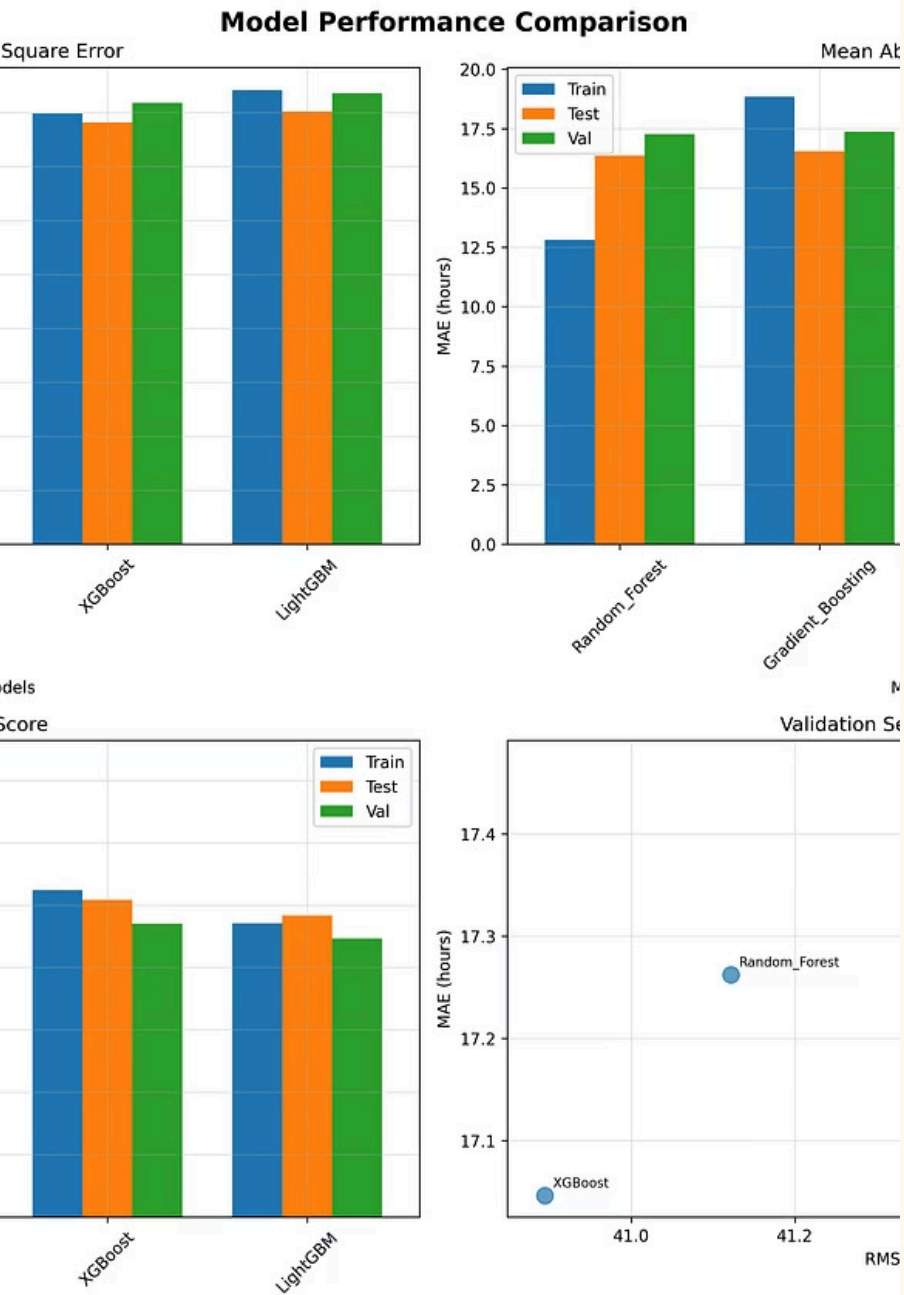




# Predicting NYC 311 Complaint Resolution Time Using Machine Learning Algorithms

A data science exploration into understanding and forecasting municipal service response times



# Introduction: NYC 311 Dataset Overview

The NYC 311 system represents one of the most comprehensive municipal service datasets in the world, containing over 7 million service requests spanning from 2010 to present.

This rich dataset consists of more than 500 distinct complaint types, providing detailed information including complaint classification, creation and closure timestamps, geographic location by borough, responsible agency, and precise coordinates.

## Project Goal

Develop a predictive model that accurately forecasts resolution timeframes for citizen complaints, allowing better resource allocation and improved public service delivery across New York City's five boroughs.

