# Environmental Impact Assessment of Special Economic Zones (SEZs) Using Air Quality Data

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# Abstract

Special Economic Zones (SEZs) are being developed to drive economic growth, but their rapid industrialization may harm public health and the environment. This project analyzes district-level air pollution data around recently established SEZs in India, focusing on key pollutants like PM2.5, PM10, $NO_2$, $SO_2$, CO, and $O_3$. Using ArcGIS, we map SEZ locations and pollutant levels. We then fit Lognormal, Weibull, and Gamma models to the data to identify the best statistical fit. The goal is to assess pollution trends and support sustainable SEZ development.

# Objectives

The objective of this study is to assess the environmental impact of newly established Special Economic Zones (SEZs) in India by analyzing district-level air pollution data. We aim to map SEZs and pollution levels using GIS tools, examine changes in pollutant concentrations over time, and statistically model these trends using Lognormal, Weibull, and Gamma distributions. By evaluating model fits and spatial patterns, the study seeks to understand the extent to which SEZ development influences local air quality.

# Introduction

India was one of the first in Asia to recognize the effectiveness of the Export Processing Zone (EPZ) model in promoting exports, with Asia's first EPZ set up in Kandla in 1965. With a view to overcome the shortcomings experienced on account of the multiplicity of controls and clearances; absence of world-class infrastructure, and an unstable fiscal regime and with a view to attract larger foreign investments in India, the Special Economic Zones (SEZs) Policy was announced in April 2000.

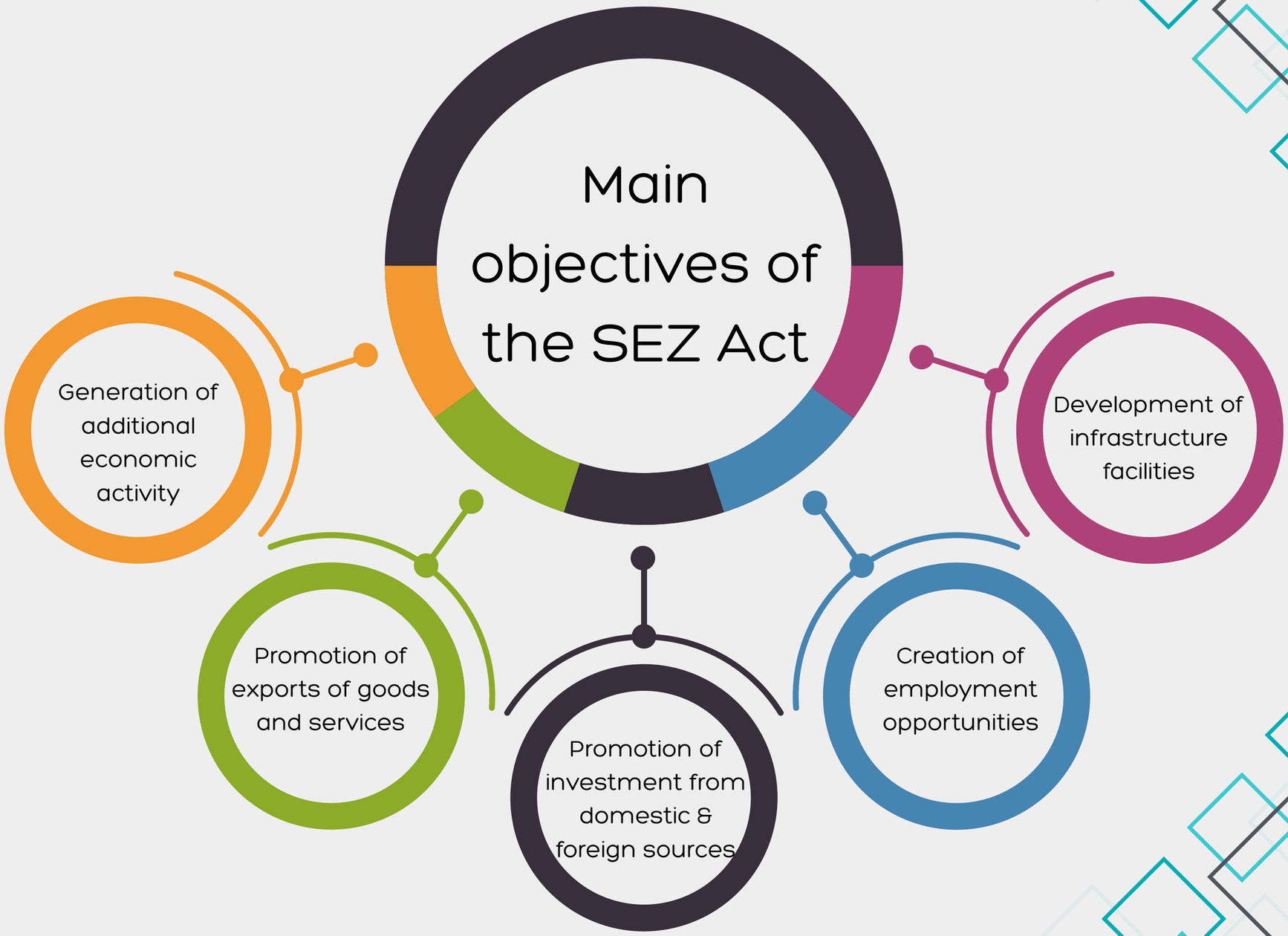
The policy aims to make SEZs engines of economic growth by providing quality infrastructure, attractive fiscal incentives from both Centre and States, and minimal regulations.

From 1.11.2000 to 09.02.2006, SEZs in India operated under the Foreign Trade Policy, with fiscal incentives implemented through relevant statutes.

The Special Economic Zones Act, 2005, was passed by Parliament in May, 2005 which received Presidential assent on the 23rd of June, 2005

After extensive consultations, the SEZ Act, 2005 and supporting SEZ Rules came into effect on 10th February 2006, simplifying procedures and enabling single-window clearance for both central and state matters.

# Main objectives of the SEZ Act



# Problem Statement

SEZs are established to accelerate industrial and economic growth through policy and fiscal incentives.

Rapid industrialization in SEZs poses risks of environmental degradation, particularly air pollution.

There is limited spatial and temporal analysis of pollution levels around SEZs across India.

A lack of comprehensive statistical modeling makes it difficult to understand long-term pollution trends in SEZ areas.

The absence of integrated data visualization and analysis hampers environmentally informed SEZ planning and policy-making.

