Predicting Citi Bike Availability in NYC

DATA 698 Research Project
CUNY Fall 2022

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2022-11-24

Citi Bike Availability

Predict bike availability to avoid an empty docking station

Problem and Objectives

Problem

- Citi Bike offers live map of availability for immediate bike rental but the availability of a bike at a location at a future date and time is not guaranteed

Objectives:

- Construct a model of the bikeshare system usage and availability patterns across New York City
- Predict the number of available bikes in Brooklyn within a quarter mile of a given location with user-friendly inputs

Previous Work

- Wang, Lindsey, Schoner, and Harrison (2016)
  - Log-linear and negative binomial regression models
- Wang and Chen
  - Zero-inflated negative binomial regression model
- Hyland, Hong, Pinto and Chen
  - Hybrid clustering and regression models
- Médard de Chardon, Caruso, and Thomas
  - Rebalancing evaluation

Data Collection

Citi Bike System Data

- Download CSV files for each month
- API call every 15 minutes for two weeks

NYC Open Data

- Borough shapes via GeoJSON files

Docking Station Elevation

- R library `elevatr`

Surplus/Shortage Timetable

- Convert trip data to dataframe of bike departure and arrival counts by docking station for a given time interval

Data Statistics

Ridership patterns

- Timeframe: August - October of 2022 (92 days)
- Location: New York City departing trips
- Number of trips: 10,210,102
- Docking Stations: 1,717
- Abandoned trips: 24,887

Bike Availability

- Timeframe: Oct. 31 - Nov. 13 of 2022 (14 days)
- Location: Brooklyn
- Docking Stations: 474

Challenges

Large volume of data

- Over 10 million trips in 3 months
- Over 1700 docking stations in NYC

Rebalancing

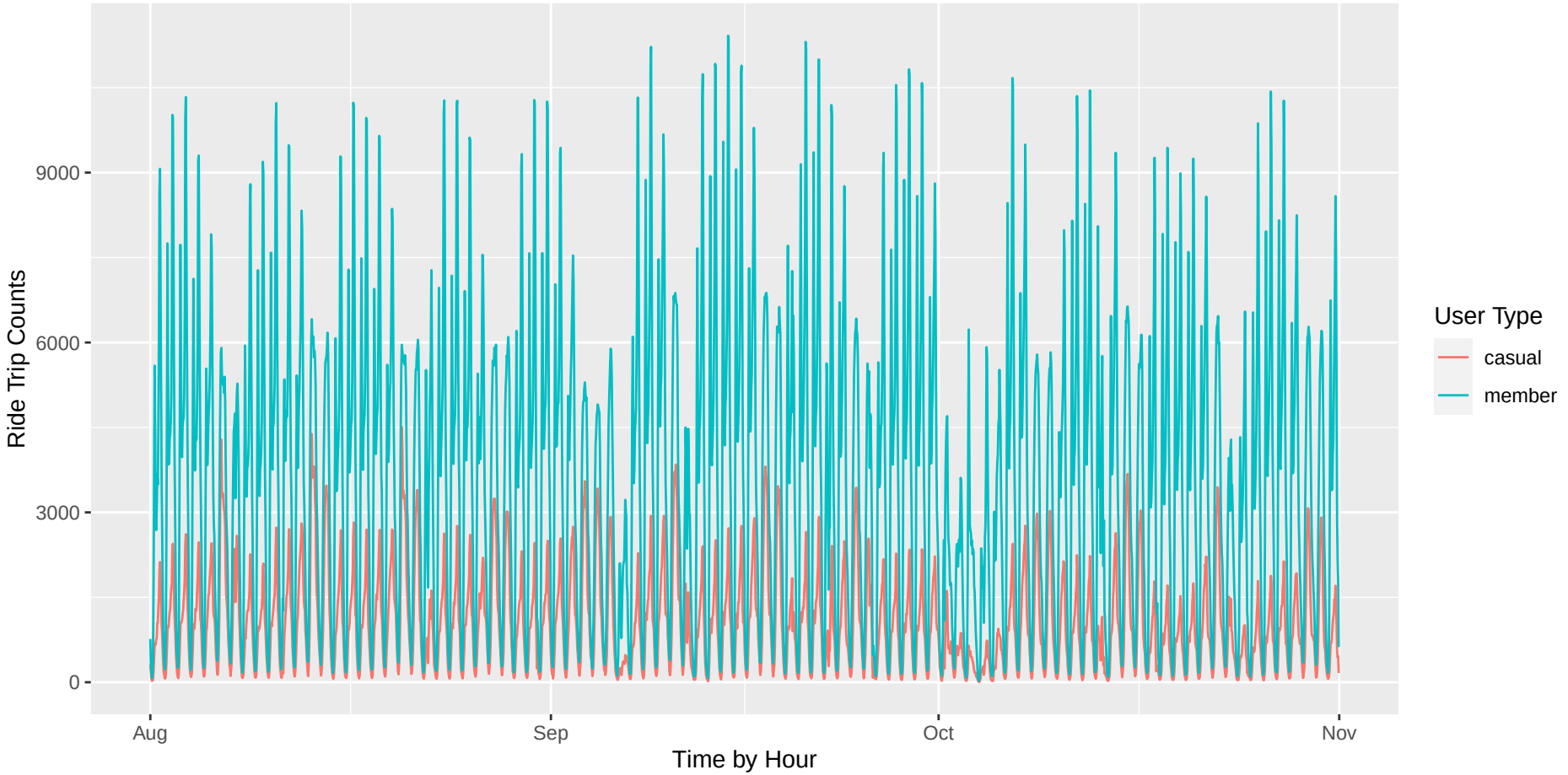
- System action of moving bikes to restock docking stations
- Identification and inconsistency