# End-to-End Pipeline Architecture

An approach that splits the project into distinct phases in order to better visualize each step separately with an easy and efficient way to run the entire architecture:

01

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## Data Acquisition

Download 2M service requests from NYC Open Data API

03

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## EDA

Analyze complaint distributions and resolution patterns

05

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## ML Modeling

Train and tune regression models

02

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## Preprocessing

Clean missing values, standardize formats, handle outliers

04

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## Feature Engineering

Create temporal, spatial, and categorical features

06

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## Performance Analysis

Evaluate by category and time bins





# Complaint Volume: What New Yorkers mostly report

The analysis of the 2 million complaints reveals clear patterns in what frustrates NYC residents:



## Illegal Parking

**300,000+ complaints**

By far the dominant issue



## Heat/Hot Water

**~180,000 complaints**

Critical housing concern



## Noise - Residential

**~160,000 complaints**

Quality of life issue



## Blocked Driveway

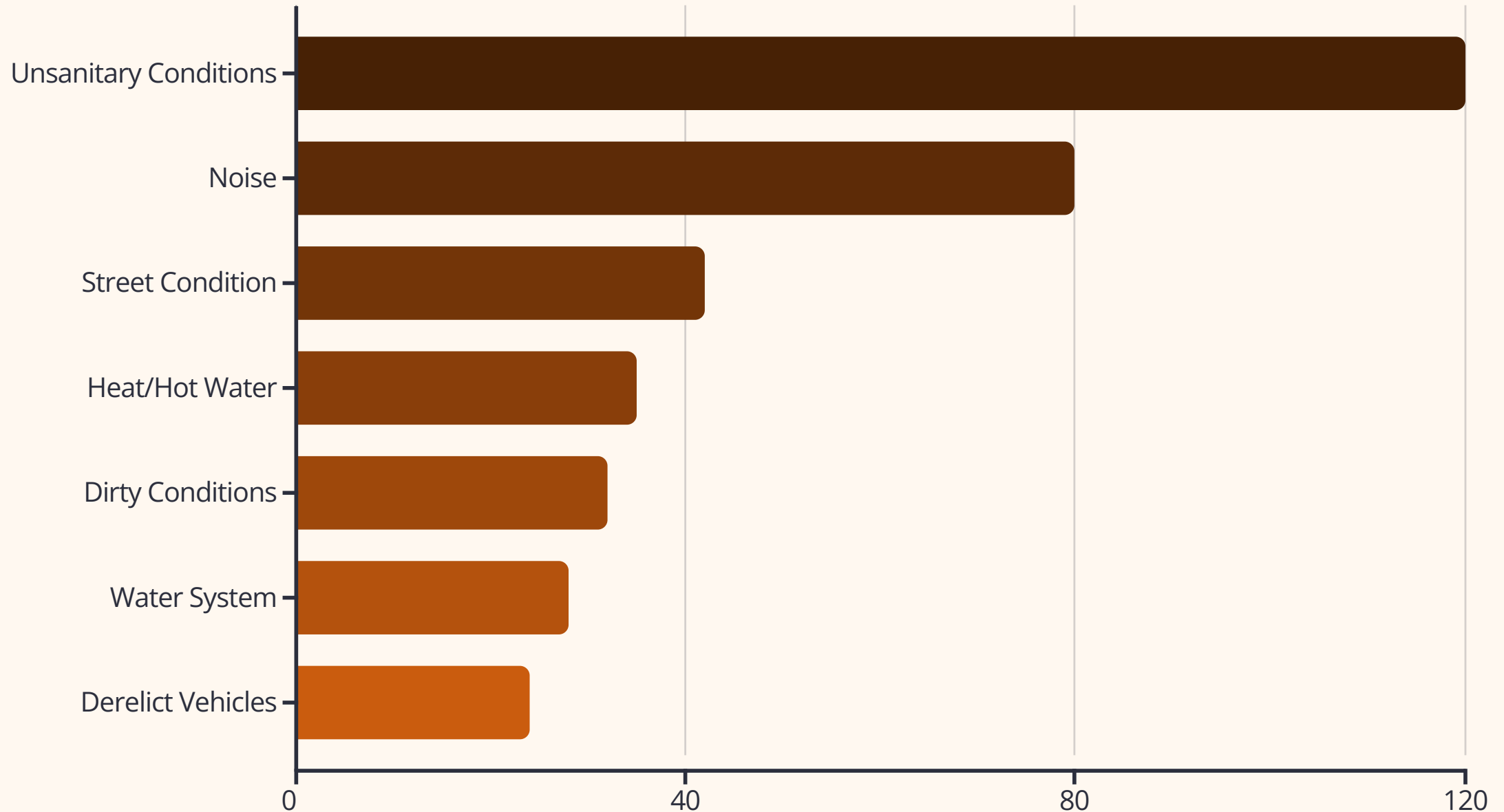
**100,000+ complaints**

Access and mobility

These top categories represent nearly 40% of all service requests, with noise (street/sidewalk), street conditions, and commercial noise following closely.

