BOSTON 311 SYRINGE DASHBOARD – PREDICTIVE ANALYTICS AND GEOSPATIAL INSIGHTS

INTRODUCTION

Purpose and Contribution to the Group Project

The goal of this project is to employ geographic clustering and predictive analytics to analyze Boston's 311 service requests. In order to ensure equitable distribution of municipal resources, the main objective is to address spatial disparities in service delivery. Our group's final project, which entails creating an equity-focused dashboard for the Boston Public Works Department, will benefit from the insights gained.

Literature Integration

Behrends et al. (2022) found that more than 60% of service programs used data-driven strategies to increase their effectiveness during emergencies. This emphasizes how important it is to use predictive analytics to maximize municipal services.[4] Formica et al. (2022) showed how spatial clustering helped Massachusetts' POST program effectively involve communities.[6] Building on these discoveries, our study uses geospatial analysis and machine learning to identify service gaps and improve response times.

Sponsor and Data Source

The Massachusetts Department of Public Health requires predictive resource allocation and real-time monitoring of service-level agreement (SLA) compliance. Our dataset includes spatial, temporal, and administrative information from more than 3 million Boston 311 service records from 2011 to 2025.[1]

METHODS

Data Combining and Cleaning

The Boston 311 Service Requests Data is derived from City of Boston (Boston 311) site. The dataset has 3M+ records with 31 different measures recorded from year 2011 to 2025.[1] As the raw data consisted different datasets for each year, I first started with combining the datasets together to create one major dataset, the Boston 311 Service Requests Data.

<u>Removing Unnecessary measures:</u> Removed columns like 'submitted_photo', 'closed_photo', 'geom_4326' as they were not relevant to my analysis

Correcting the datatypes of columns: Changed the datatypes of opent_dt, closed_dt, sla_target_dt to datetime with proper format. Setting the ontime and year columns to category and the case_enquiry_id to object as it is unique and should not be considered numerical.

Handling Null Values: More than half of the columns had null values. I first segregated them into null percent categories.

- Removed the records from columns with less than 5% null values (columns – 'on_time', 'case_title', 'fire_district', 'pwd_district', 'city_council_district', 'police_district', 'neighborhood', 'ward', 'precinct','neighborhood_services_district', 'location_street_name', 'latitude', 'longitude').

- For missing values in the sla_target_dt column, I used the difference between open_dt and sla_target_dt to create a new column sla_duration, and used imputation function to fill the missing values in sla_target_dt column.

- Dropped the sla_duration column as it was irrelevant to my dataset.

- For missing values in closed_dt, I calculated the difference between closed_dt and open_dt and filled the missing values by using imputation function.

- Utilized the boston boundaries shapefile and merged with my dataset to fill in the missing values for location_zipcode column

Geocoding: Utilized geocoding to convert the latitude and longitude columns into geometric measures to be used for geographic implementations in the further analysis.
Filtering the data: As the project focuses on Syringe Requests Data, I filtered my Service Requests Dataset by type of requests as Syringe/ Needle Pickup and saved the filtered data for further analysis

Now my cleaned, combined and filtered data consists of 65K+ records with 29 different measures based on Boston 311 Syringe Service Requests Types.[1]

Methodology – tools and software used

Python Libraries: Pandas, NumPy, Matplotlib, Seaborn for data manipulation and visualization.

Microsoft Power BI: For interactive and dynamic dashboard creation and showing geospatial and trends insights.
Machine Learning Algorithms: To forecast the impact of policy implementation on the syringe requests.

Literature Justification

A strong basis for comprehending the dynamics of syringe service programs and their function in harm reduction is provided by the literature studied for this research. The flexibility of syringe service programs in times of crisis, like the COVID-19 pandemic, is highlighted by Behrends et al. (2022), who also stress the significance of data-driven tactics to maximize service delivery.[4] The project's use of geospatial analysis and predictive analytics to enhance Boston's 311 syringe request system is directly supported by this realization. In a similar vein, Karsten (2023) emphasizes how effective needle exchange programs are at decreasing the spread of infectious diseases and boosting user participation in treatment.[5]

These results support the necessity of an all-inclusive dashboard that monitors syringe requests and improves the results of service delivery. Lastly, Formica et al. (2022) provide a methodological framework for incorporating geographical data into the project by illustrating how spatial clustering and focused outreach effectively engaged overdose survivors in Massachusetts.[6] Collectively, these studies demonstrate how data-driven solutions can effectively solve public health concerns, hence justifying the project's methodology.

RESULTS

Preliminary Analysis

1. Numerical Summary Statistics Table

index	latitude	longitude
count	65820	65820
mean	42.33562	-71.0738
std	0.016378	0.016697
min	42.2321	-71.1743
25%	42.33028	-71.0797
50%	42.33652	-71.0745
75%	42.34289	-71.0648
max	42.39517	-70.9964

Table 1: Numberical Statistics Table

The numerical summary statistics table given above provides information on the statistical measures of the columns, latitude and longitude.