User-friendly availability prediction

- Independent variables to prediction model
- End-user input values

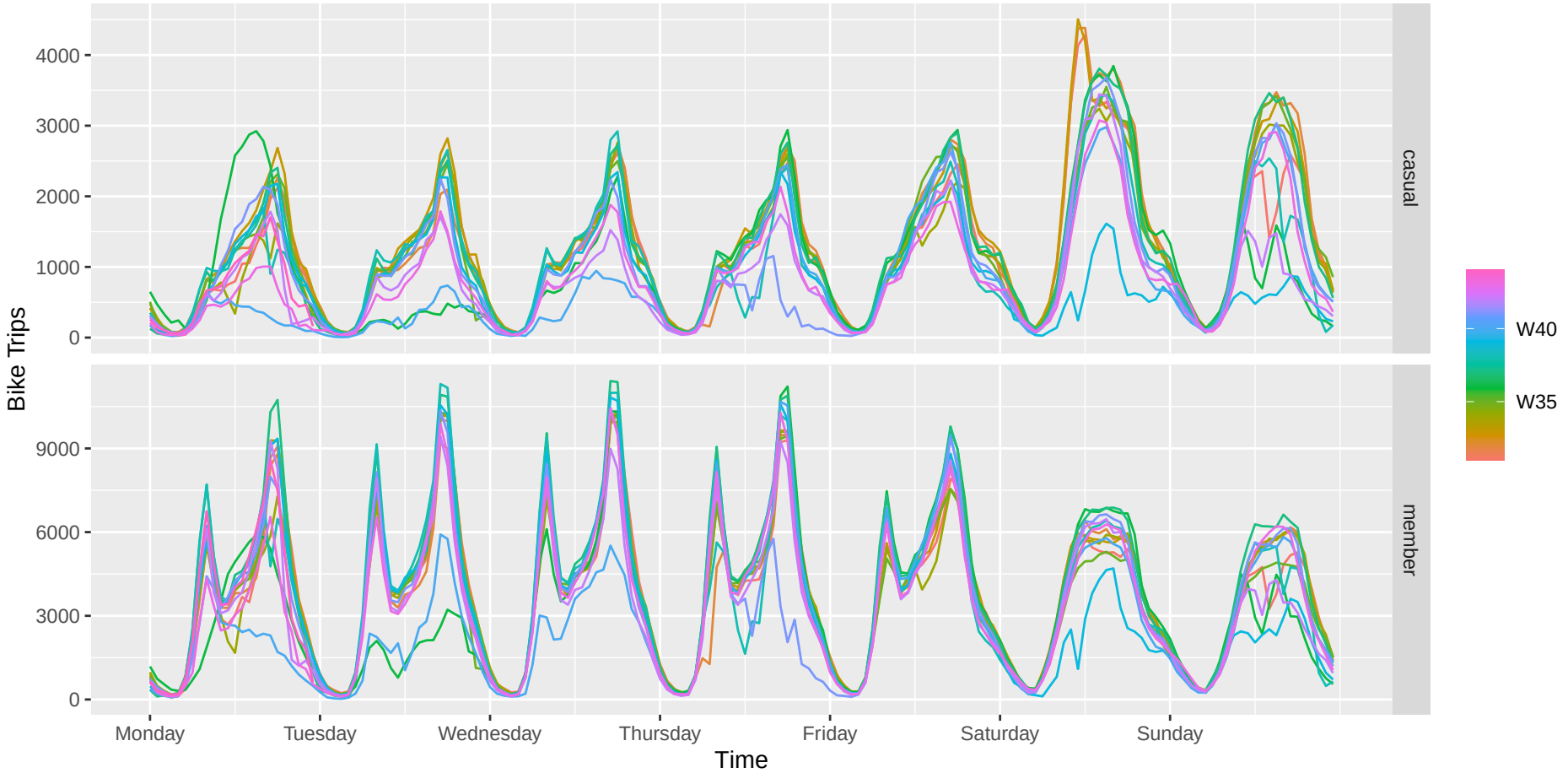
EDA: Bike Trips by Hour

Bike Trips by Hour by User Type for Aug. - Oct. 2022



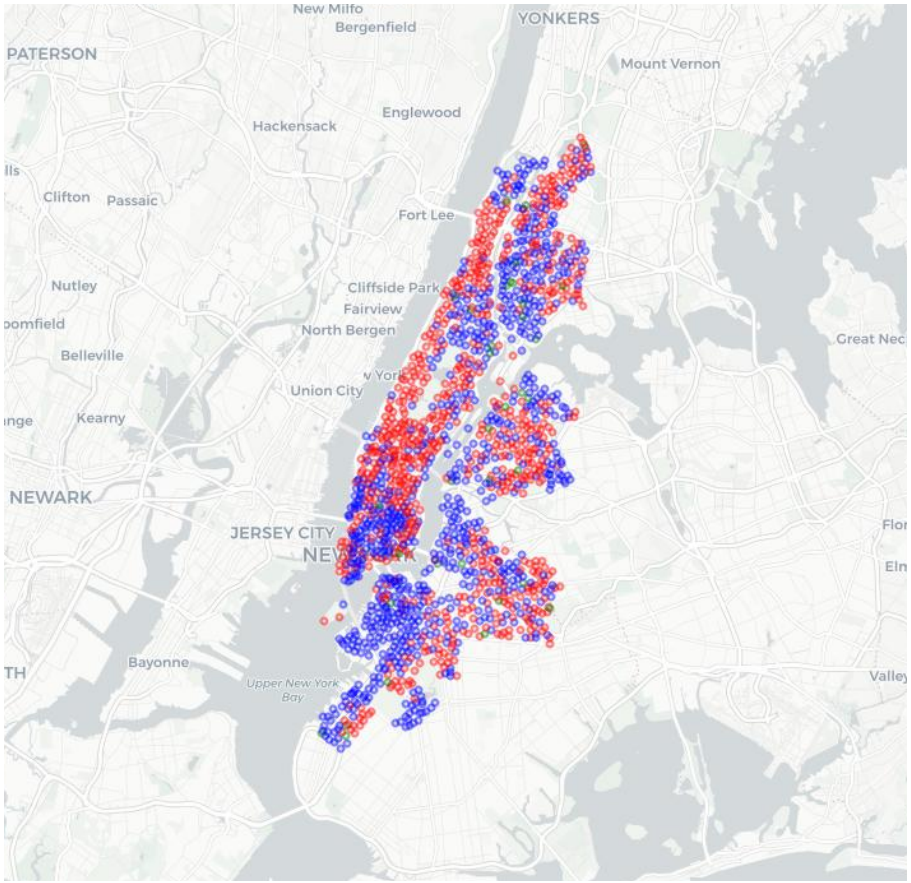
EDA: Weekly Seasonal Pattern

Weekly seasonal plot of the bike trips for Aug. - Oct. 2022