# Prediction Target: Resolution Time

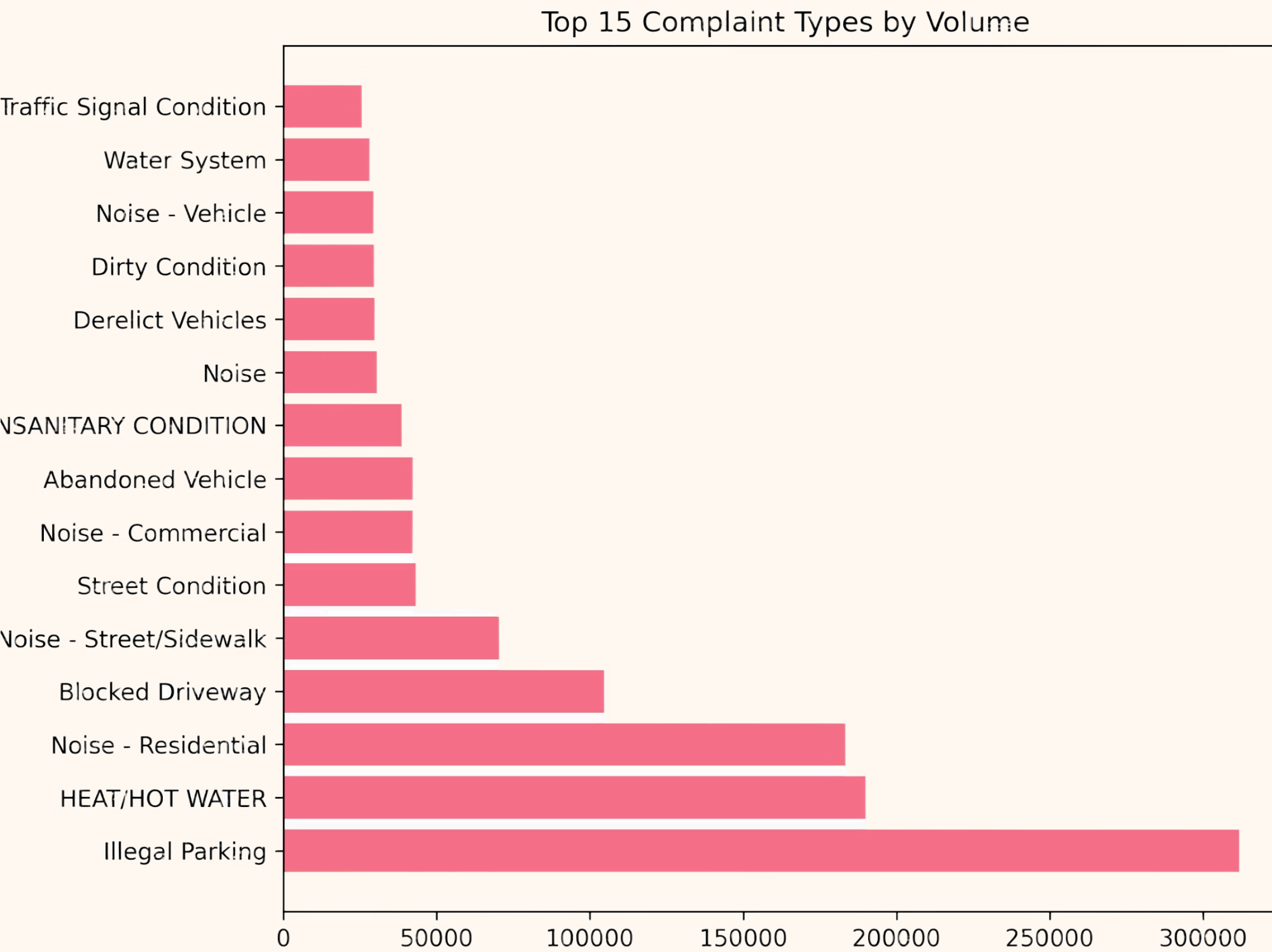
The key modeling challenge in this case is that the average resolution times vary dramatically by complaint type



**Key insight:** Unsanitary conditions take 5+ days on average to resolve, while some categories resolve in hours. This 50x variance makes category-specific modeling essential.

# Complaint Volume Analysis: Understanding NYC's Most Pressing Issues

The following chart illustrates the top 15 complaint types by volume, which shows the most frequent issues reported by New Yorkers.



## Key Observations

01	02	03
<h3>Dominance of Illegal Parking</h3> <p>Illegal Parking stands out as the most reported issue, with approximately 300,000 complaints, indicating a significant challenge in urban mobility and regulation.</p>	<h3>Widespread Noise Concerns</h3> <p>Noise-related complaints spread across residential, street/sidewalk, commercial, and vehicle categories sums up a total around 320,000 reports, highlighting a major quality of life issue affecting residents all over the city.</p>	<h3>Critical Housing Quality Issue</h3> <p>HEAT/HOT WATER complaints represent a substantial volume (~180,000 reports), showing persistent issues with housing maintenance and tenant well-being, particularly most pressing during colder months.</p>
04	05	
<h3>Infrastructure and Public Space Challenges</h3> <p>Issues like Blocked Driveway, Street Condition, Abandoned/Derelict Vehicles, Dirty Condition, Water System, and Traffic Signal Condition point to ongoing challenges in maintaining public infrastructure and the overall quality of public spaces.</p>	<h3>Diverse Range of Urban Problems</h3> <p>The variety of complaint types reflects the complexity of managing a large metropolis, from minor nuisances to critical service failures, each requiring dedicated attention.</p>	

