To better understand the spatial patterns of CitiBike usage, an exploratory spatial data analysis (ESDA) was conducted, encompassing spatial visualization, spatial autocorrelation diagnostics, and assessments of spatial heterogeneity.

**Ride Activity Distribution**

The analysis began by examining ride counts and median trip durations at station and census tract levels for three specific months. In both January and July, CitiBike usage was predominantly concentrated in Manhattan, especially in commercial and commuter hubs. However, January showed significantly lower ride activity across all areas, reflecting reduced demand during the winter. Median trip durations were notably longer in January, particularly in outer boroughs, suggesting a shift toward occasional or recreational cycling rather than regular commuting. These seasonal variations highlight the impact of colder weather, which reduced overall activity and shifted the focus away from commuter-oriented trips.

**Spatial Autocorrelation Analysis**

In January, Moran’s I statistic (0.47, p ≤ 0.001) and a Monte Carlo simulation indicated significant global spatial autocorrelation, revealing strong clustering of CitiBike usage. Local Moran’s I analysis identified high-usage clusters in Midtown and Lower Manhattan, driven by dense commercial and commuter activity, while low-usage clusters were observed in peripheral areas such as the Bronx and Staten Island. The Getis-Ord Gi\* statistic further corroborated these findings, pinpointing hotspots in Times Square, Union Square, and the Financial District, alongside cold spots in suburban neighborhoods.

For July, Moran’s I statistic (0.44, p ≤ 0.001) and a Monte Carlo simulation similarly highlighted strong spatial clustering. High-usage clusters remained concentrated in downtown Manhattan, including Midtown and Lower Manhattan, while low-usage clusters persisted in outer boroughs. The Getis-Ord Gi\* statistic confirmed these patterns, with significant hotspots in central Manhattan and cold spots in less active suburban areas.

Comparatively, January exhibited a slightly higher Moran’s I statistic (0.47 vs. 0.44), indicating stronger spatial clustering during the winter. This difference may reflect centralized commuter patterns in colder months. Despite seasonal variations, the spatial distribution of hotspots and cold spots remained consistent, with Midtown and Lower Manhattan serving as focal points for CitiBike activity year-round.

**Spatial Heterogeneity**

Spatial heterogeneity was assessed by visualizing the influence of demographic and spatial variables. Variations in population density and station availability revealed differing regional impacts, underscoring the importance of localized policy interventions. The pronounced spatial autocorrelation observed further emphasizes the need for spatial regression models to account for these dependencies. These findings provide a foundation for the subsequent analytical framework.