EDA: Three-Month Summary

System-wide view of surplus or shortage for every NYC docking station

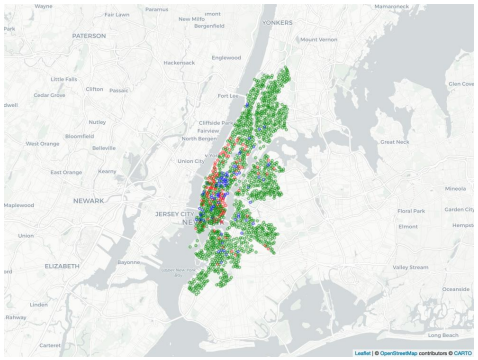


Docking Station Color

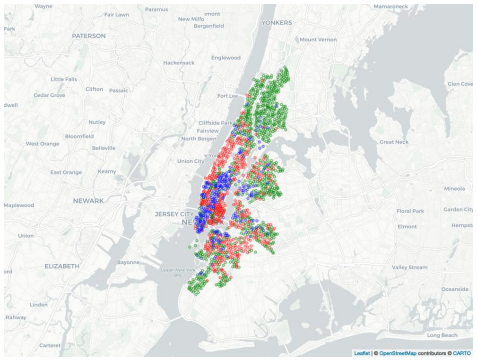
- Blue: Surplus
- Red: Shortage
- Green: Even

EDA: Daily Pattern

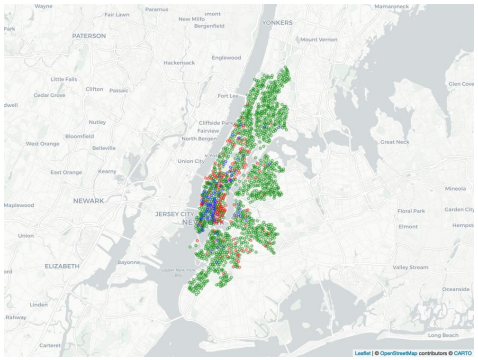
Time lapse of surplus or shortage for every NYC docking station