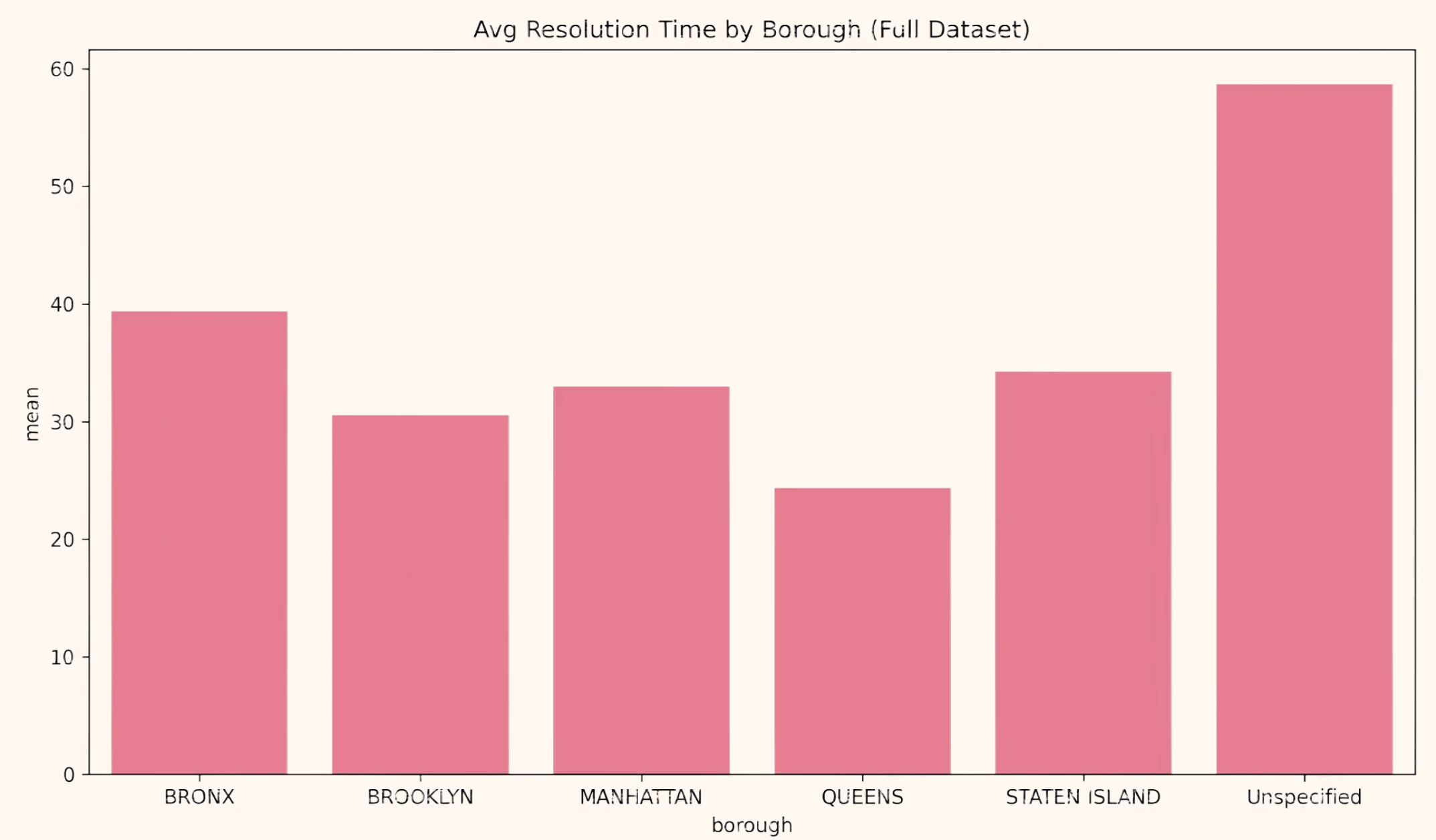
## Recommendations for City Management

- New rules for Parking:** Increase enforcement for illegal parking hotspots, buy specialized technology for more efficient monitoring and ticketing.
- Integrated Noise Reduction Programs:** Adopt programs to address noise pollution, increase public awareness campaigns, new soundproofing regulations.
- Proactive Building Maintenance Initiatives:** Launch initiatives to ensure proper heating and hot water in residential buildings, including more inspections and support for landlords to make necessary upgrades.
- Infrastructure Improvement Projects:** Plan for repairs and maintenance for street conditions, water systems, and traffic signals based on complaint data to improve public safety and efficiency.
- Enhance Public Space Management:** Increase efforts in cleaning public spaces and rapidly collect abandoned vehicles to improve the overall aesthetic of neighborhoods.
- Data-Driven Resource Allocation:** Utilize this complaint volume data to inform resource allocation, ensuring that high-volume issues receive adequate staffing and funding for effective resolution.