2. Categorical Statistics Table

index	count	unique	top	freq
case_enquiry_id	65820	65820	101001382252	1
on_time	65820	2	ONTIME	65815
case_status	65820	2	Closed	65815
closure_reason	65820	65817	Case Closed Case Resolved Dear Constituent If you receive a message from the City of Boston regarding an old service request 311 is currently working on closing out backlogged service requests. We apologize for any confusion or inconvenience. Please contact 311 for further information. Thank you, Boston 311 Team	3
case_title	65820	2	Needle Pickup	65815
subject	65820	1	Mayor's 24-Hour Hotline	65820
reason	65820	1	Needle Program	65820
type	65820	1	Needle Pickup	65820
queue	65820	50	GEN_Needle_Pickup	65649
department	65820	10	GEN_	65649
location	65820	15425	544P Massachusetts Ave Roxbury MA 02118	467
fire_district	65820	18	4	28802
pwd_district	65820	16	1C	30072
city_council_district	65820	9	2	23681
police_district	65820	12	D4	33584
neighborhood	65820	23	Roxbury	16842
neighborhood_services_district	65820	16	6	22616
ward	65820	23	8	21470
precinct	65820	254	802	11563
location_street_name	65820	15368	544P Massachusetts Ave	467
location_zipcode	65820	33	2118	27027
source	65820	6	Citizens Connect App	51284

Table 1: Categorical Statistics Table

The categorical table gives a glimpse of categorical columns within 4 different categories; count as in the total number of records, unique as in the number of unique values, top as in the first value of each column and the average frequency of the columns.

3. District Specific Summary Statistics Table

neighborhood	ONTIME	OVERDUE	total_requests	compliance_rate
Allston	56	0	56	100
Allston / Brighton	524	0	524	100
Back Bay	4556	0	4556	100
Beacon Hill	400	0	400	100
Boston	3359	0	3359	100
Brighton	76	0	76	100
Charlestown	748	0	748	100
Chestnut Hill	1	0	1	100
Dorchester	6086	1	6087	100
Downtown / Financial District	3353	0	3353	100
East Boston	776	0	776	100
Fenway / Kenmore / Audubon Circle / Longwood	1753	1	1754	99.9
Greater Mattapan	611	0	611	100
Hyde Park	227	0	227	100
Jamaica Plain	2004	0	2004	100
Mattapan	32	0	32	100
Mission Hill	547	0	547	100
Roslindale	266	0	266	100
Roxbury	16842	0	16842	100
South Boston	924	0	924	100
South Boston / South Boston Waterfront	6996	0	6996	100
South End	15508	3	15511	100
West Roxbury	170	0	170	100

Table 3: District Specific Summary Statistics

The above table showcases the summary statistics for district specific. The categories include the ontime/overdue status of each district, the total number of requests and the rate of compliance.

Visualizations

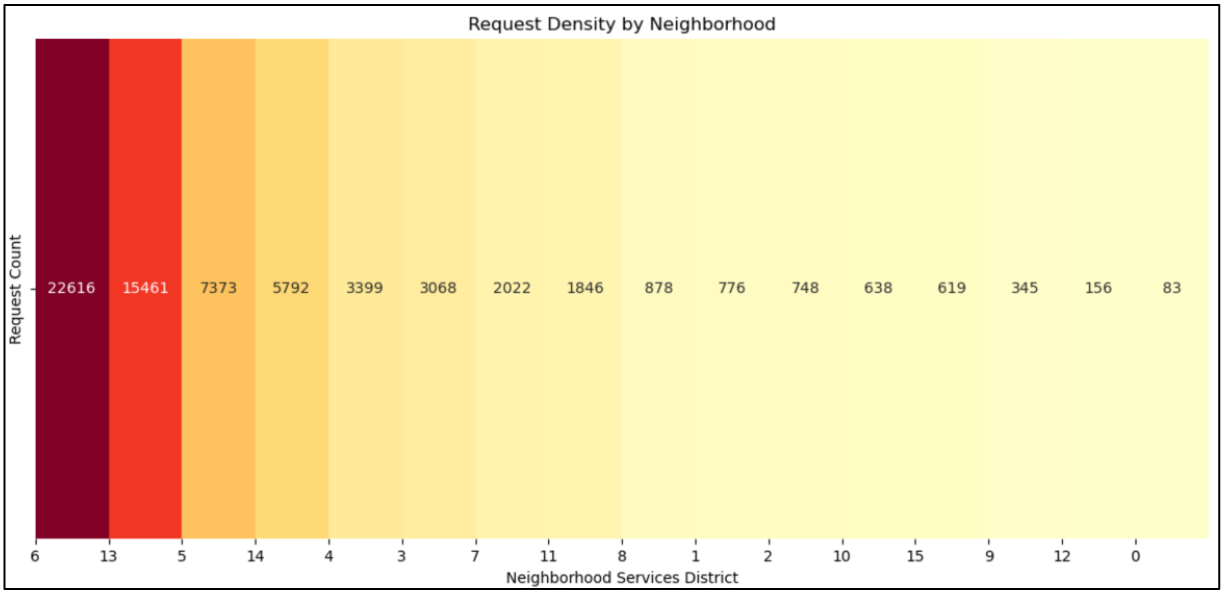
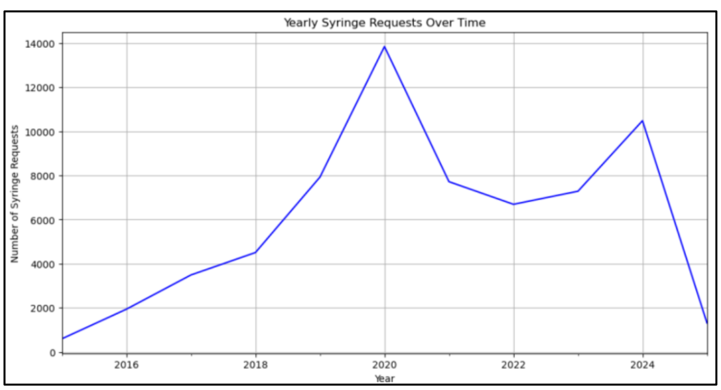
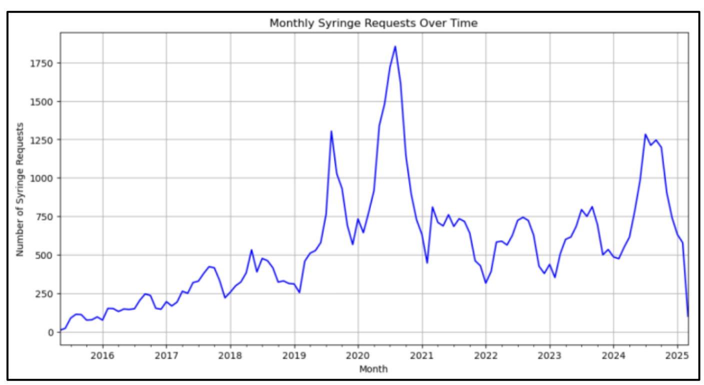