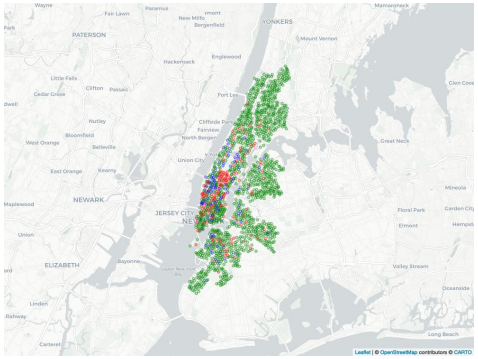
(a) 5 a.m.



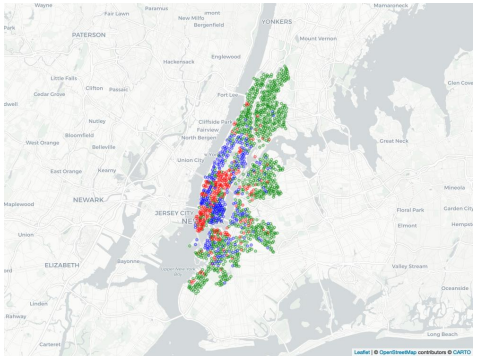
(b) 8 a.m.



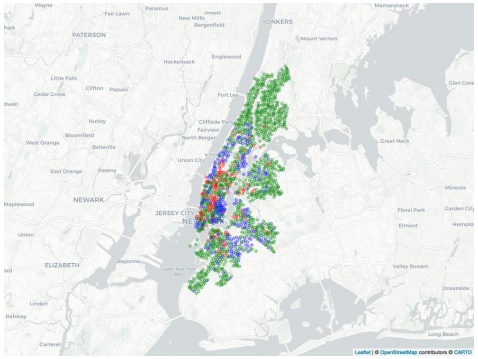
(c) 11 a.m.



(d) 2 p.m.



(e) 5 p.m.



(f) 8 p.m.

Overview of Algorithm Approach

Goal: Predict number of available bikes in Brooklyn within quarter mile

Inputs

- Latitude and longitude (location on map)
- Day of the Week
- Time of Day

Step 1: Hierarchical Clustering

- Cluster all the Brooklyn docking stations
  - Distance: 400m (Quarter mile)