# Geographic Analysis: Average Resolution Time by Borough

The following plot illustrates the average resolution times for 311 service requests across New York City's boroughs, based on the full dataset analysis.



## Key Observations

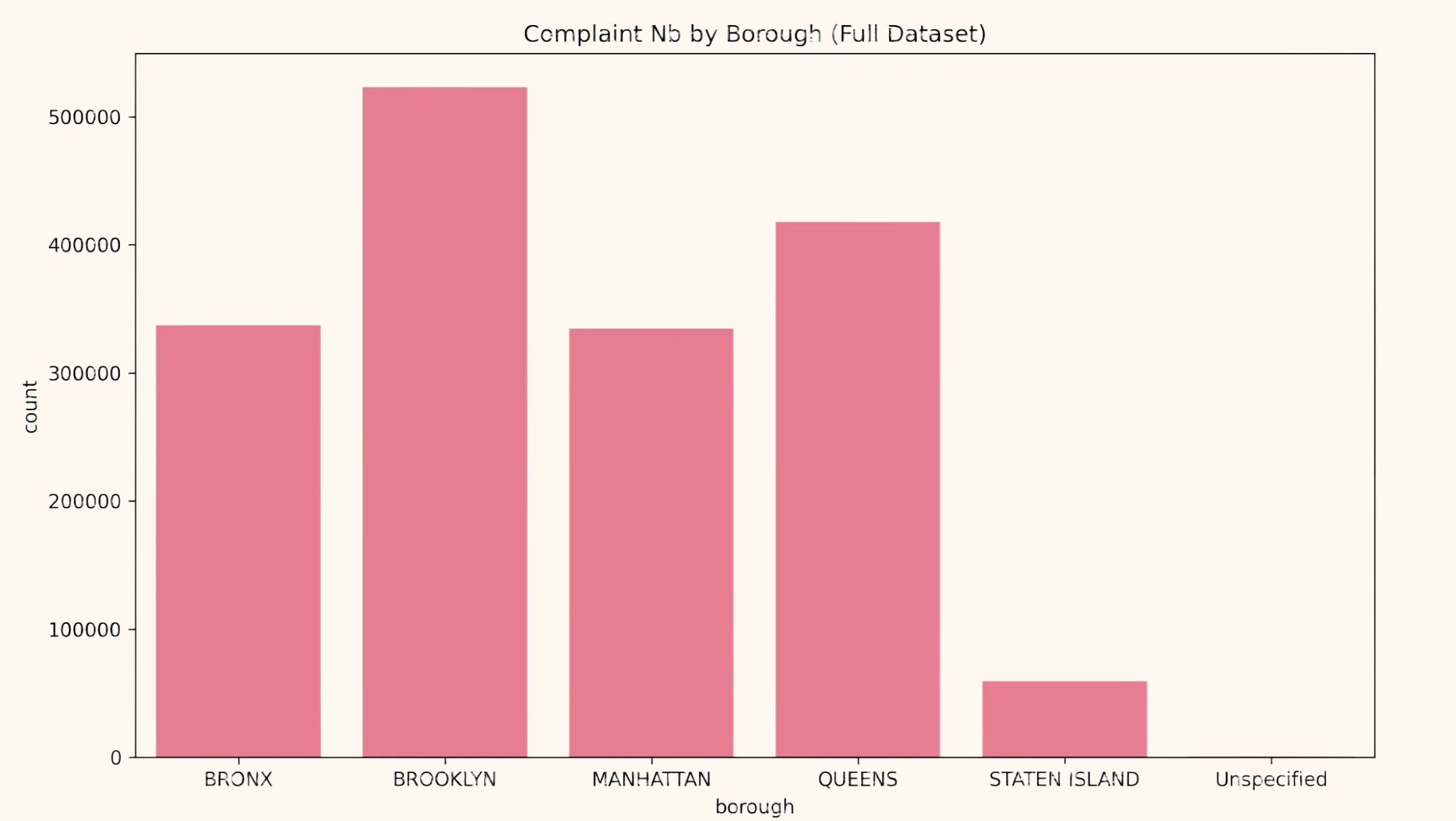
01	02	03
<h3>Significant Variation in Resolution Times</h3> <p>The resolution times varies across the boroughs, from Queens' efficient (~24 hours) to the Bronx's (~40 hours), showing performance differences based on each borough</p>	<h3>Queens: The Fastest Performer</h3> <p>Queens demonstrates the most efficient service delivery with an average resolution time of approximately 24 hours, setting a benchmark for other boroughs.</p>	<h3>Unspecified Locations: The Slowest and a Data Quality Concern</h3> <p>Complaints without a specified location take an alarming ~58 hours to resolve, indicating significant data quality issues or challenges in processing unassigned requests. This is the slowest category.</p>
04	05	
<h3>Brooklyn and Manhattan: Moderate and Consistent Performance</h3> <p>Brooklyn and Manhattan show comparable resolution times, averaging around 30 and 33 hours respectively.</p>	<h3>The Bronx: Longest Resolution Time Among Specified Boroughs</h3> <p>Among the explicitly identified boroughs, the Bronx experiences the longest resolution time at approximately 40 hours, suggesting potential areas for improvements.</p>	