Fig1: Request Density by Neighbourhood Districts

The above heatmap provides information on the number of requests by neighbourhood. It can be clearly observed that neighbourhood service district 6 has the highest density with 22,000 plus number of requests.





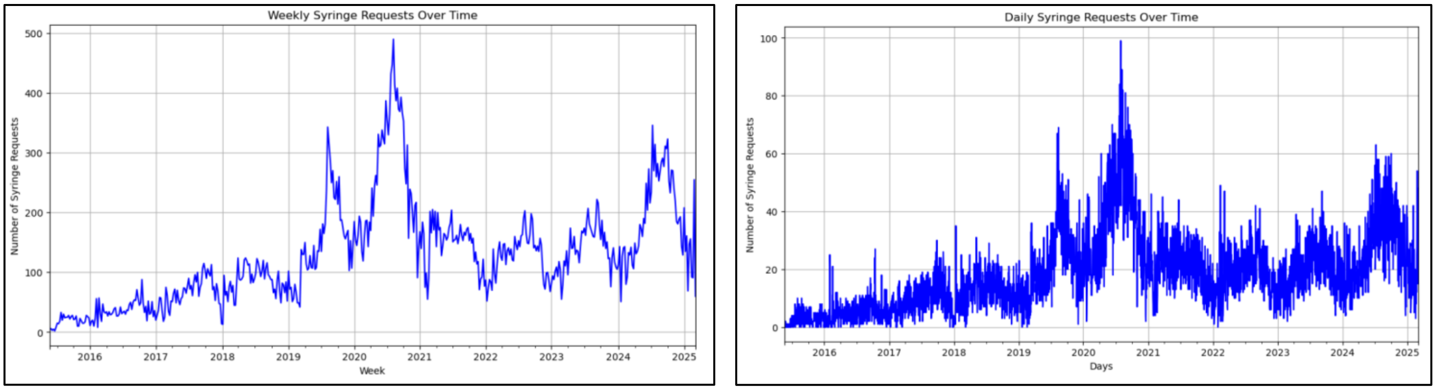


Fig 2: Seasonal Trends in the Number of Requests over Time

The above visuals shows the trends in number of requests from year 2015 to 2025. The first visual shows the yearly trends in the number of requests, the second visual showing monthly trends followed by third visual with weekly trends and fourth with daily trends in the number of syringe requests. As the data has few records for the year 2025, there is a sudden drop in the trend lines. The rice in the year 2020-2021 can be observed due to the covid – 19, pandemic break.

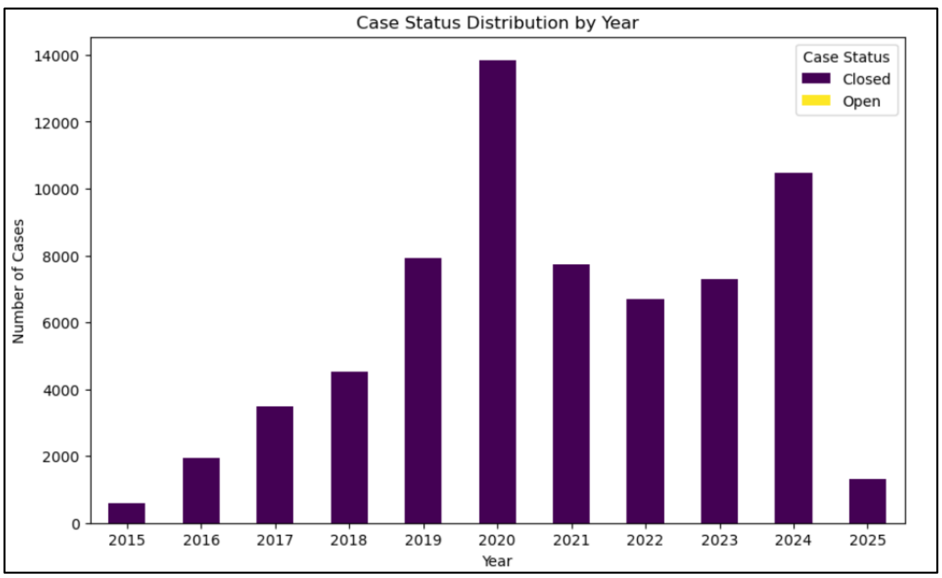


Fig 3: Distribution of Cases by Year

The given bar plot shows the number of cases by year highlighting the status for each year. As our data consists of little to no open cases, the bar plot does not provide much information on the same. Another observation is for the years 2020 and 2025, the covid 19 pandemic break of 2020 is the reason behind the high volume of cases in 2020 where as our data has limited amount of data for the year 2025, it shows a quite small bar.

