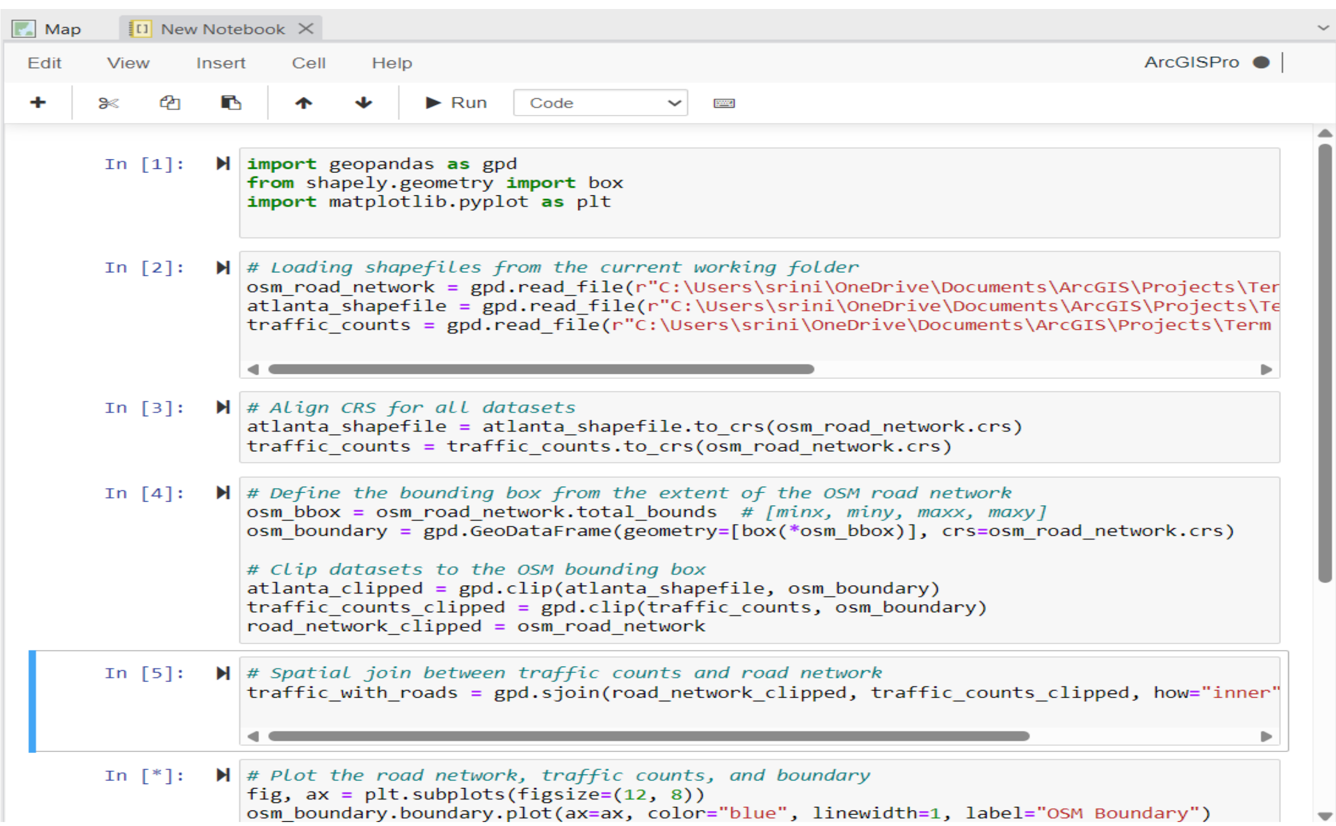
Infrastructure Impact Maps: Analyzing the relationship between congestion and proximity to ramps, intersections, or public transit.

7. Spatial Overlay:
Intersection Analysis: Overlaying traffic volume data with road network layers to find critical intersections contributing to congestion.
8. Statistical Analysis:
Quantify traffic congestion patterns and evaluate their proximity to critical infrastructure, which involves identifying key traffic hotspots