# Tools and Data Sources

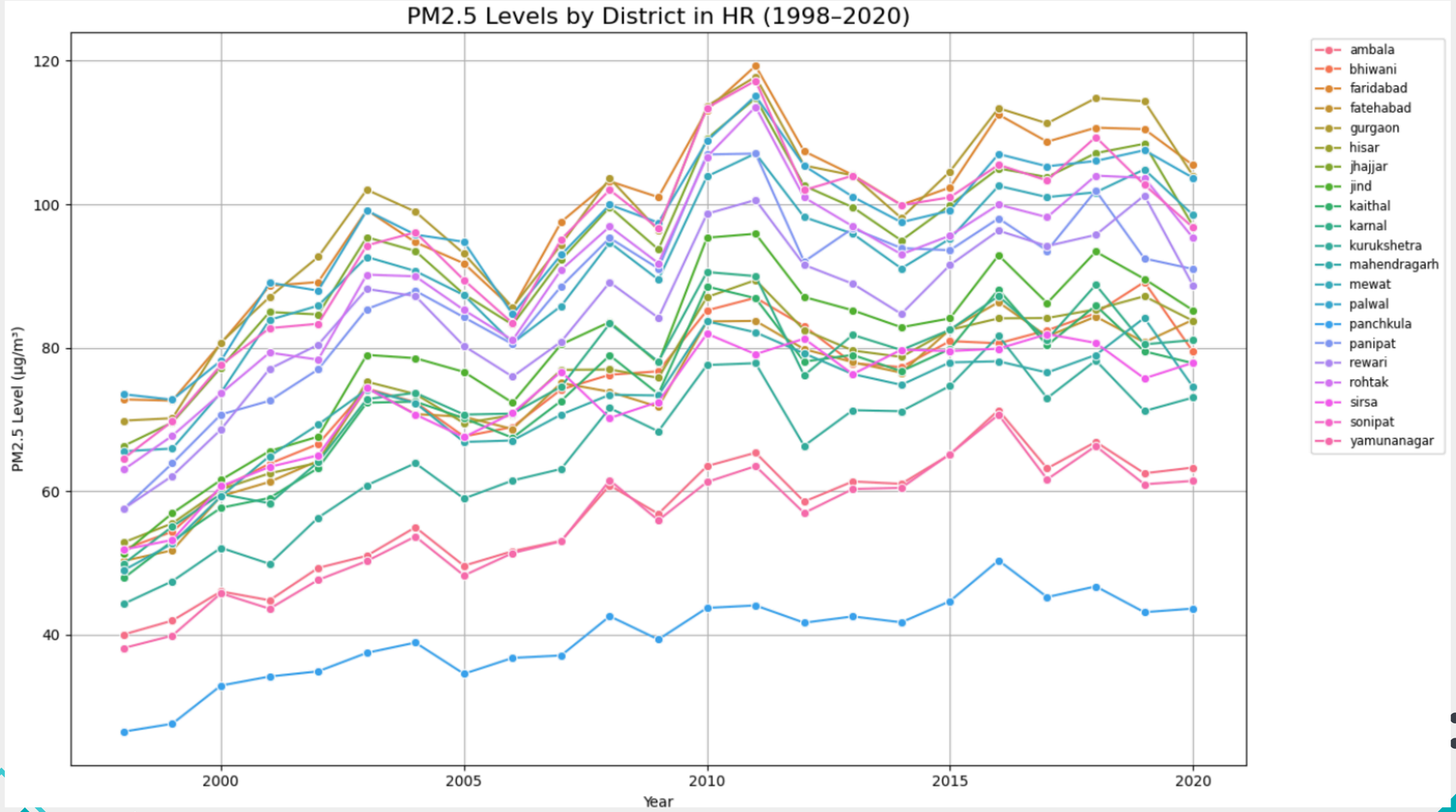
## Tools Used

- Python (for data cleaning, statistical analysis & plotting)
  - Libraries: pandas, matplotlib, seaborn, scipy.stats
- Microsoft Excel (initial data handling & visualization)
- Arc GIS and QGIS for creating maps

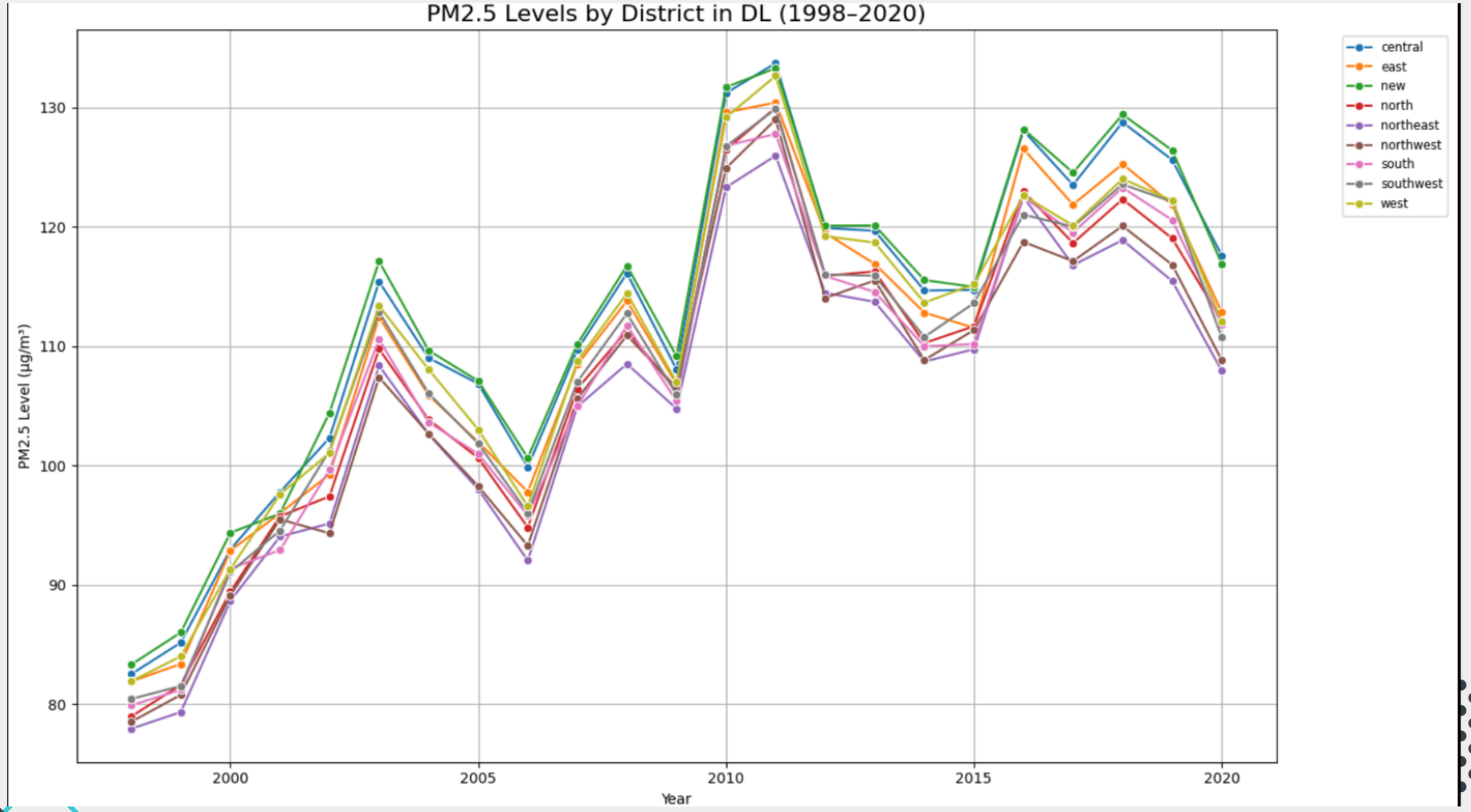
## Data Sources

- Ambient Air Quality Data:
- Central Pollution Control Board (CPCB)
- State Pollution Control Board reports (for pre- and post-SEZ periods)
- National Ambient Air Quality Standards (NAAQS):
- Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India
- SEZ Development Records:

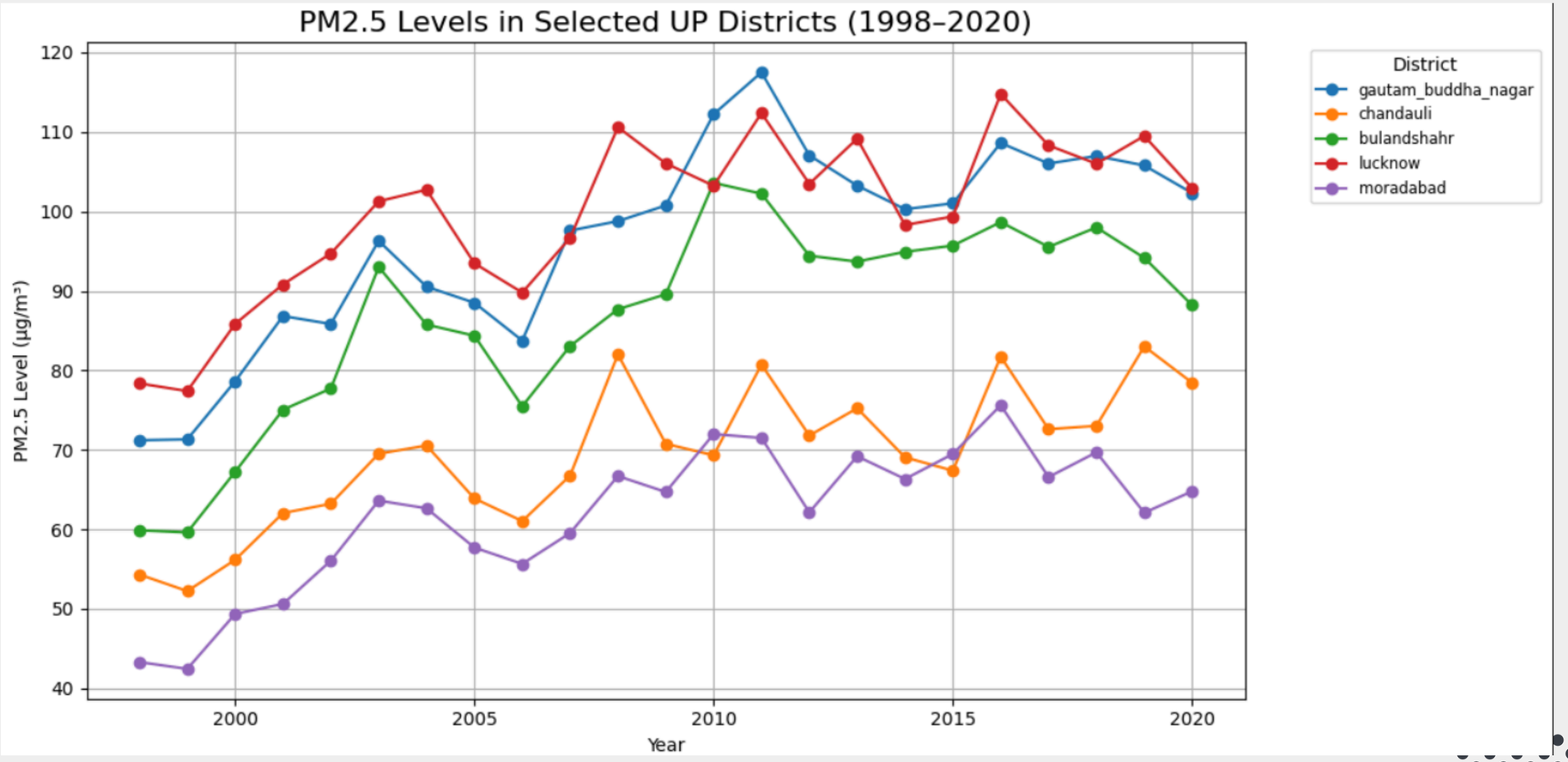
# Plots of Annual Average of PM2.5



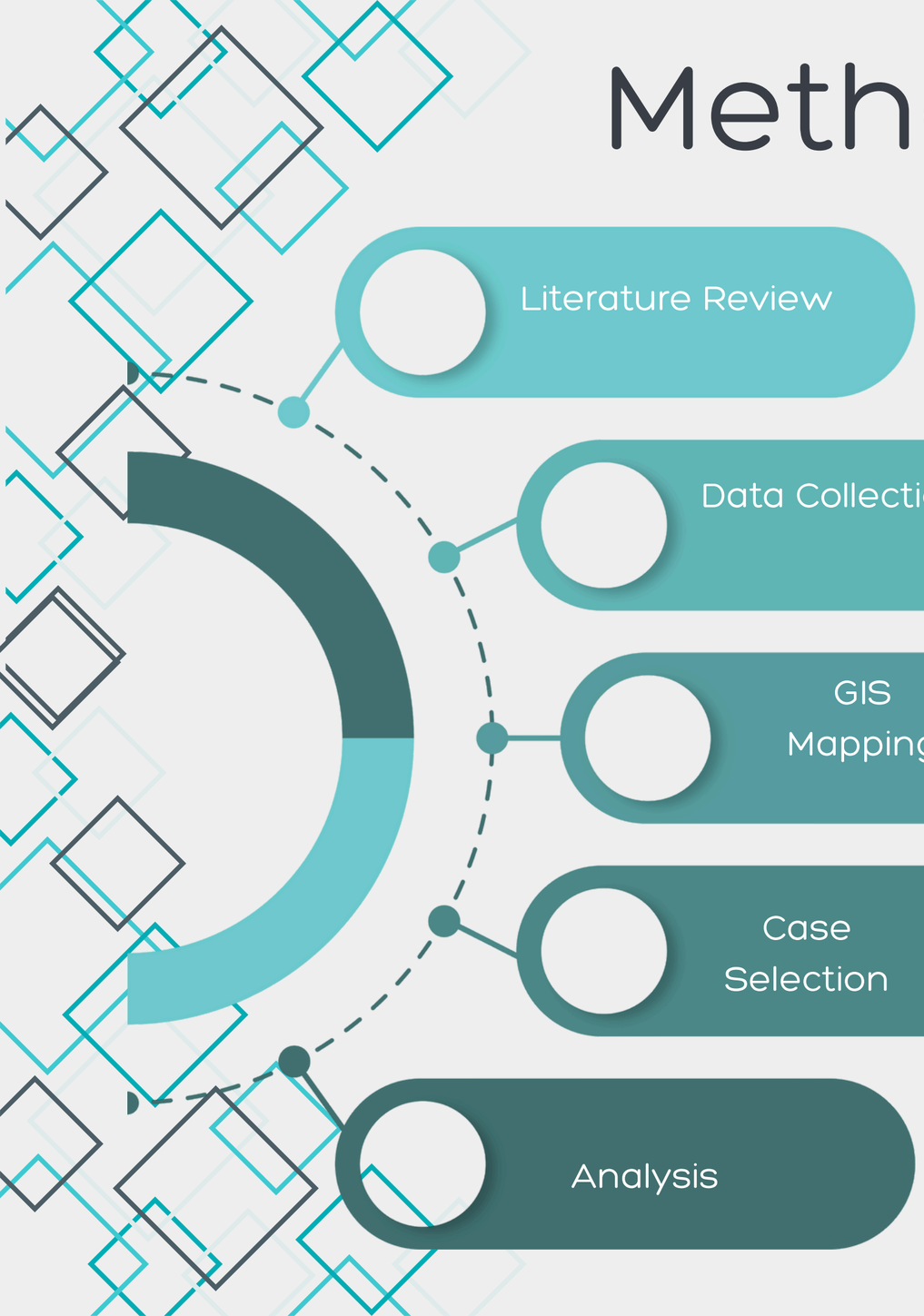
# Plots of Annual Average of PM2.5



# Plots of Annual Average of PM2.5



# Methodology Overview




- Studied prior work on SEZs and their environmental consequences.
- Identified gaps in data availability and analysis techniques.

- SEZ Data: Extracted from SEZ India official portal.
- Air Quality Data: Retrieved daily pollutant data (2017-2024) from CPCB and AQICN.

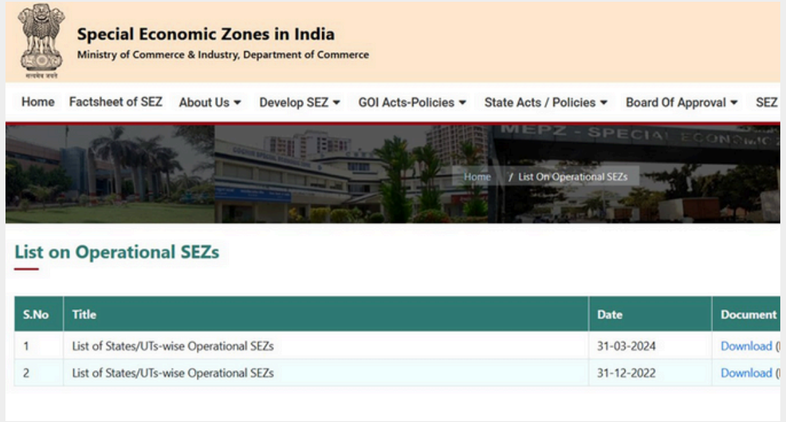
- Mapped SEZs and AQI monitoring stations across India using ArcGIS.
- Matched SEZs with nearest AQI stations in the same districts.