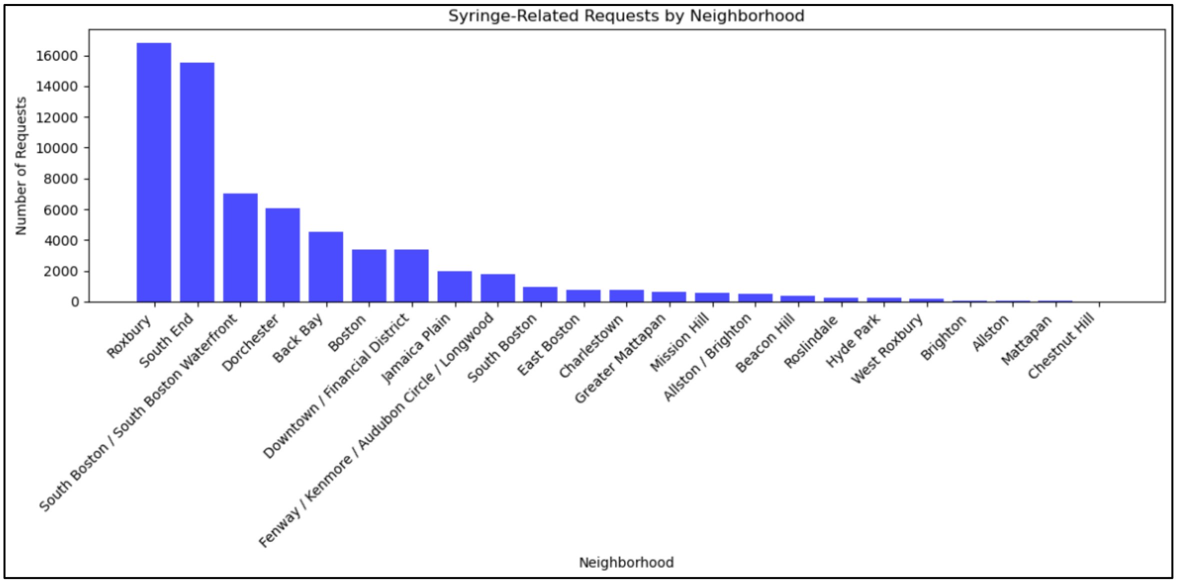


Fig 4: Distribution of Syringe Requests by Neighbourhood

The given bar plot, shows the distribution of the syringe requests by neighbourhood. Roxbury has the highest number of syringe requests with the number going above 16,000 while the places like Brightno, Allston, Mattapan and Chestnut Hill observed to have minimum to zero requests.