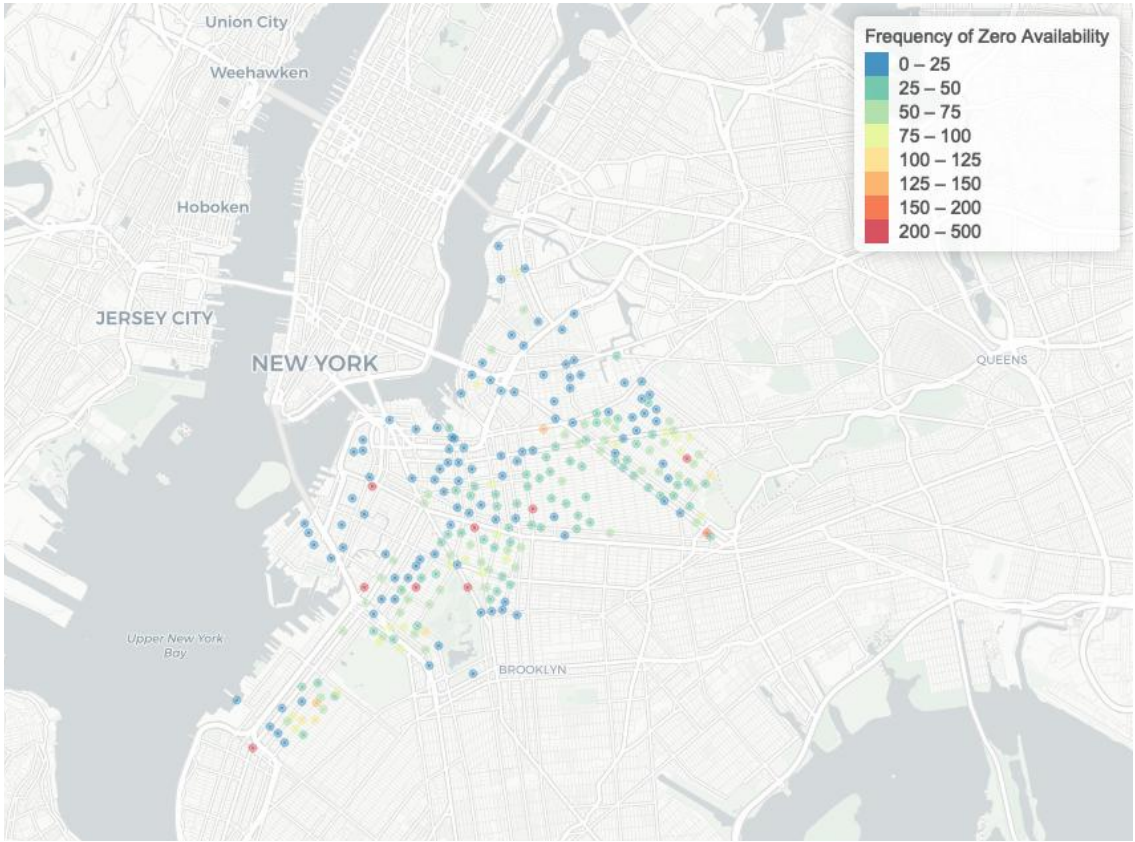
Step 2: Apply Generalized Linear Models

- Predict number of bikes available per cluster
  - Count Models: Poisson, Negative Binomial, Zero-Inflated

Model Decision: Zero Bike Availability

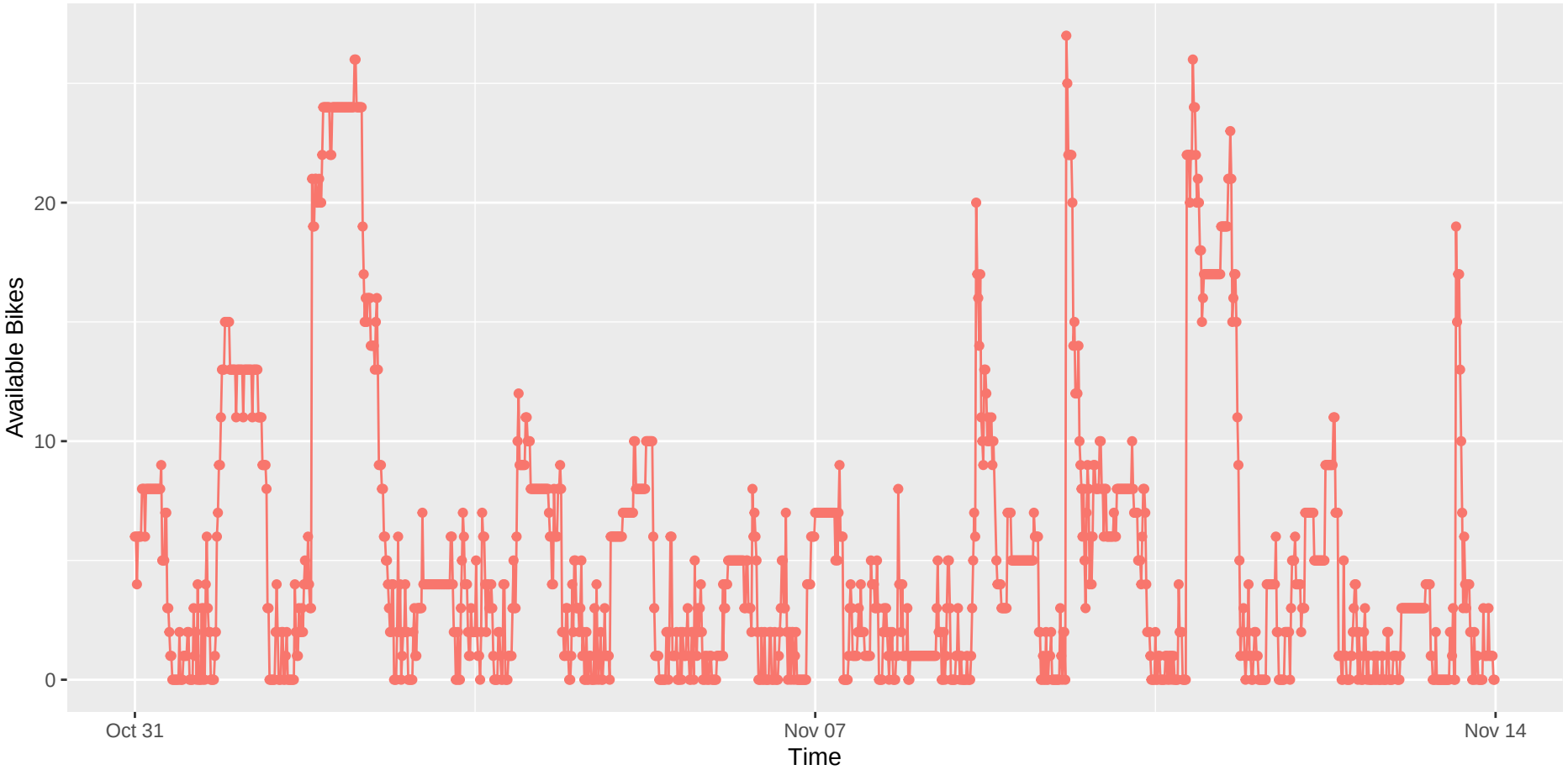
Frequency of zero bikes available per docking station in Brooklyn