## Recommendations for NYC 311 System Improvement

- Investigate Queens' Best Practices:** Analyze the operational workflows, resource allocation, and specific complaint types in Queens to identify best practices that can be adopted in other boroughs, particularly the Bronx.
- Address Unspecified Location Data Quality:** Implement measures to minimize "unspecified" locations in incoming requests. This could involve improving data entry protocols, providing better tools for residents to pinpoint locations, or dedicating resources to promptly assign these requests.
- Targeted Interventions for the Bronx:** Deeper analysis of the factors contributing to longer resolution times in the Bronx. This may include looking into agency response times, complaint volume, geographical challenges, or resource availability.
- Standardize Performance Metrics:** Establish clear, measurable performance targets for resolution times across all boroughs, considering specific challenges each may face, to drive consistent improvement.
- Resource Reallocation based on Performance:** Utilize this geographic data to inform strategic reallocation of resources (personnel, equipment) to areas experiencing higher backlogs or slower resolution times.

# Complaint Volume by Borough: Where is the Location of NYC's 311 Calls

This chart illustrates the distribution of 311 complaint volumes across New York City's five boroughs and unspecified locations, revealing which areas generate the most service requests.



The chart clearly shows the significant differences in complaint frequency across the boroughs, with Brooklyn and Queens leading the volume.

## Key Observations

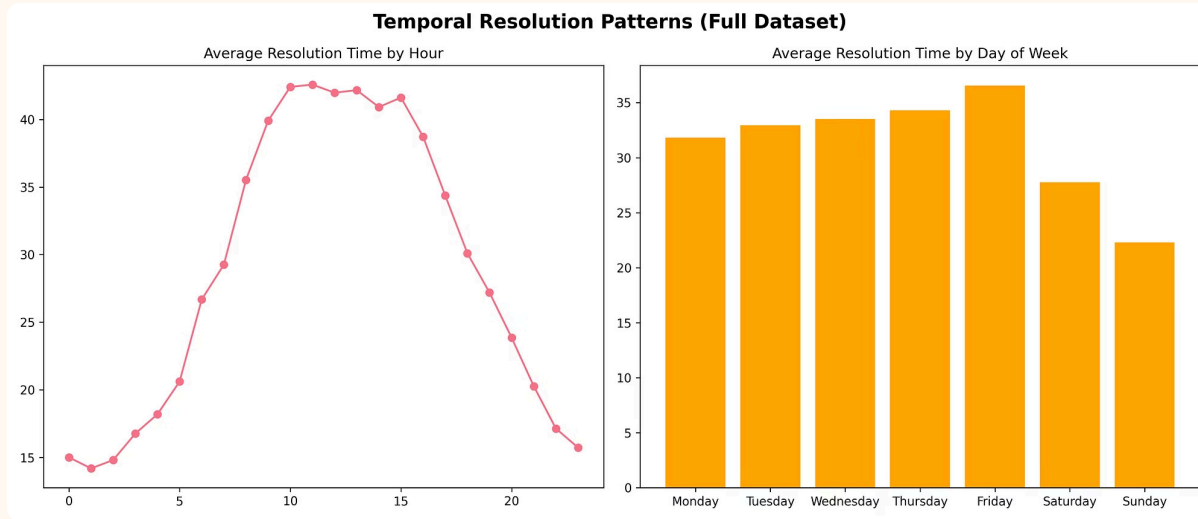
- Brooklyn Leads in Complaints:** With over 500,000 complaints, Brooklyn has the highest volume, indicating a significant demand for 311 services in this borough.
- Queens Second Highest:** Queens follows closely with more than 400,000 complaints, solidifying its position as another high-demand area for municipal services.
- Bronx and Manhattan Moderate Volume:** Both the Bronx and Manhattan show similar complaint volumes, each between 300,000 and 350,000, placing them in a middle tier for service requests.
- Staten Island Lowest:** Staten Island consistently reports the fewest complaints, suggesting a relatively lower volume of service issues or different reporting patterns.
- Minimal Unspecified Complaints:** The low number of complaints (869) categorized as "unspecified" indicates effective data collection for location information in most cases.

## Recommendations for Resource Allocation

- Targeted Resource Deployment:** Prioritize resource allocation and service improvements in high-volume boroughs like Brooklyn and Queens to address the disproportionate demand.
- Borough-Specific Problem Solving:** Investigate the root causes of high complaint volumes in Brooklyn and Queens to think solutions that address specific local challenges.
- Service Optimization:** Analyze the types of complaints specific to each borough to optimize service delivery and take measures more effectively.
- Monitoring for Shifts:** Continuously monitor complaint volumes to detect patterns or shifts in demand across boroughs, allowing for specific adjustments in city planning and services.