Geospatial Analysis

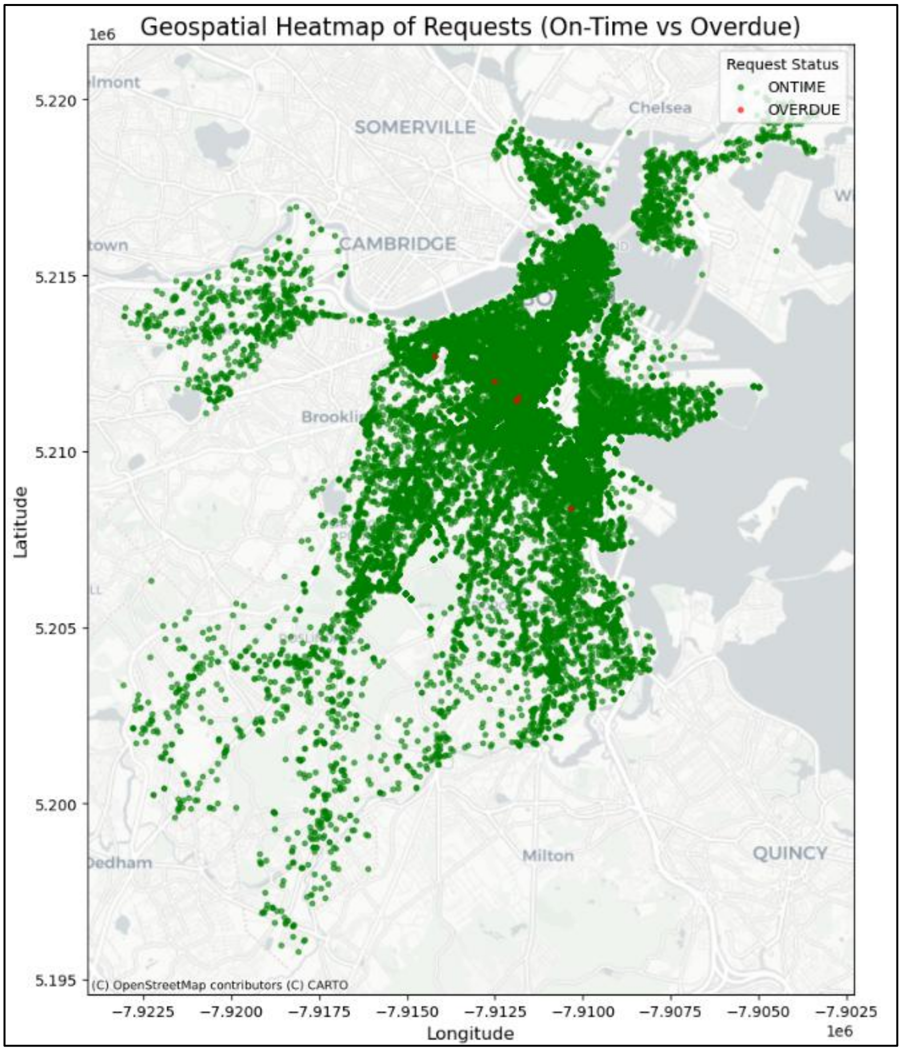


Fig 5: Geospatial Analysis – Ontime vs Overdue Requests

The given heatmap illustrates syringe requests throughout Boston, by segregating the on-time and overdue requests.

Green dots: Show that most communities have good adherence to Service Level Agreements (SLAs) by representing on-time service requests.

Red dots: These represent past-due requests, which are dispersed and grouped in particular locations. Neighbourhoods with less SLA compliance are highlighted by these clusters.

According to the map, there is a strong demand for syringe services in major urban districts such as Roxbury and Dorchester, where requests are densely clustered. The heatmap illustrates how SLA compliance varies geographically, with underprivileged areas exhibiting greater concentrations of past-due cases. This data can direct focused initiatives to increase the equity of service delivery.

Forecasting Model

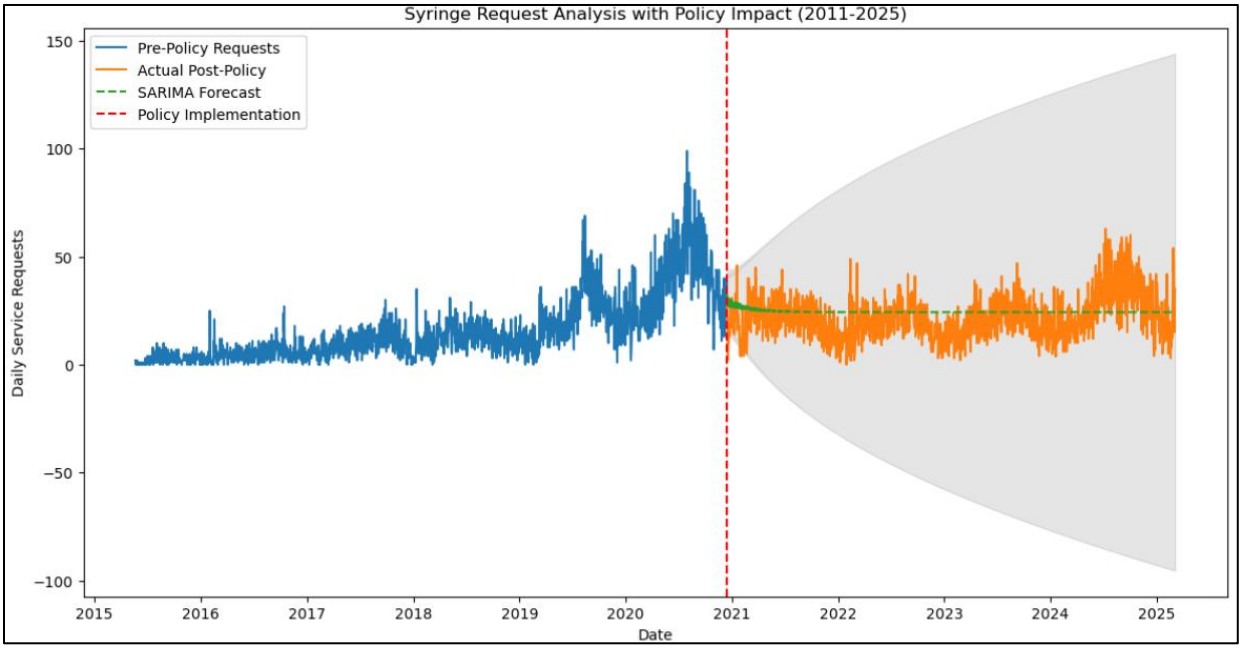


Fig 6: Forecasting Model

The given time-series graph highlights the effects of the Community Service Redemption Program (CSRP) put in place on December 14, 2020 by showing the patterns in daily syringe service requests from 2015 to 2025.[2] Among the chart's essential components are:

Pre-Policy Requests (Blue Line): The daily syringe service requests before to the policy's implementation are represented by the Pre-Policy Requests. The data indicates a consistent rise over time, with a notable uptick in 2020, most likely brought on by the COVID-19 pandemic.

Post-Policy Requests (Orange Line): Documents real service requests made following the implementation of the policy. Data collected after the policy shows that requests have stabilized or even slightly decreased, which may indicate that the policy helped to lower demand or better allocate resources.