Preliminary Results

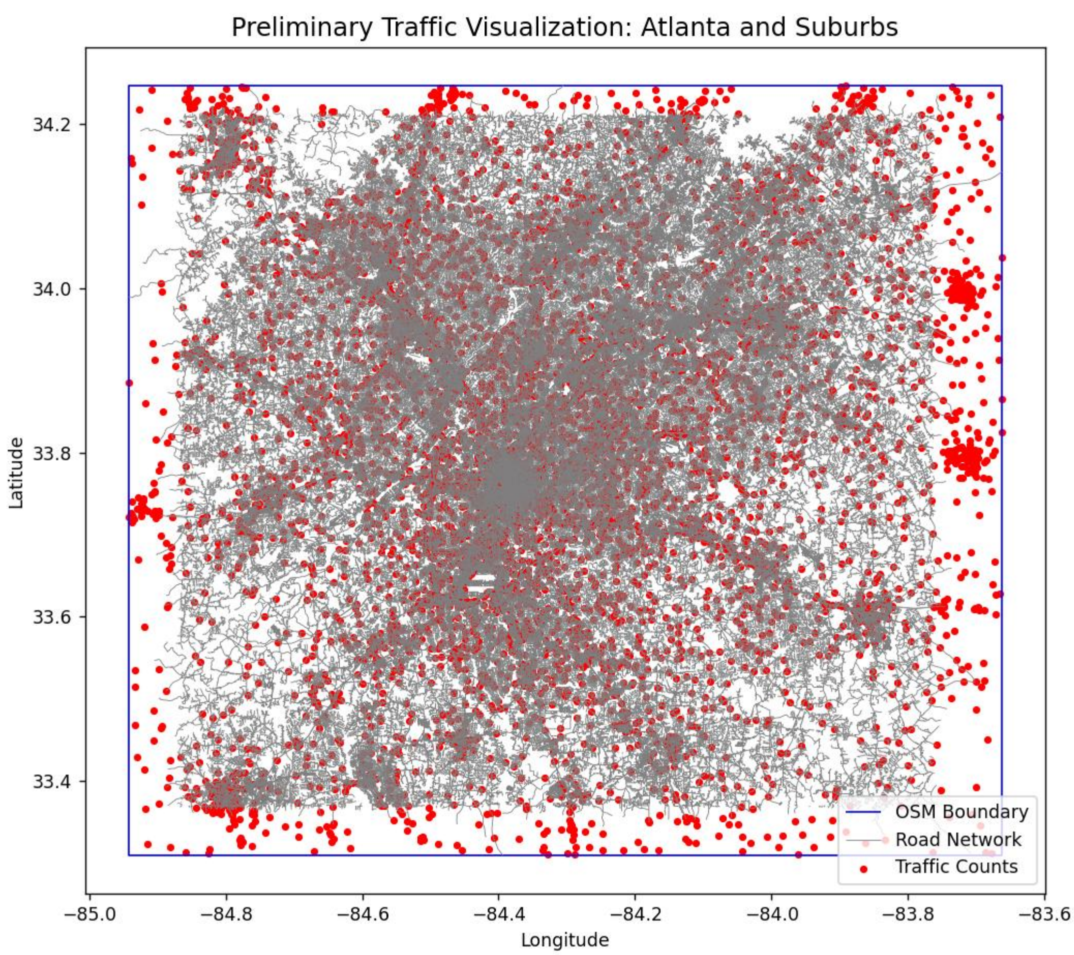
The spatial preprocessing ensures that all datasets are prepared for accurate analysis and visualization. Key steps include clipping larger datasets like statewide road networks and traffic data to focus specifically on the Atlanta metropolitan area and its suburbs. This step removes irrelevant data, optimizes performance, and enhances analysis accuracy. Ensuring all datasets share the same Coordinate Reference System (CRS) is also critical to maintain spatial alignment and prevent errors during overlay and computation.

Next, traffic count data is spatially joined to road segments, linking traffic volumes to specific sections of the road network. Basic maps are then created to visualize the spatial distribution of roadways and traffic volumes, enabling the identification of potential errors or gaps. These preparatory steps establish a robust foundation for advanced analysis and thematic mapping.