Based on overlap of SEZ establishment year and AQI station proximity:

- DLF SEZ, Gurugram (2022)

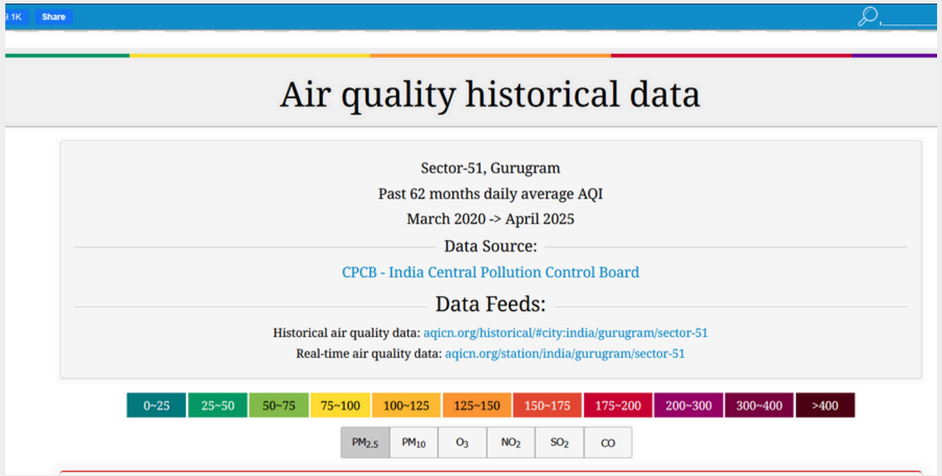
- Pre-post SEZ air quality comparison (1 year before & after).
- Distribution fitting & goodness-of-fit analysis using Chi-square test.

# Data Collection




https://sezindia.gov.in/


https://cpcb.nic.in




https://aqicn.org

# Data Preprocessing & Cleaning

**Initial Filtering:**

- Focused only on districts with established SEZs between 2017-2024
- Chose only relevant AQI monitoring stations closest to SEZs

**Pollutant Selection:**

- Retained major pollutants: PM2.5, PM10, NO, $NO_2$, $O_3$, $SO_2$ and CO

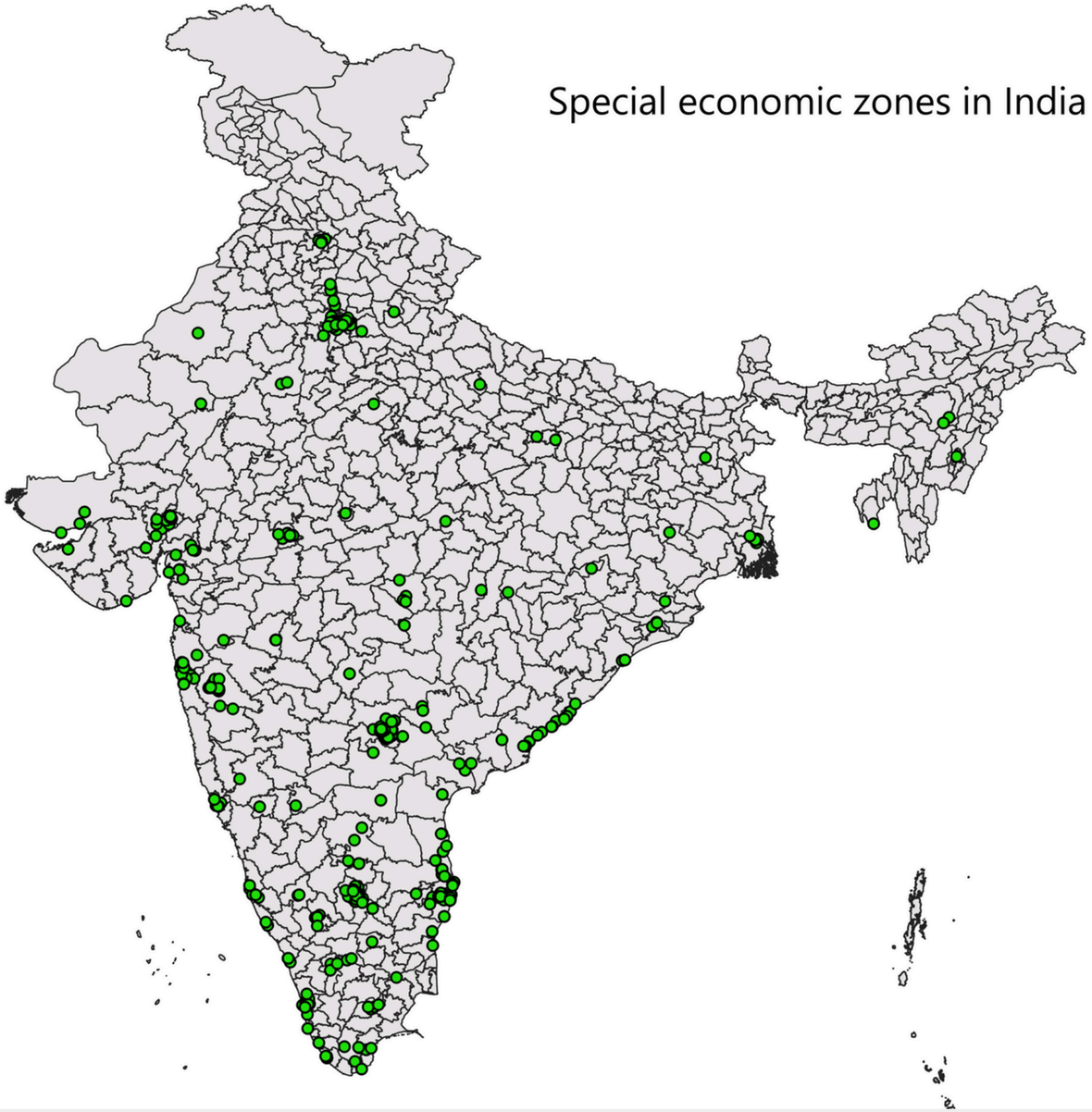
**Missing Values:**

- Handled 'NA' or missing data by:
  - Removing incomplete days
  - Forward/backward filling (if necessary for trends)