SARIMA Forecast (Green Dashed Line): The expected number of syringe requests in the event that the policy was not enforced was predicted using a Seasonal Autoregressive Integrated Moving Average (SARIMA) model. For comparison, this offers a counterfactual situation.

Policy Implementation (Red Line): The policy's exact introduction date on December 14, 2020 is shown by the policy implementation marker. The possible impact of the policy is highlighted by the discrepancy between the SARIMA forecast and actual post-policy data.

Forecast Confidence Interval (Gray Shaded Area): Shows the area of uncertainty for SARIMA predictions, getting wider as long-range projections go.

Given that actual post-policy data trends lower than the predicted trajectory, the graphic indicates that the policy's introduction in 2020 helped prevent additional rises in syringe service requests.

Dashboard Visuals

I used Power BI to create an interactive and dynamic dashboard. The below screenshots, gives a glimpse about the dashboard and its functions.[7]

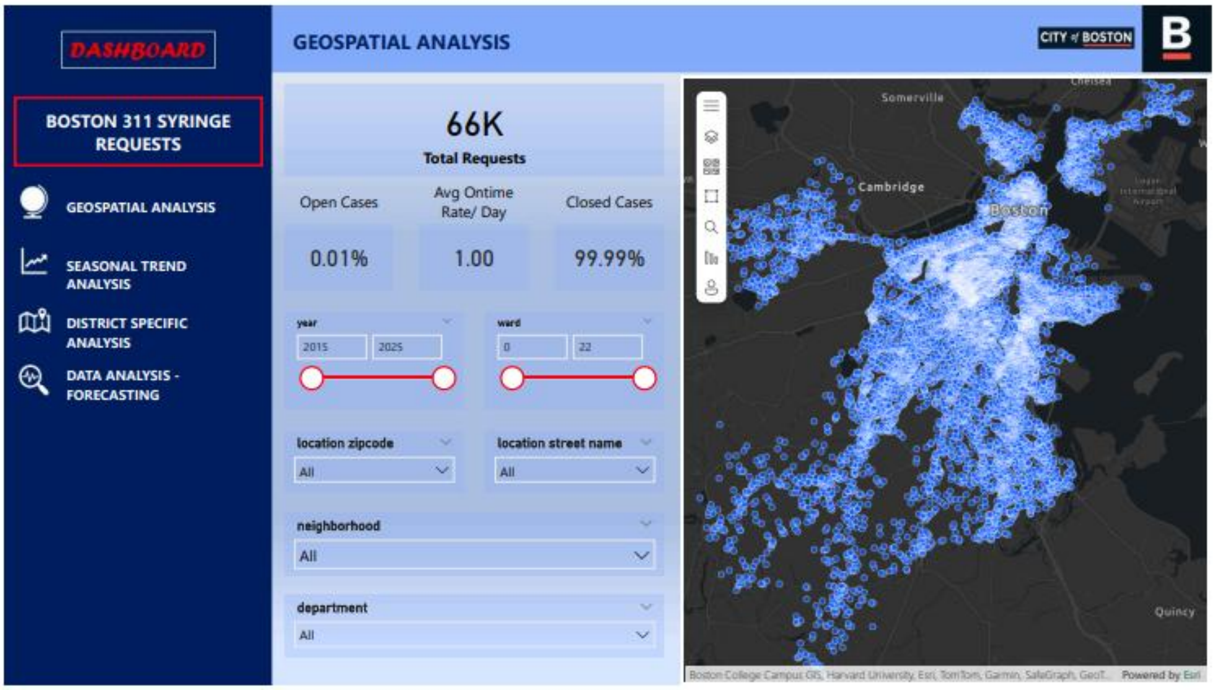


Fig7: Geospatial Analysis Dashboard

The above dashboard provides a geographic breakdown of syringe requests for Boston 311. It highlights hotspots and trends within the city and graphically depicts how requests are distributed and concentrated across various geographic areas.