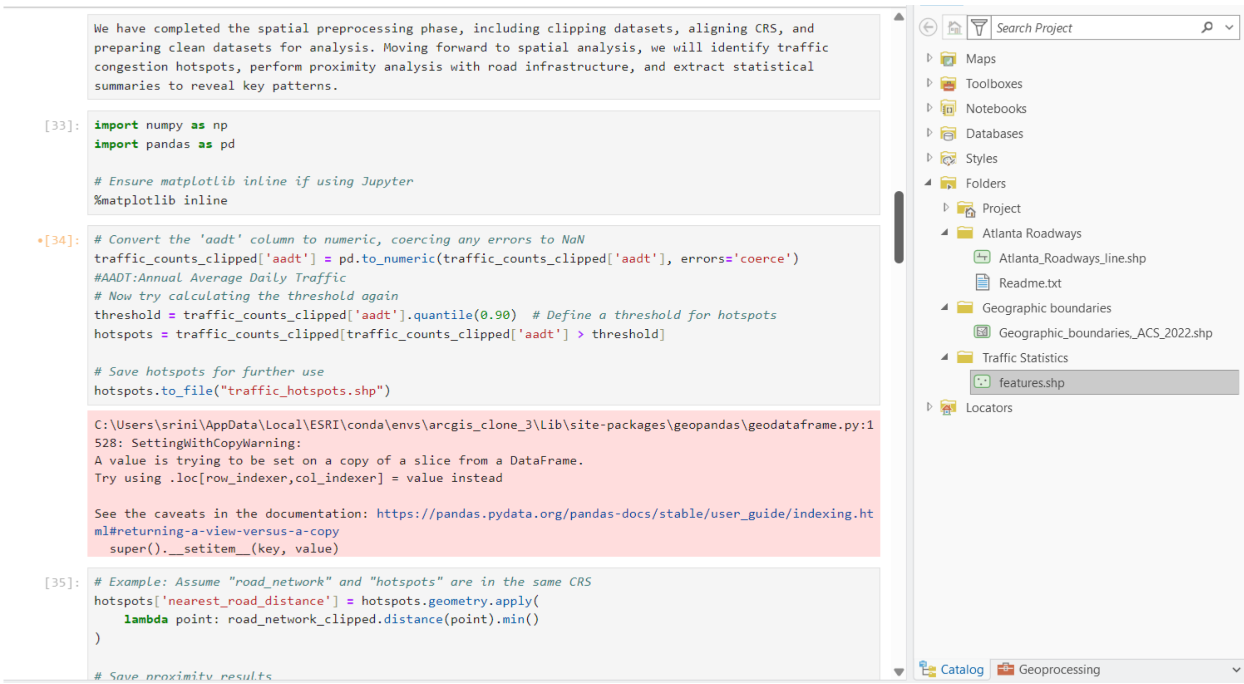
```
In [*]:  # Plot the road network, traffic counts, and boundary
fig, ax = plt.subplots(figsize=(12, 8))
osm_boundary.boundary.plot(ax=ax, color="blue", linewidth=1, label="OSM Boundary")
road_network_clipped.plot(ax=ax, color="grey", linewidth=0.5, label="Road Network")
traffic_counts_clipped.plot(ax=ax, color="red", markersize=10, label="Traffic Counts")

# Customize the map
ax.set_title("Preliminary Traffic Visualization: Atlanta and Suburbs", fontsize=14)
ax.set_xlabel("Longitude")
ax.set_ylabel("Latitude")
ax.legend()
plt.show()
```

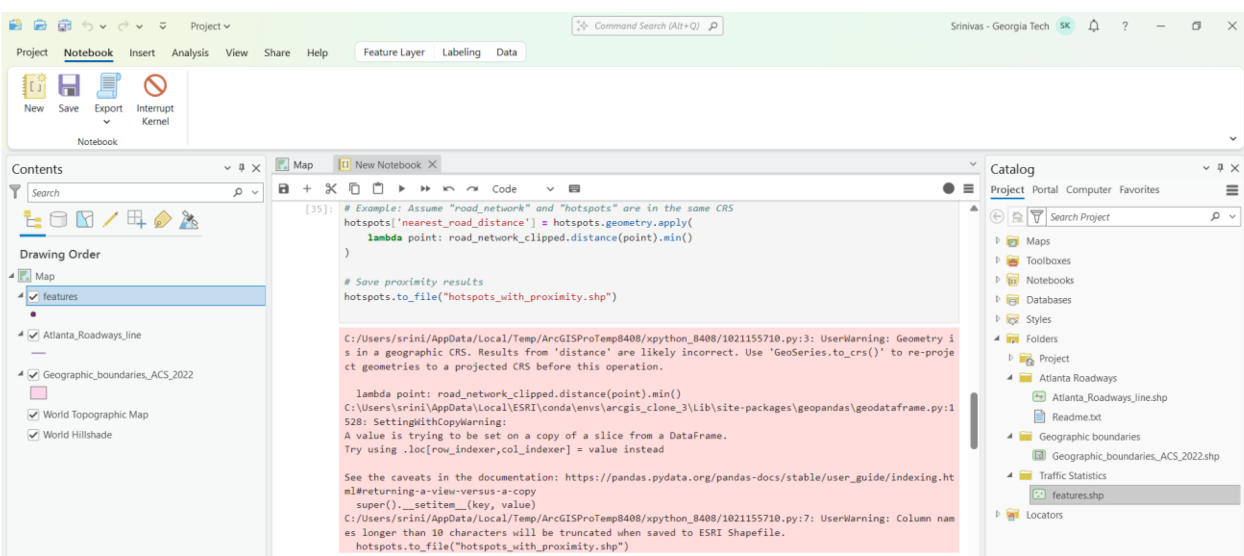
The initial graph obtained from the spatial preprocessing is, where the red dots represent all the points where GDOT collects traffic data through sensors, these are referred to as traffic counts:



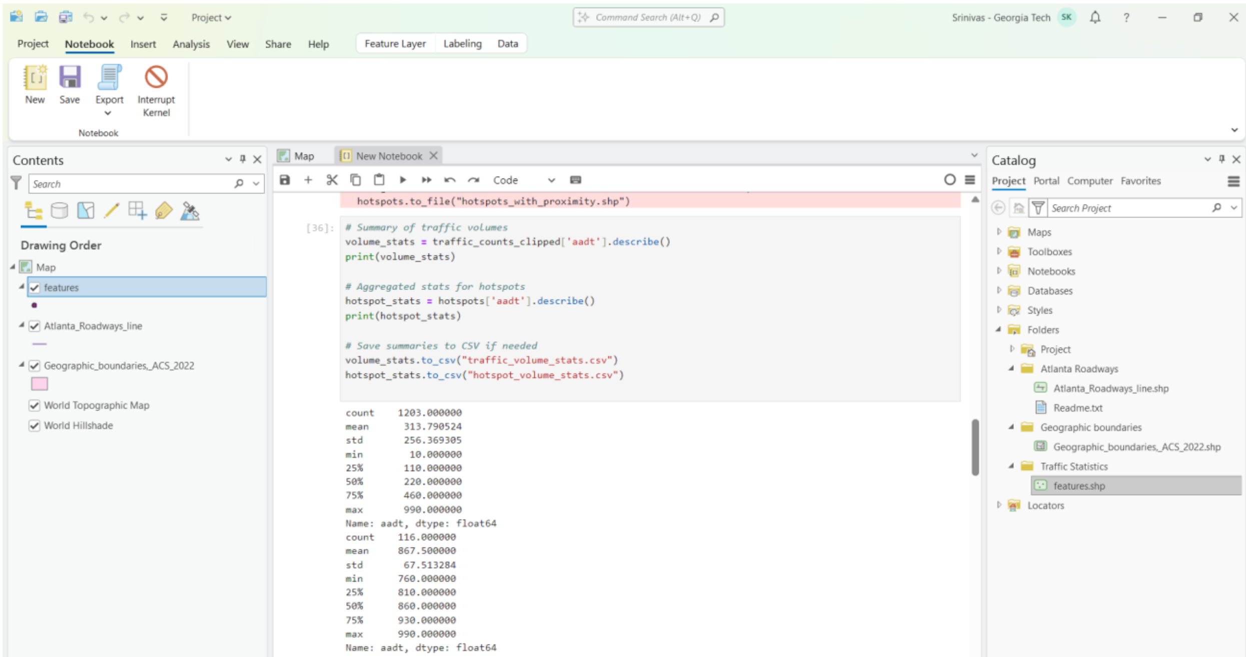
Spatial Analysis:

In this phase, we identified traffic congestion hotspots, analyzed their proximity to major roads, and generated statistical summaries to understand traffic patterns in the study area. Using the traffic volume data, hotspots were defined as locations where traffic exceeded the 90th percentile, highlighting the most congested areas. These hotspots were further analyzed for their proximity to the road network by calculating the minimum distance to major roads, providing insights into potential causes of congestion. Statistical summaries of traffic volumes, including descriptive metrics for the entire dataset and hotspots, revealed significant variations, emphasizing critical areas for intervention. Finally, a visualization combining the study area boundary, road network, traffic data points, and hotspots provided a comprehensive view of congestion patterns, serving as a valuable tool for urban planning and decision-making. These analyses set the stage for evaluating how congestion hotspots impact accessibility to essential infrastructure in subsequent steps.