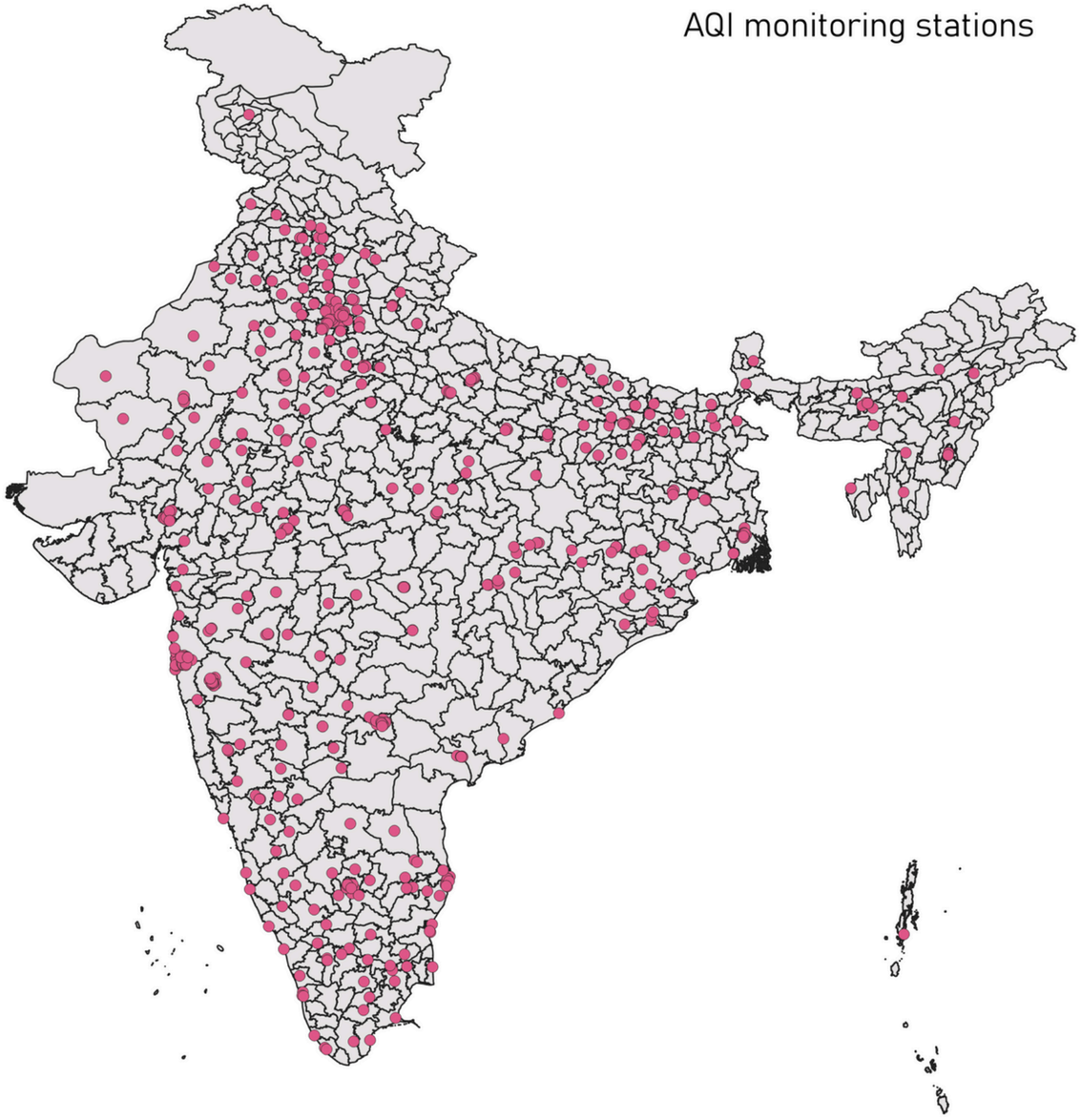
**Standardization:**

- Converted units to $\mu g/m^3$ or $mg/m^3$ where required
- Aligned daily data into uniform timeframes (365-day windows pre/post)