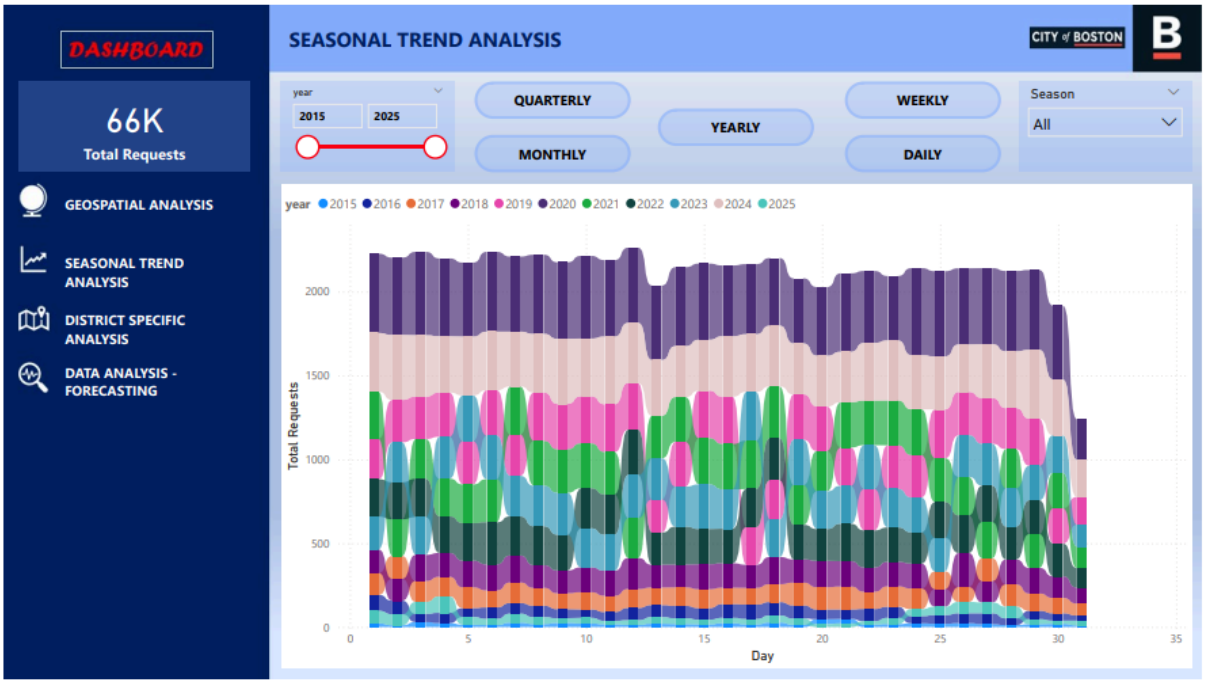


Fig8: Seasonal Trend Analysis Dashboard

The seasonal patterns of syringe requests across several years (2015–2025) are displayed in this dashboard. In order to show variations and seasonal peaks or decreases in requests throughout several months and years, it incorporates graphical representations, such as line or bar charts.

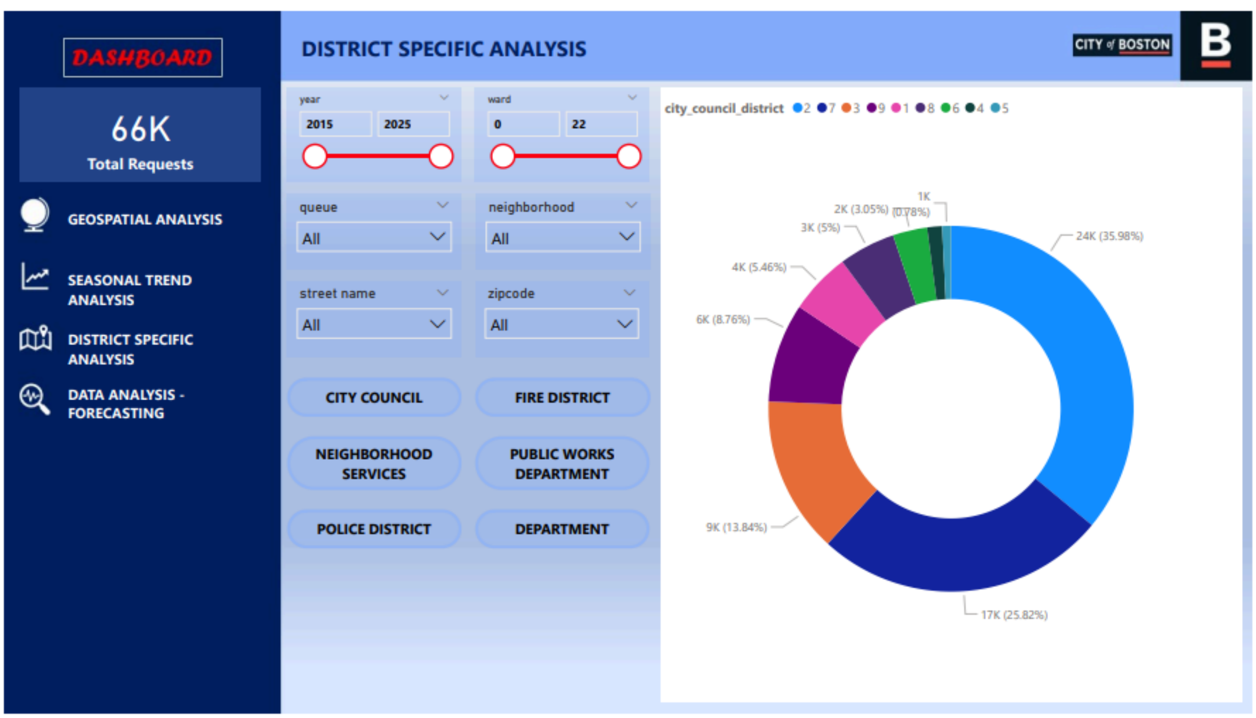


Fig9: District Specific Analysis Dashboard

This dashboard offers an analysis tailored to Boston's different districts. In order to identify districts with a larger volume of syringe requests, it probably includes comparative visualizations, data, or maps, which aid in identifying regional problems and patterns.