- Span: Two weeks
- Instance: 15-minute interval



Model Decision: Rebalancing

Inconsistent bike availability at Docking Station 3582 in Brooklyn



Proposed Methodologies

Predictors

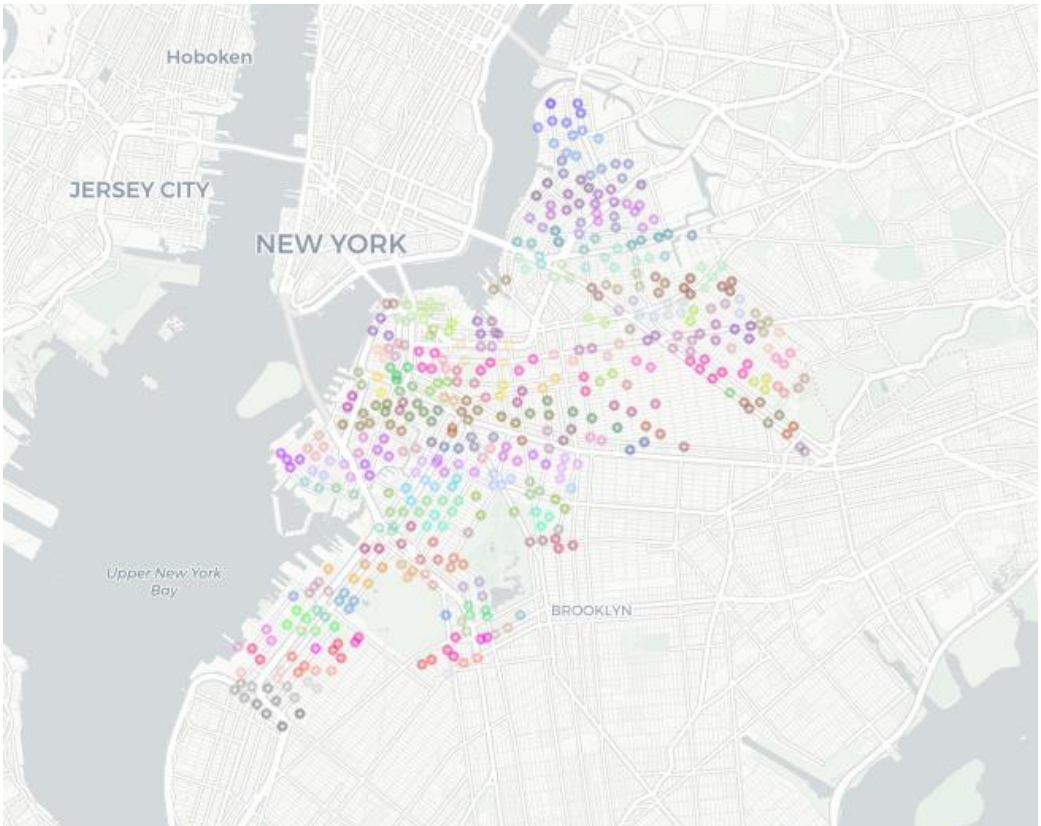
- Latitude and longitude converted to cluster
- Day of the Week converted to 'Weekday' or 'Weekend'
- Time of Day in 1-hour intervals
- Average elevation of cluster omitted

Model Methodologies

- Selected: Generalized Linear Model for Counts
  - Poisson Regression Assumptions:
    - Response variable is count per unit of time
    - Independence: Observations are independent in nature
    - Mean equal to Variance: Not true
- Alternate Consideration: Time Series Model
  - Forecasting does not provide instance prediction
  - Not easily translatable from user-friendly inputs
  - Requires constantly up-to-date info to forecast from given point in time