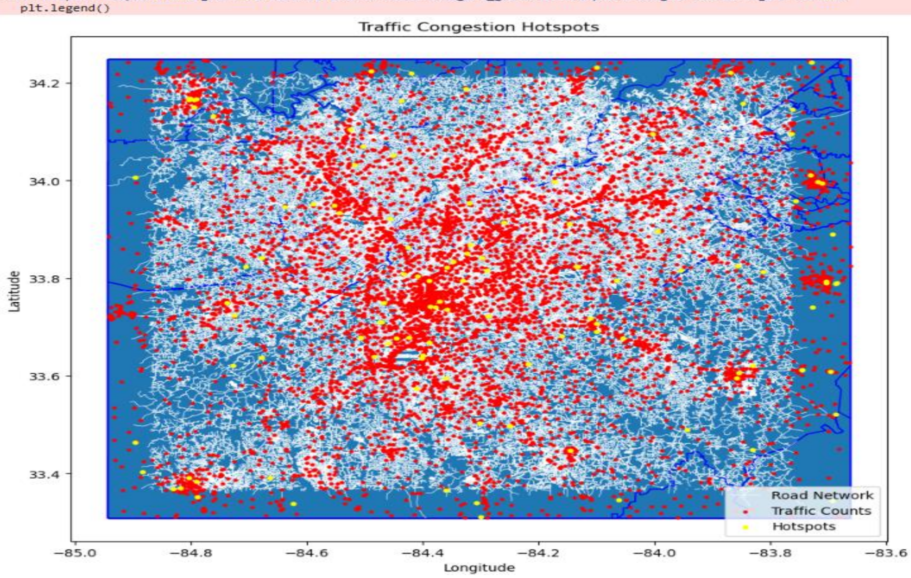


In the next step, we will be running statistical analysis to be out the statistical parameters for calculating the hotspots




```
[39]: fig, ax = plt.subplots(figsize=(10, 10))

# Plot the layers with specified z-order
atlanta_clipped.plot(ax=ax, edgecolor='blue', linewidth=1, label="Boundary", zorder=1)  # Boundary layer
road_network_clipped.plot(ax=ax, color='white', linewidth=0.5, label="Road Network", zorder=2)  # Road network background
traffic_counts_clipped.plot(ax=ax, color='red', markersize=5, label="Traffic Counts", zorder=3)  # Traffic counts foreground
hotspots.plot(ax=ax, color='yellow', markersize=10, label="Hotspots", zorder=4)  # Hotspots foreground

# Add legend and titles
plt.legend()
plt.title("Traffic Congestion Hotspots")
plt.xlabel("Longitude")
plt.ylabel("Latitude")
plt.show()
```

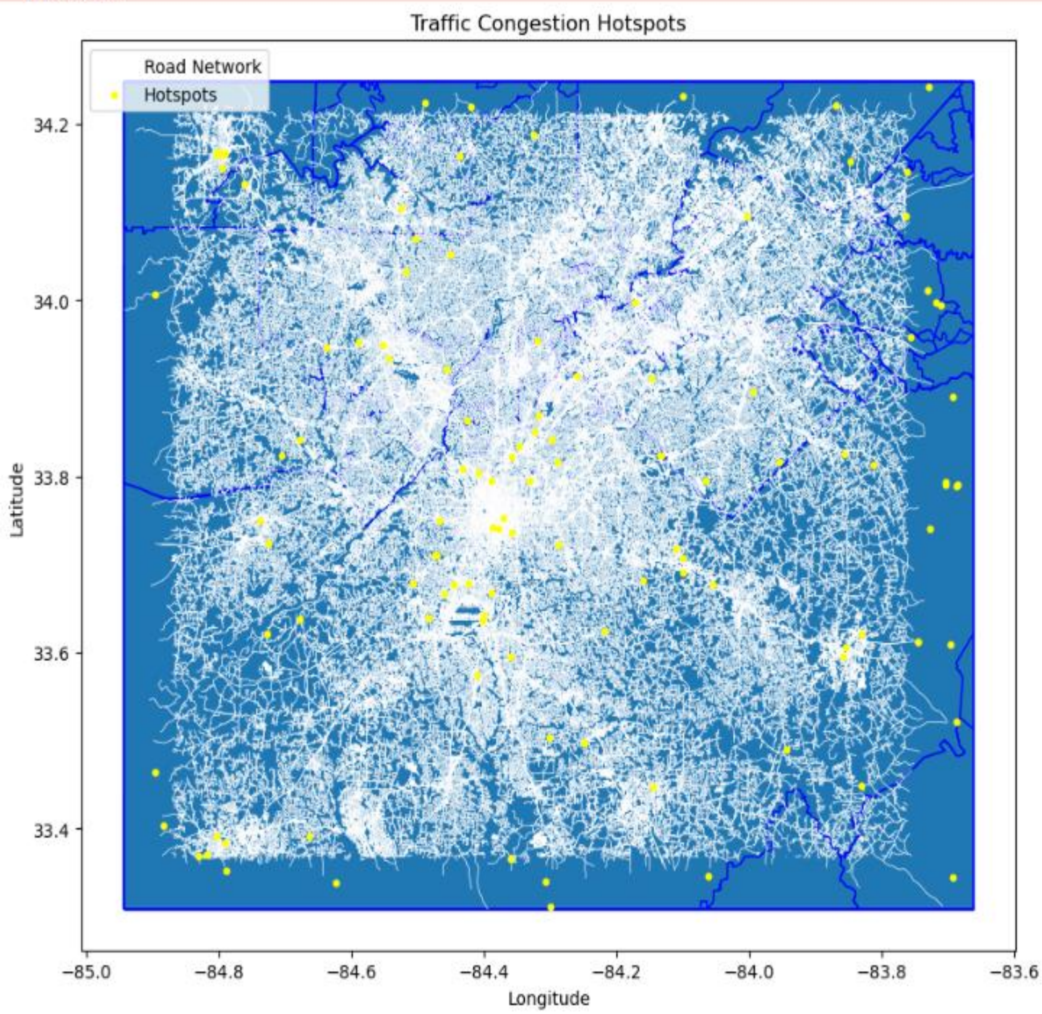
```
C:/Users/srini/AppData/Local/Temp/ArcGISProTemp8408/xpython_8408/1324644264.py:10: UserWarning: Legend does not support handles for PatchCollection ins
tances.
See: https://matplotlib.org/stable/tutorials/intermediate/legend_guide.html#implementing-a-custom-legend-handler
  plt.legend()
```