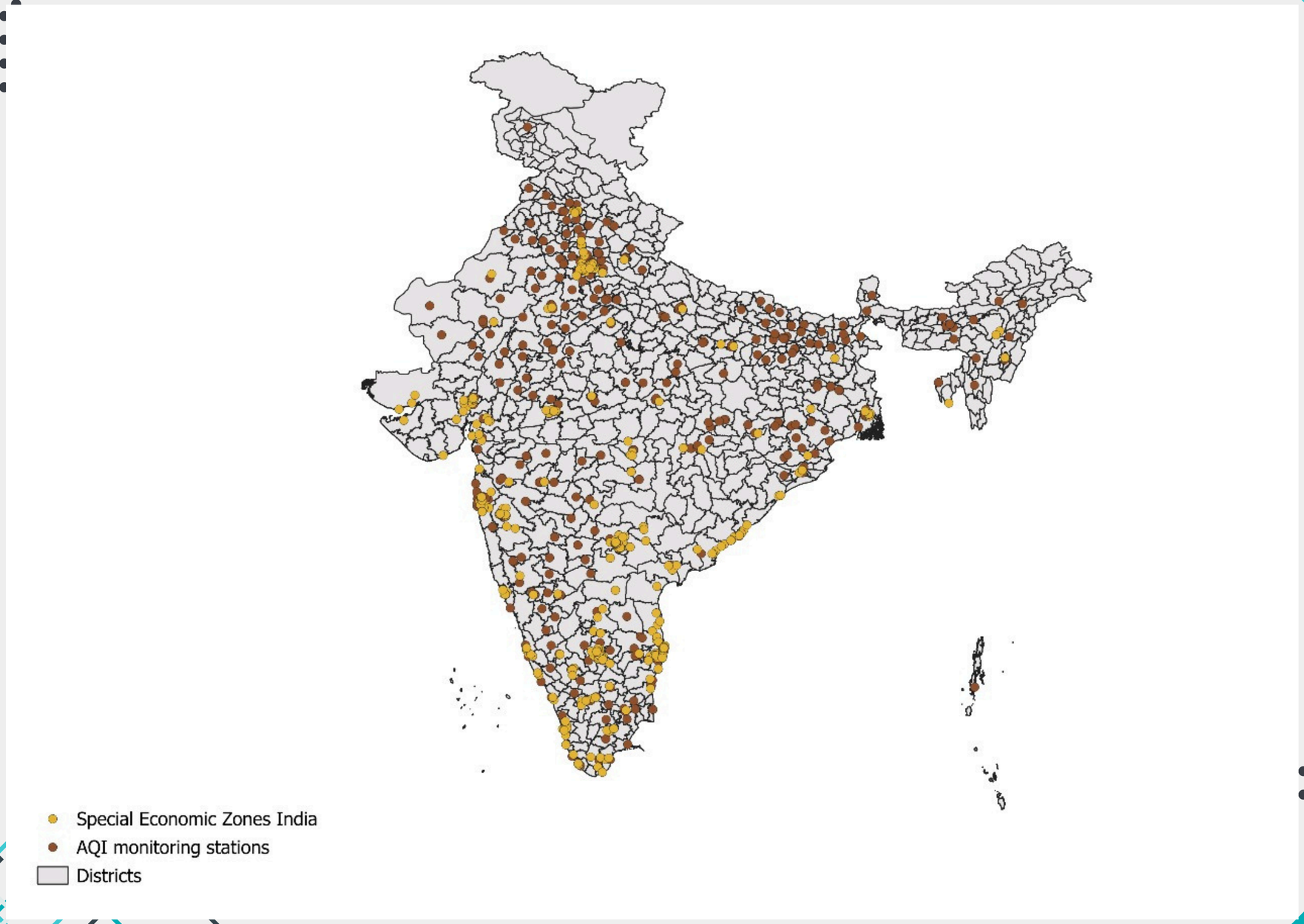
# GIS MAPS



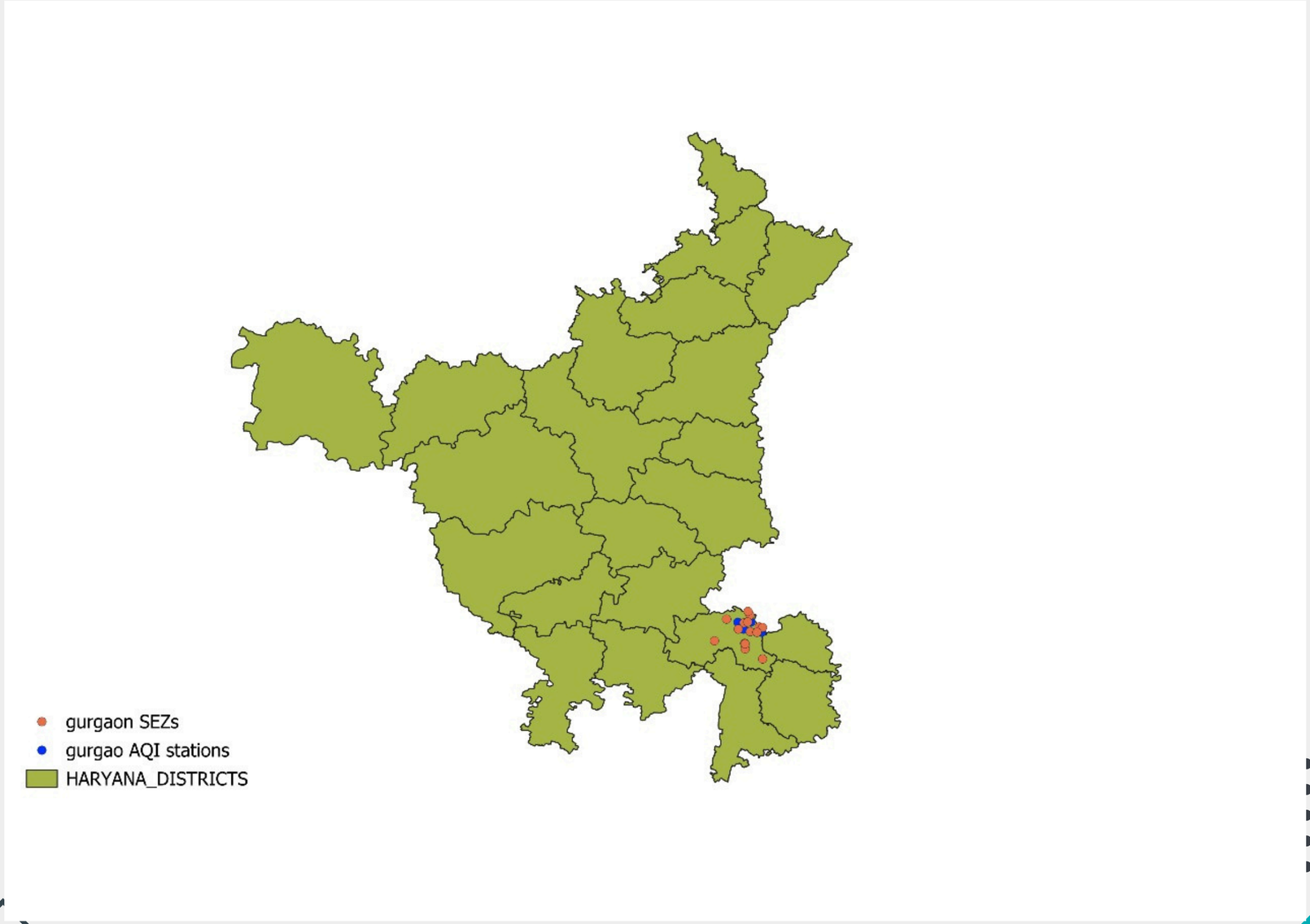
# GIS MAPS



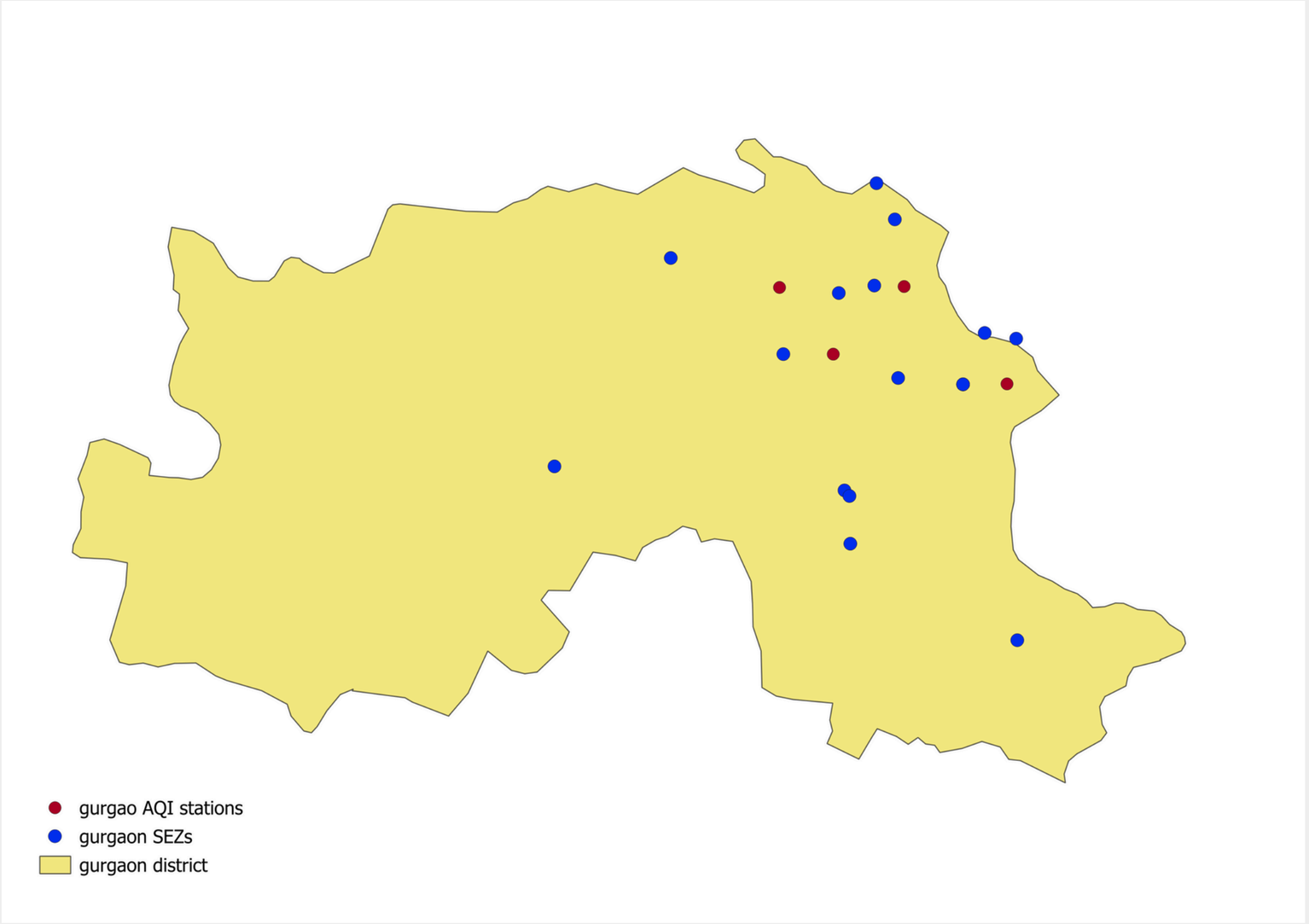
# Combined Map



# Haryana Map



# Gurgaon Map



# Case Study Selection - DLF SEZs

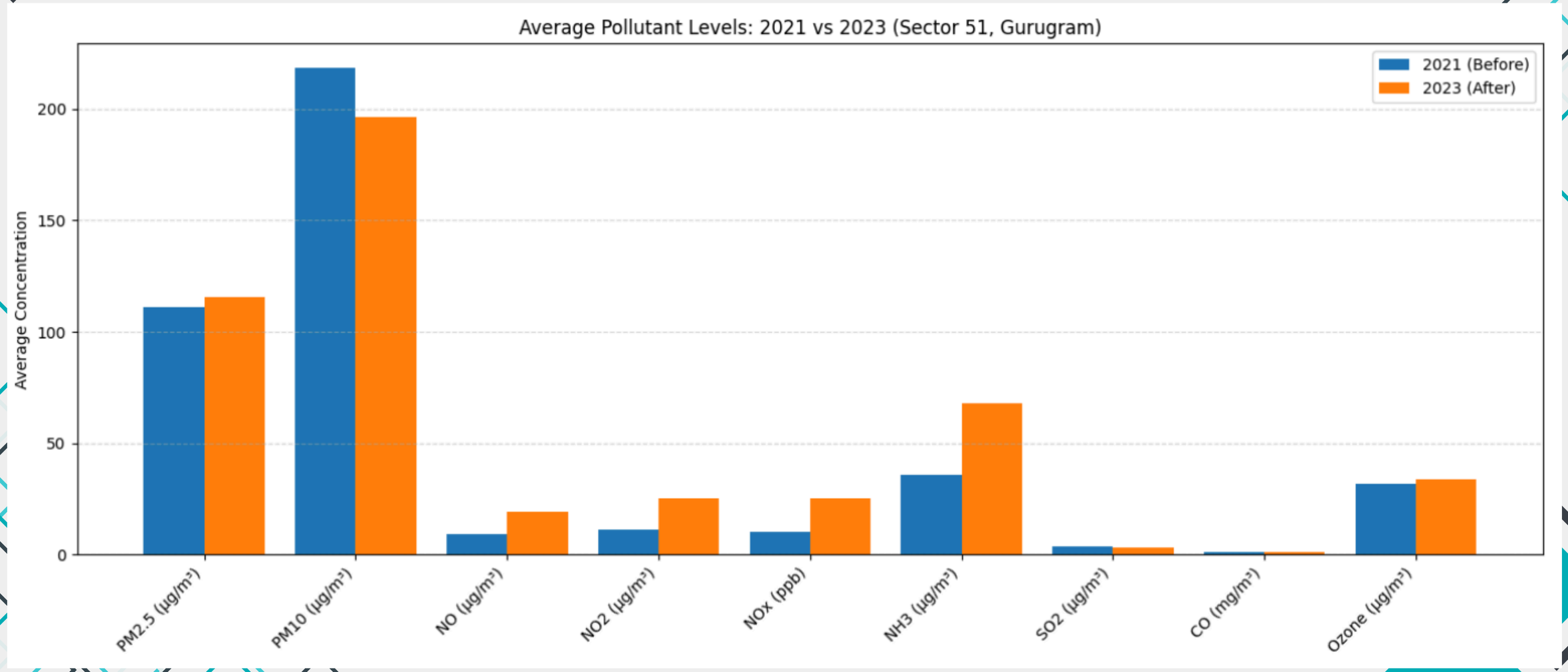
**.DLF Limited SEZ**

- **Location**: Village Kherki Daula, Tehsil Manesar, Gurugram, Haryana
- SEZ Established: 2022
- Nearest AQI Station: Sector 51, Gurugram
- Category: IT/ITES Special Economic Zone