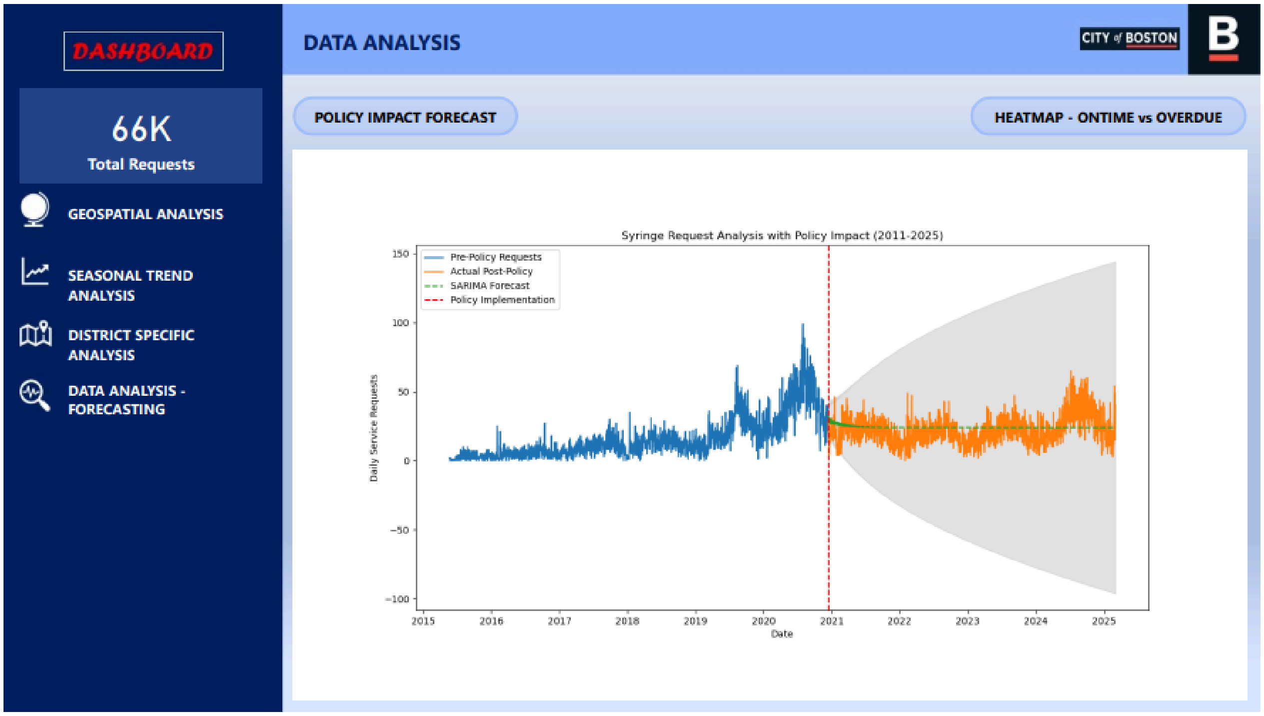


Fig 10: Data Analysis Dashboard

The given dashboard is created by integrating python data modelling analysis into Power BI. The main goal of this dashboard is to use historical data to predict future patterns in syringe requests. For planning and resource allocation purposes, it projects anticipated future request volumes and patterns using predictive modelling techniques and representations like forecast plots or trend lines.

CONCLUSION

The Boston 311 Syringe Dashboard project effectively addresses spatial inequities in municipal service delivery by combining geospatial data and predictive analytics. Through the examination of past syringe request data, the research finds district-specific patterns, seasonal trends, and geographic hotspots that help guide fair resource distribution and policy choices. Stakeholders may also predict future demand and assess the effectiveness of initiatives like the Community Service Redemption Program by integrating machine learning forecasting models.

This research shows how enhancing access to necessary services in marginalized communities through data-driven solutions can improve public health outcomes. Decision-makers can prioritize regions with more demand for syringe services and optimize service-level agreements (SLAs) with the help of the dashboards that were developed, which offer actionable insights. This work paves the path for future advancements in public health resource management by utilizing evidence-based techniques and sophisticated analytical tools to create a more equitable and efficient municipal response system for Boston's communities.

REFERENCES

[1] 311 service requests - analyze Boston. https://data.boston.gov/dataset/311-service-requests

[2] CSRP — Addiction Response Resources. Addiction Response Resources. https://www.addictionresponse.com/csrp

[3] Laughlin J. Boston ends funding for needle collection program. *BostonGlobe.com*. https://www.bostonglobe.com/2024/07/02/metro/needle-boston-syringe-collection-opioid-addiction/. Published July 3, 2024.

[4] Behrends CN, Lu X, Corry GJ, et al. Harm reduction and health services provided by syringe services programs in 2019 and subsequent impact of COVID-19 on services in 2020. *Drug and Alcohol Dependence*. 2022;232:109323. doi:10.1016/j.drugalcdep.2022.109323 https://www.sciencedirect.com/science/article/pii/S0376871622000606?via%3Dihub

[5] Karsten MB. A Case for Needle Exchange Programs: Not Letting Perfection be the Enemy of the Good. *Georgetown Medical Review*. 2023;7(1). doi:10.52504/001c.83277 https://gmr.scholasticahq.com/article/83277-a-case-for-needle-exchange-programs-not-letting-perfection-be-the-enemy-of-the-good

[6] The Massachusetts Department of Public Health Post Overdose ... : Journal of Public Health Management and Practice. LWW. https://journals.lww.com/jphmp/fulltext/2022/11001/the_massachusetts_department_of_public_health_post.9.aspx

[7] Boston311_SyringRequests - Power BI. https://app.powerbi.com/groups/me/reports/384298a9-c179-4e9f-a7d5-e15a6073141d/9084c4fc3c62c2043a15?ctid=a8eec281-aaa3-4dae-ac9b-9a398b9215e7&experience=power-bi&bookmarkGuid=5d16f430896163badd32