# Insights from Temporal Resolution Analysis



- **Weekday vs. Weekend:** Weekday performance is consistently slower compared to weekends, with Friday being the slowest day for complaint resolution.
- **Sunday's Edge:** Sunday shows the best overall performance, having the lowest average resolution time at approximately 22 minutes, but this might be due to the fact that on weekends citizens are less likely to file a complaint

Analysis of resolution times across different periods reveals crucial operational insights:

- **Peak Hours:** Resolution times significantly spike during core business hours (10:00–15:00), reaching up to 43 minutes for average resolution
- **Off-Peak Efficiency:** The fastest resolution occurs overnight and during late evening hours, indicating lower complaint volumes and quicker response cycles by city agencies



# Why Predict Resolution Time?



## Efficient Resource Allocation

Predictive models enable city agencies to better deploy staff, equipment, and budget where they're most needed, reducing bottlenecks and improving overall service delivery efficiency.



## Transparent Public Communication

Setting realistic expectations with citizens builds trust. Accurate predictions allow 311 operators to provide honest timeframes rather than generic responses, improving satisfaction even when waits are long.



## Proactive Management

Identifying complaint types that are prone to delays allows agencies to address systemic issues, streamline workflows, and implement preventive measures before backlogs become critical.

# Modeling Approach: Why XGBoost?

Models Evaluated:

In this analysis I tested multiple machine learning approaches to identify the optimal predictor:

- Gradient Boosting
- Light GBM
- Random Forest
- **XGBoost(Winner)**

Why XGBoost?

On unseen test data:

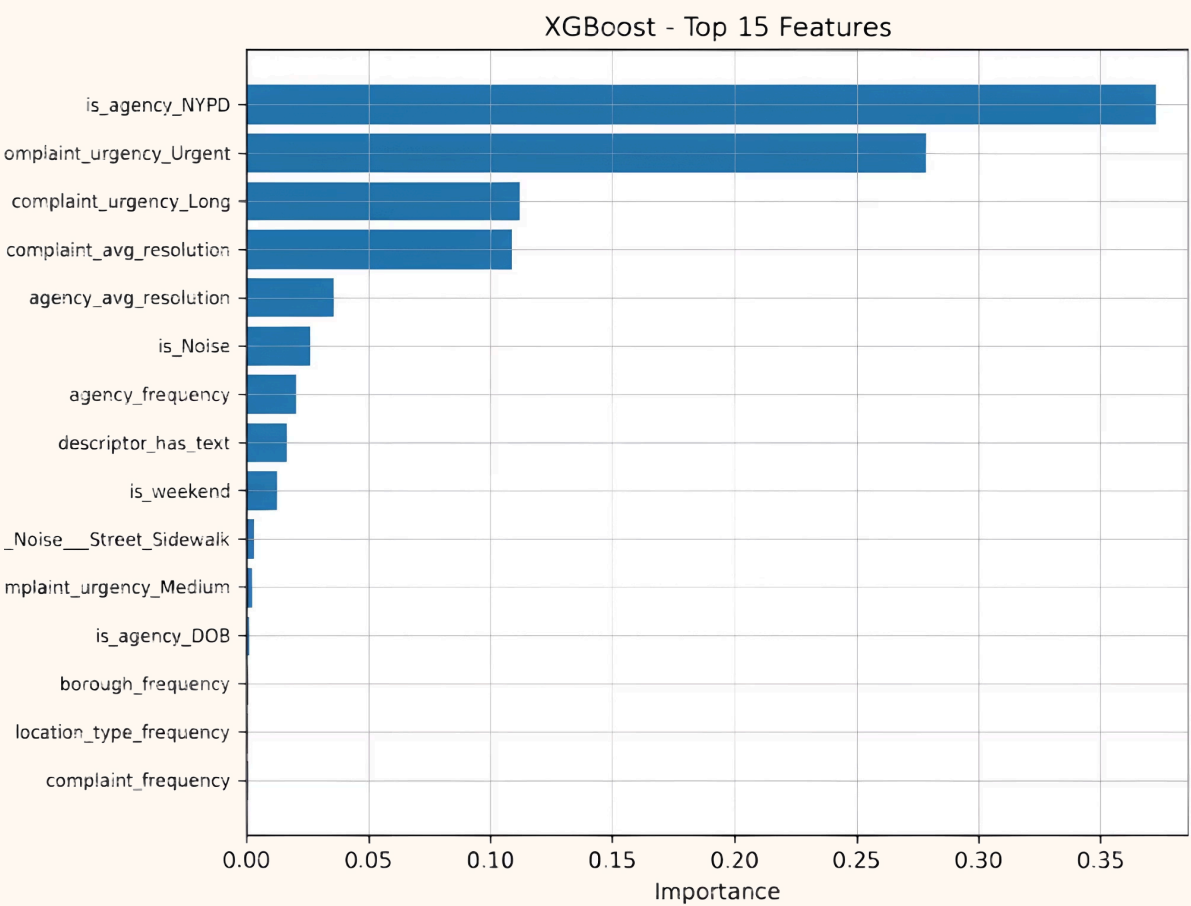
- **Average prediction error (MAE): ~16-17 hours best performance**
- **Typical larger errors (RMSE): ~39-40 hours less from all other models**