Modeling Step 1: Clustering Model

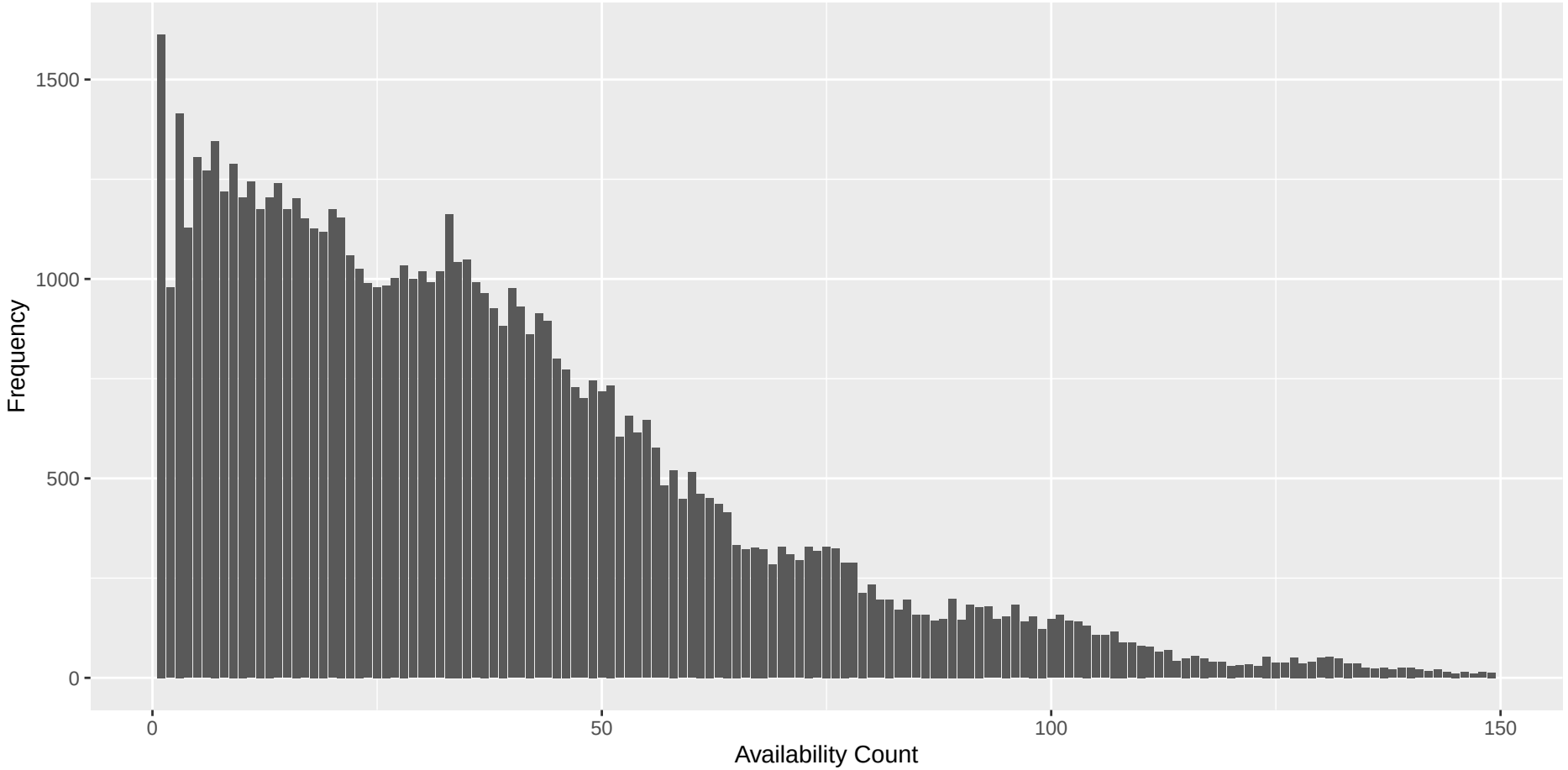
- Borough: Brooklyn
- Docking Stations: 474
- Clusters: 213 (2.23 stations/cluster)



Bike Availability Count Frequency

Histogram of availability based on 1HR intervals for Brooklyn clusters

- High frequency at 0 and plateaus at docking station capacities



Modeling Step 2: Count Models

Generalized Linear Models for Count Data

5 Models Attempted

- Poisson
  - `stats` library
- Quasi-Poisson
  - `stats` library
- Negative Binomial
  - `MASS` library
- Zero-Inflated
  - Poisson and Negative Binomial
  - `pscl` library

Model Results

Model	RMSE	MAE	Missed.Zero
Zero (Poisson)	11.2482	8.0648	280
Poisson	11.3075	8.1143	263
Quasi-Poisson	11.3075	8.1143	263
Zero (Neg. Binomial)	11.8260	8.3998	280
Negative Binomial	12.0320	8.5401	263