In the above plot, the white lines represent the roadway network, traffic counts (red dots) represent all the points where GDOT is calculating data and the yellow lines represent the hotspot, in the next step we will filter out the hotspots from the traffic count station and visualize all the bottleneck or high-density junctions in and around Atlanta.

```
fig, ax = plt.subplots(figsize=(10, 10))

# Plot the layers with specified z-order
atlanta_clipped.plot(ax=ax, edgecolor='blue', linewidth=1, label="Boundary", zorder=1)  # Boundary layer
road_network_clipped.plot(ax=ax, color='white', linewidth=0.5, label="Road Network", zorder=2)  # Road network background
hotspots.plot(ax=ax, color='yellow', markersize=10, label="Hotspots", zorder=4)  # Hotspots foreground

# Add legend and titles
plt.legend()
plt.title("Traffic Congestion Hotspots")
plt.xlabel("Longitude")
plt.ylabel("Latitude")

# Show plot in a new window
plt.show(block=True)
```

```
C:/Users/srini/AppData/Local/Temp/ArcGISProTemp8408/xpython_8408/2446413706.py:12: UserWarning: Legend does not support handles for PatchCollection ins
tances.
See: https://matplotlib.org/stable/tutorials/intermediate/legend_guide.html#implementing-a-custom-legend-handler
  plt.legend()
```



Bottlenecks identified through traffic congestion hotspots present significant challenges for emergency services, particularly hospitals, as they can delay critical response times during emergencies. Timely access to medical care is crucial for saving lives, making it essential to understand the relationship between these congestion zones and hospital locations.

To address these concerns, we propose a detailed analysis of the spatial proximity of hospitals to identified traffic hotspots. This involves mapping hospital locations relative to areas of high congestion and visualizing these patterns to assess the potential risks posed by delayed emergency access. By integrating geospatial data with traffic flow and congestion metrics, we can identify regions where hospital accessibility may be severely impacted.

This analysis will not only highlight areas of high risk but also provide valuable insights for urban planners, transportation engineers, and healthcare administrators to develop strategies for mitigating these challenges. Potential interventions may include optimizing traffic signal timings, prioritizing emergency vehicle routes, or strategically situating new healthcare facilities to improve accessibility. The goal is to enhance the resilience of emergency response systems, ensuring that critical medical services are readily available to all individuals, even in areas prone to traffic bottlenecks.

[47]:
```python
# Calculate the minimum distance from each hotspot to the nearest hospital
hotspots['nearest_hospital_distance'] = hotspots.geometry.apply(
    lambda point: hospitals.distance(point).min()
)

# Statistical summary of distances
hospital_proximity_stats = hotspots['nearest_hospital_distance'].describe()
print(hospital_proximity_stats)

# Save statistics if needed
hospital_proximity_stats.to_csv("hospital_proximity_stats.csv")
```

```
C:/Users/srini/AppData/Local/Temp/ArcGISProTemp8408/xpython_8408/217142612.py:3: UserWarning: Geometry is
in a geographic CRS. Results from 'distance' are likely incorrect. Use 'GeoSeries.to_crs()' to re-project
geometries to a projected CRS before this operation.

  lambda point: hospitals.distance(point).min()
C:\Users\srini\AppData\Local\ESRI\conda\envs\arcgis_clone_3\Lib\site-packages\geopandas\geodataframe.py:1
528: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.ht
ml#returning-a-view-versus-a-copy
  super().__setitem__(key, value)
count    116.000000
mean       0.104696
std        0.115032
min        0.004596
25%        0.023658
50%        0.055048
75%        0.147752
max        0.540547
Name: nearest_hospital_distance, dtype: float64
```