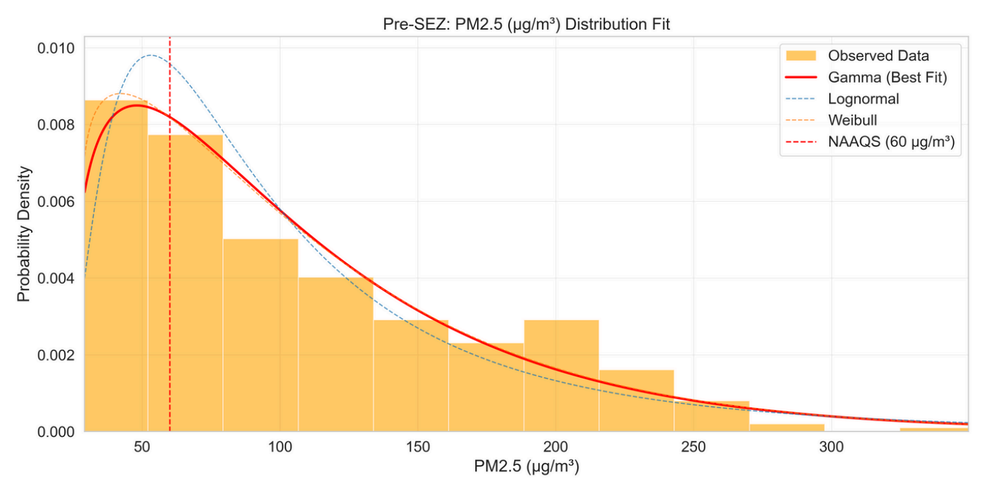
# Introduction to DLF Limited SEZ - Gurugram

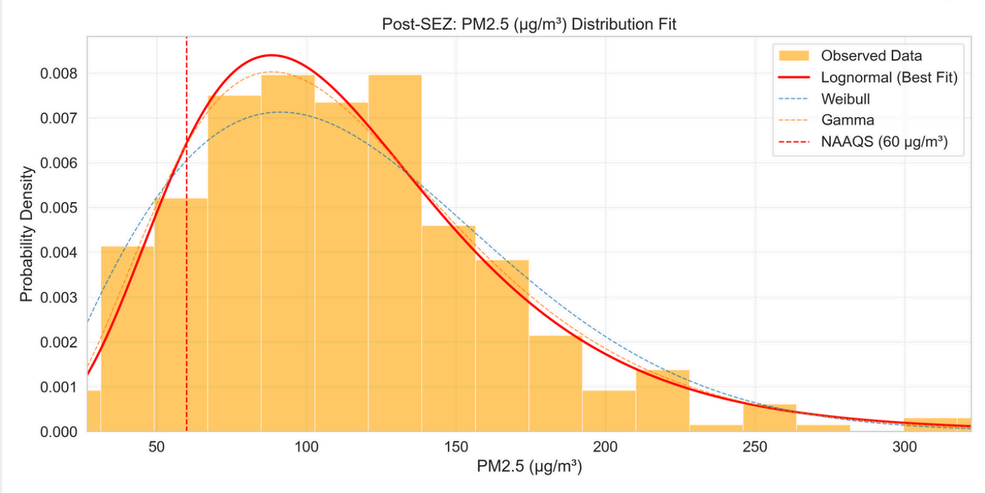
- Focus: Software development, IT services, and export-oriented business processing
- Formal Approval: 2019
- Functional/Operational Since: 2022
- Spread across several acres with world-class infrastructure
- Hosts multiple corporate IT tenants
- Part of Gurugram's rapid digital and commercial transformation

# Comparative study



# Comparative study



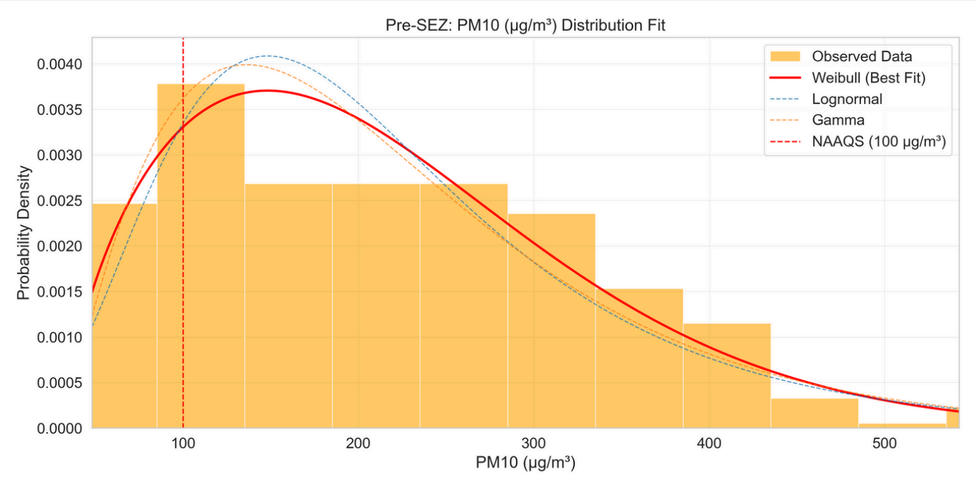

**Pre-SEZ PM2.5 Distribution Analysis:**

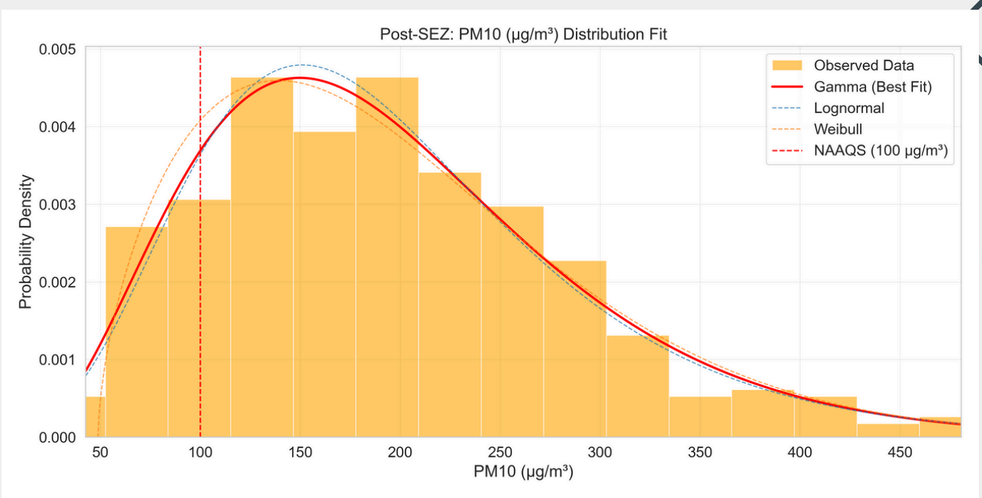
- Follows a Gamma distribution, indicating moderate skewness and variability.
- Most values lie between 50-75 µg/m$^3$, with a peak around this range.
- The distribution is more compact with a thin right tail, implying fewer extreme pollution events.
- A considerable portion of the data lies near above the NAAQS standard (60µg/m$^3$), showing moderate exceedances.

**Post-SEZ PM2.5 Distribution Analysis:**

- Follows a Lognormal distribution, indicating increased skewness and dispersion.
- Values are concentrated in the 100-125 µg/m$^3$ range, significantly higher than pre-SEZ.
- The distribution is wider with a heavier right tail, suggesting frequent high pollution events.
- Almost all values exceed the NAAQS safe limit, indicating poor air quality post-SEZ.