Selection: Poisson regression equation

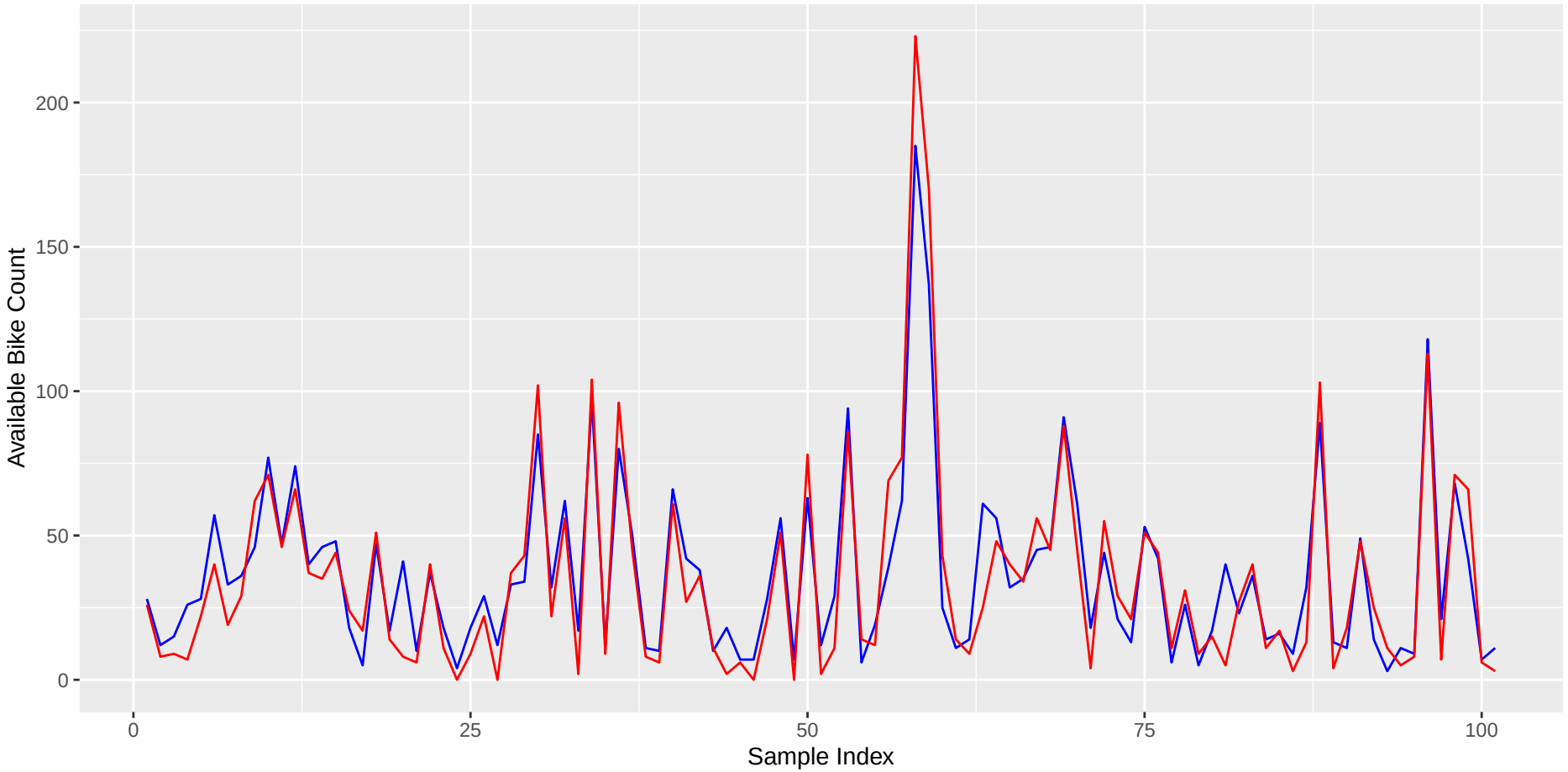
$$log(bikes) = 3.9209 + \beta_1 \cdot cluster + \beta_2 \cdot time + \beta_3 \cdot day \quad (1)$$

Second best RMSE and lowest count of missed Zero availability

Model Results Visualization

Plot subset of Predicted vs Actual counts for select model - Poisson

- Blue: Prediction; Red: Actual



Availability Prediction

- Longitude and Latitude (GPS location of user)
- Hour of the day (dropdown proposed)
- Weekday or Weekend (dropdown proposed)

(-73.960859, 40.67355, “22:00:00”, “WDAY”)

```
## [1] "Crown Heights - Available Bikes: 13; Cluster: 58"
```

(-73.9617, 40.7192, “18:00:00”, “WKND”)

```
## [1] "Williamsburg - Available Bikes: 57; Cluster: 201"
```

(-74.00509, 40.64338, “17:00:00”, “WDAY”)

```
## [1] "Sunset Park - Available Bikes: 5; Cluster: 10"
```

Current Achievements

Bike Availability prediction model for Brooklyn

- Hierarchical clustering
  - Location-based
- Poisson Model
  - Simplest count model
  - Second best RMSE value
  - Better predictor of zero availability

Ridership usage patterns

- Capture patterns of Citi Bike usage
  - System wide evaluation of NYC
  - Weekly and daily bike trip patterns

Future Work

- Deploy web application or smartphone app to use GPS location
- Improve zero availability accuracy
- Model all docking stations of New York City
- Real-time clustering to identify all docking stations within quarter-mile of user at the time
- Increase amount of availability data

Thank You

Thank you Dr. Paul Bailo along with all the CUNY professors, staff, and fellow students for support and guidance.