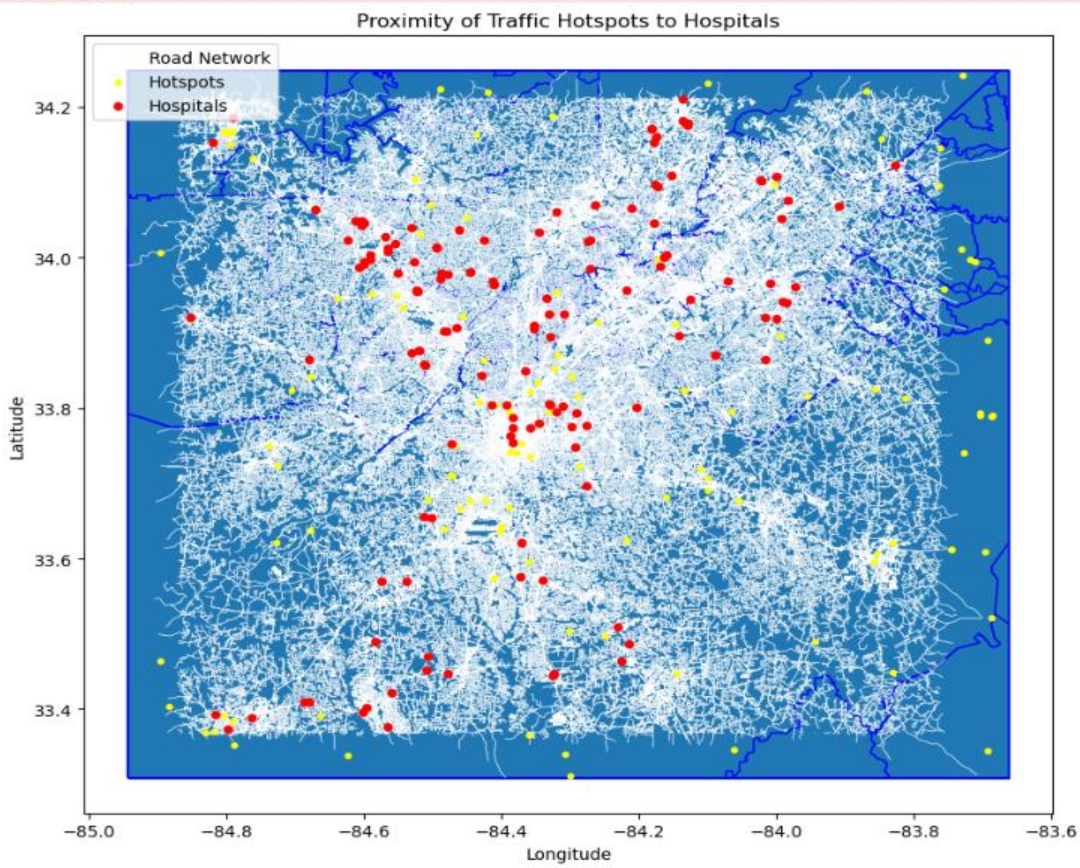
Upon analyzing the spatial relationship between hospitals and traffic congestion hotspots in Atlanta, we observed that the average distance between a hospital and a congestion zone is approximately 0.104 miles, with the maximum distance reaching 0.540 miles. These findings highlight a concerning trend: hospitals, which are essential for providing emergency medical care, are in close proximity to areas prone to traffic bottlenecks. This poses significant risks to emergency response times, potentially delaying life-saving services when every second counts.

These results underscore the urgent need for comprehensive network analysis and the implementation of alternative routing strategies to alleviate traffic congestion in these critical zones. By improving the efficiency of emergency service routes and mitigating congestion, we can enhance accessibility to hospitals and ensure timely response during emergencies.

While this project focuses exclusively on hospitals as a sample of critical infrastructure, it is important to note that similar concerns apply to other emergency services such as police stations and fire departments.

```python
# Plot the boundary and road network
atlanta_clipped.plot(ax=ax, edgecolor='blue', linewidth=1, label="Boundary",zorder=1)
road_network_clipped.plot(ax=ax, color='white', linewidth=0.5, label="Road Network",zorder=2)

# Plot the traffic hotspots and hospitals
hotspots.plot(ax=ax, color='yellow', markersize=10, label="Hotspots",zorder=3)
hospitals.plot(ax=ax, color='red', markersize=20, label="Hospitals",zorder=4)

# Add legend and titles
plt.legend()
plt.title("Proximity of Traffic Hotspots to Hospitals")
plt.xlabel("Longitude")
plt.ylabel("Latitude")
plt.show()
```

```
C:/Users/srini/AppData/Local/Temp/ArcGISProTemp8408/xpython_8408/252322638.py:12: UserWarning: Legend does not support handles for PatchCollection inst
ances.
See: https://matplotlib.org/stable/tutorials/intermediate/legend_guide.html#implementing-a-custom-legend-handler
  plt.legend()
```



The time required for these services to reach their destinations is equally, if not more, critical in certain situations. Future research and analysis could expand this framework to include these essential services, broadening the scope of the study.