Model	Dataset	MA	RMSE	R2
XGBoost	train	17.93	39.92	0.52
XGBoost	test	16.15	39.1	0.51
XGBoost	val	17.05	40.89	0.47
Random_Forest	train	12.81	30.18	0.73
Random_Forest	test	16.37	39.35	0.5
Random_Forest	val	17.26	41.12	0.46
Gradient_Boosting	train	18.85	41.63	0.48
Gradient_Boosting	test	16.54	39.99	0.49
Gradient_Boosting	val	17.37	41.68	0.45
LightGBM	train	19.12	42.1	0.47
LightGBM	test	16.64	40.11	0.48
LightGBM	val	17.48	41.84	0.45

# Model Performance & Insights

The **XGBoost model** demonstrated strong predictive accuracy, consistently estimating how long different types of complaints will take to be resolved. It performs well at identifying both **quick resolutions** and **longer-running cases** that may require several days or weeks.

Results on the **validation set** show that XGBoost maintains similar accuracy even on data the model has never seen before. This confirms that its performance is stable across different **time periods, boroughs,** and **agency workloads**, making it a reliable candidate for operational use.



## Average resolution time

Across all models, the strongest predictors of resolution time are historical averages (how long similar complaints usually take)



## Borough

Resolution time varies significantly by borough, reflecting differences in workload volume, staffing levels, and operational efficiency across city regions.



## Urgency

Urgency strongly influences resolution time, with high-priority complaints being processed significantly faster and low-priority ones tending to accumulate delays



## Agency & Timing

Agency is one of the strongest drivers of resolution time — different agencies operate with very different workloads, resources, and process speeds, which significantly affects how quickly complaints are closed



# Feature Engineering Highlights

Transforming raw data into predictive signals required careful feature engineering and domain expertise:



## Target Variable Features

- Raw resolution hours → baseline prediction target
- Log-transformed → normalizes heavy-tailed resolution times
- Square-root transformed → alternative normalization
- Binned target (Very Fast → Very Slow) → classification-friendly version



## Temporal Features

- Extract hour, day, month, quarter, year → captures seasonality patterns
- Business-hours flag → some issues are addressed faster during working hours
- Weekend indicator → resolution slows on weekends
- Monday/Friday flags → edge-of-week processing delays
- Time-of-day bins (Night/Morning/Afternoon/Evening) → behavior varies by time
- Cyclical encodings (sin/cos) → model understands circular patterns (24h, 7d, 12m).



## Complaint Type Features

- Frequency encoding → common complaint types behave differently
- Avg resolution time per complaint → captures historical difficulty
- Urgency bins (Urgent → Very Long) → simplifies complaint severity
- Top complaint flags → preserves most important complaint categories
- Descriptor text metrics → longer or detailed descriptions may imply complexity



## Geographic Features

- Borough frequency & avg resolution → some boroughs process faster/slower
- Borough one-hot encoding → spatial patterns captured cleanly
- ZIP cleaned & frequency encoded → detects high-activity neighborhoods
- Top ZIP indicator → identifies ZIPs with recurring operational load
- Location type frequency + flags → indoor vs outdoor, residential vs commercial differences



## Agency Features

- Agency frequency → workload and specialization vary
- Avg resolution time per agency → some agencies are more efficient
- Top-agency flags → highlights key players in the dataset
- Agency × complaint interactions → captures agency-specific behavior in complaints

# Challenges & Learnings

1

## Imbalanced Data Distribution

A severe data imbalance, with most complaints resolved quickly and a few extremely slowly, required specialized sampling and evaluation to prevent biased predictions.

2

## Extreme Outliers

Extreme outliers have been excluded

3

## Model Refinement Necessity

Dynamic temporal patterns and evolving urban issues mandate continuous model retraining with updated data to maintain prediction accuracy and relevance.

# Visualizing Predictions: Before & After

## Before Model

- Citizens and 311 operators faced wide uncertainty when estimating complaint resolution times.
- This uncertainty led to frustrated callers, repeated follow-up calls, and inefficient resource planning by agencies.

## After Model

The XGBoost model predictions allows better:

- Expectation-setting
- Proactive resource allocation
- Identification of cases likely to exceed acceptable timeframes

# Conclusion & Next Steps



## Key Achievement

XGBoost proved to be a powerful, production-ready tool for predicting NYC 311 complaint resolution times with actionable accuracy.



## Real-World Impact

These insights enable NYC to improve service efficiency, allocate resources strategically, and enhance citizen satisfaction through transparent communication.



## Future Directions

Next steps include real-time data integration, exploration of deep learning architectures, and expansion to other cities' 311 systems.

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