This approach has significant potential for informing urban planning and transportation strategies. For example, it could support the development of optimized emergency vehicle routing systems, adjustments to traffic signal timings, and even the strategic placement of new critical infrastructure. By applying network analysis and route optimization techniques, this study could serve as a foundation for creating a more resilient and responsive emergency service network in Atlanta, ultimately improving safety and quality of life for its residents.

The visualization reveals a striking pattern: a significant number of hospitals in and around Atlanta are in close proximity to major traffic congestion hotspots. This spatial alignment raises concerns about the accessibility of critical healthcare facilities, as the presence of traffic bottlenecks near hospitals could lead to delays in emergency medical response times.

Conclusion

Background of the Project

Modern-day cities face a growing challenge in managing traffic congestion, a problem that directly impacts urban mobility, economic productivity, and quality of life. As urban populations swell and infrastructure struggles to keep pace, traffic bottlenecks emerge as critical issues for transportation and traffic engineering. Identifying traffic congestion zones is crucial for mitigating these challenges, as these zones often become the nexus of delays, accidents, and inefficiencies.
Traffic congestion does not merely slow down commuters; it has far-reaching implications for emergency services, delivery logistics, public transportation, and overall urban accessibility. Its impact on critical infrastructure such as hospitals is profound. When traffic hotspots are located near healthcare facilities, they can severely delay emergency response times, jeopardizing lives in critical situations. The importance of understanding and addressing congestion zones is heightened by the need to create resilient urban systems that support the seamless flow of people and services.
This project addresses these challenges by focusing on Atlanta, a metropolitan area known for its complex traffic dynamics. By examining the spatial relationships between traffic congestion hotspots and critical infrastructure, the project lays the groundwork for targeted interventions to improve urban accessibility and emergency response capabilities.

What I Did in This Project

In this project, a preliminary spatial analysis was conducted to identify and assess the implications of traffic congestion zones in relation to critical infrastructure, focusing on hospitals as a case study. The analysis began with the identification of key traffic congestion hotspots, which were mapped using geospatial data. This allowed for the visualization of areas prone to delays and bottlenecks, forming the foundation for further analysis.
Next, spatial proximity analysis was carried out to evaluate the distance between identified traffic hotspots and nearby hospitals. The results revealed that, on average, hospitals are located just 0.104 miles from major congestion zones, with a maximum distance of 0.540 miles. This finding underscores the precarious positioning of these essential facilities relative to traffic bottlenecks.

The project also involved mapping and visualizing these relationships to gain insights into the distribution of congestion zones and their impact on hospital accessibility. By integrating spatial data with critical infrastructure information, the analysis provided a comprehensive understanding of how traffic congestion can impede emergency services.
Additionally, the methodology and tools used in this project were designed to be scalable and adaptable, paving the way for similar studies involving other critical services such as police and fire departments. Although this study focused exclusively on hospitals, the framework developed here can be expanded to include a broader spectrum of urban services, enabling a holistic approach to urban resilience planning.

Future Directions and Final Thoughts

While this project successfully highlights the proximity of hospitals to traffic congestion hotspots and their potential impact on emergency accessibility, it represents just the beginning of a broader conversation on urban planning and transportation optimization. Future work could focus on incorporating advanced network analysis and route optimization techniques to address the identified challenges.
Network analysis could be used to map out the most efficient routes for emergency vehicles, taking into account real-time traffic conditions and congestion patterns. By simulating various traffic scenarios and analyzing alternative routes, transportation planners can identify bottlenecks and implement strategies to improve travel times. For example, dedicated emergency lanes or optimized signal timings could be introduced in areas where hospitals are located near major congestion zones.
Route optimization, powered by algorithms and real-time traffic data, could further enhance the ability of emergency services to navigate congested areas. By integrating geospatial analysis with

advanced traffic modeling, cities could develop intelligent systems that dynamically adjust routes to minimize delays. These systems could also be applied to non-emergency scenarios, such as public transportation planning and goods delivery networks, creating a more efficient urban mobility framework.

Moreover, future studies could expand the scope of this analysis to include other critical infrastructure such as fire stations, police departments, and schools. By creating a comprehensive map of urban accessibility challenges, policymakers and urban planners can make data-driven decisions to enhance the overall functionality and resilience of the city. This could involve strategic infrastructure investments, land-use planning, and public policy initiatives aimed at reducing congestion in high-risk zones.

In conclusion, this project underscores the importance of understanding the spatial relationships between traffic congestion hotspots and critical infrastructure in modern cities. By identifying these zones and analyzing their impact on hospital accessibility, we have taken an important step toward addressing the broader challenges of urban mobility and emergency response. Through the integration of advanced spatial analysis, network optimization, and data-driven planning, cities like Atlanta can work toward building more resilient, efficient, and accessible transportation systems. Ultimately, such efforts will not only improve quality of life for urban residents but also ensure that critical services are readily available when they are needed the most.