# Comparative study



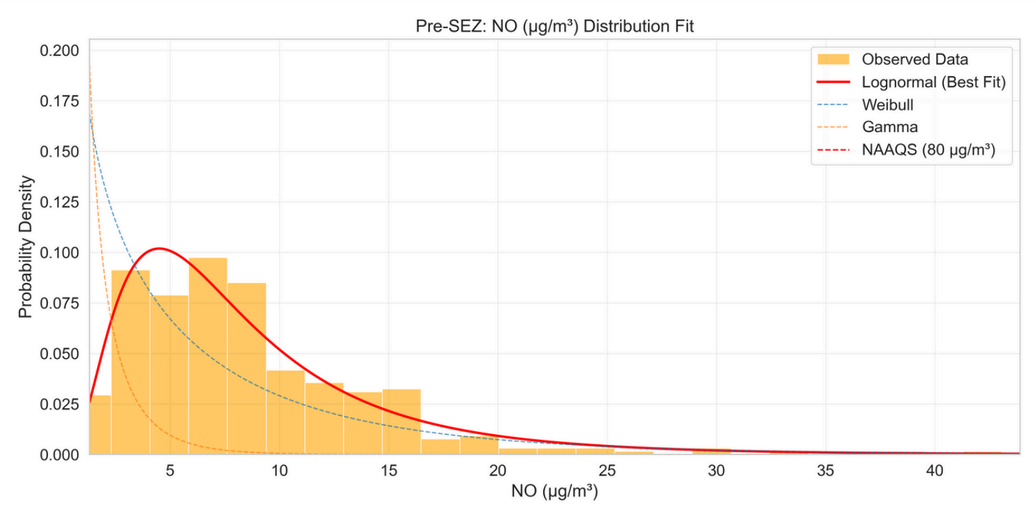

**Pre-SEZ $PM_{10}$ Distribution Analysis:**

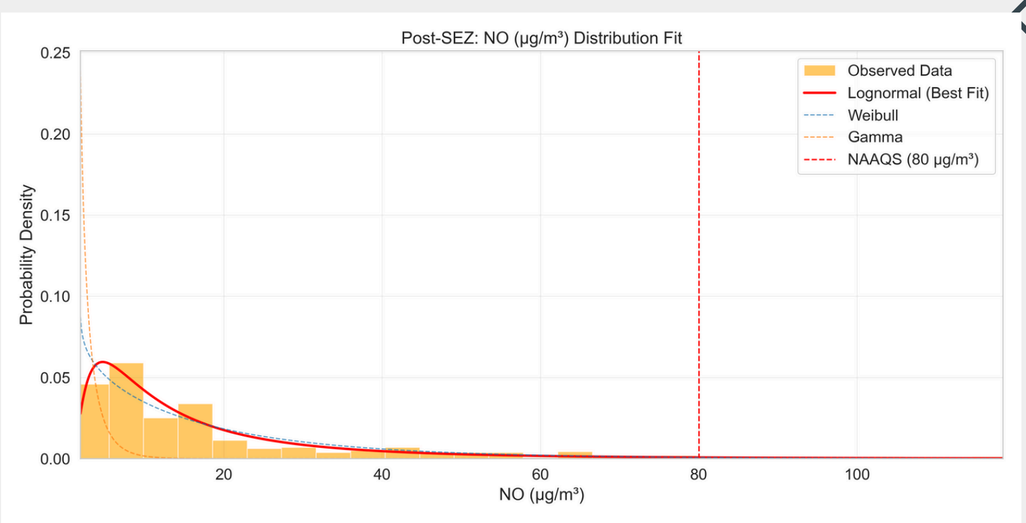
- The Weibull distribution (red line) best fits the observed data.
- Right-skewed distribution with a peak around 120-180 µg/m³.
- Long tail extends beyond 500 µg/m³, indicating some high-pollution days.
- Majority of the distribution lies above NAAQS benchmark , implying poor air quality.
- Lognormal and Gamma distributions are close but not as accurate as Weibull.

**Post-SEZ $PM_{10}$ Distribution Analysis:**

- The Gamma distribution (red solid line) now fits the data best.
- Still right-skewed, but more centered around 150-200 µg/m³.
- The tail is shorter, suggesting fewer extreme pollution events.
- Majority of the distribution lies above NAAQS benchmark , implying even worse air quality.
- Lognormal and Weibull also perform well, but Gamma is most accurate post-SEZ.

# Comparative study



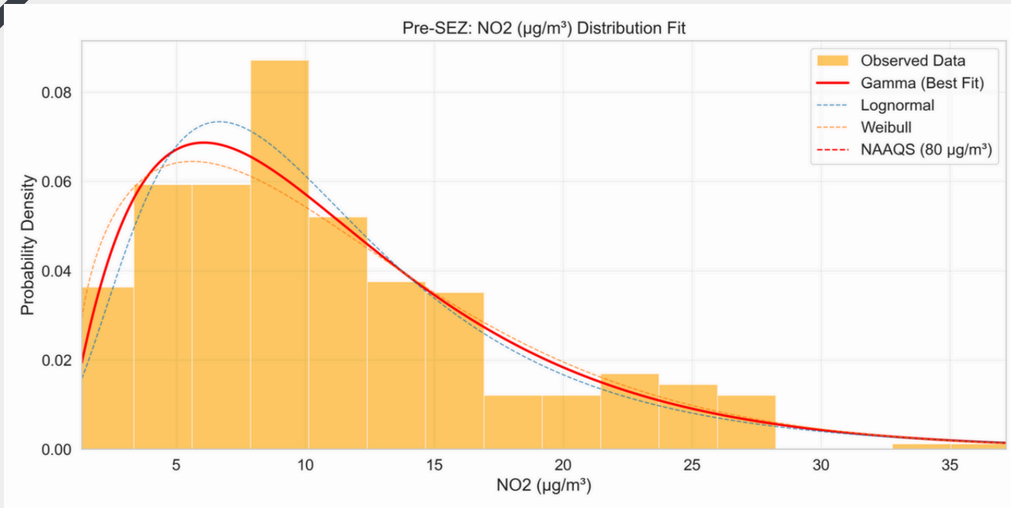

**Pre-SEZ NO Distribution Analysis:**

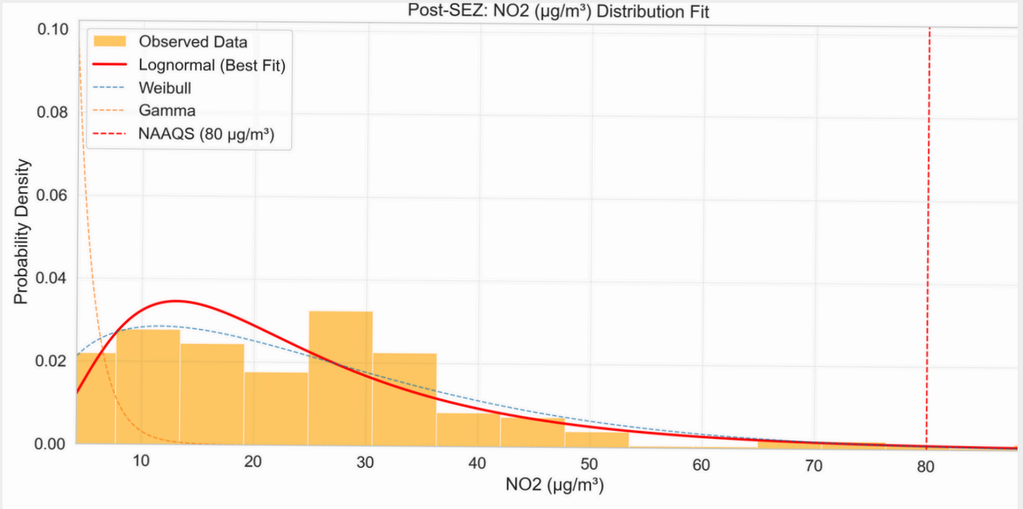
- NO concentrations are mostly between 0 and 30 µg/m$^3$.
- Distribution peaks around 4-6 µg/m$^3$.
- Lognormal distribution fits the data best.
- NO levels stay well below the 80µg/m$^3$ NAAQS limit.
- Data shows low variability and no extreme high values.

**Post-SEZ NO Distribution Analysis:**

- NO concentrations spread wider and exceed 100 µg/m$^3$ in some cases.
- Distribution peaks around 7-10 µg/m$^3$.
- Lognormal distribution fits the data best.
- NO levels sometimes cross the 80 µg/m$^3$ NAAQS limit.
- Data shows higher variability and more extreme high values.
- There is a noticeable shift towards higher NO concentrations after SEZ establishment.

# Comparative study



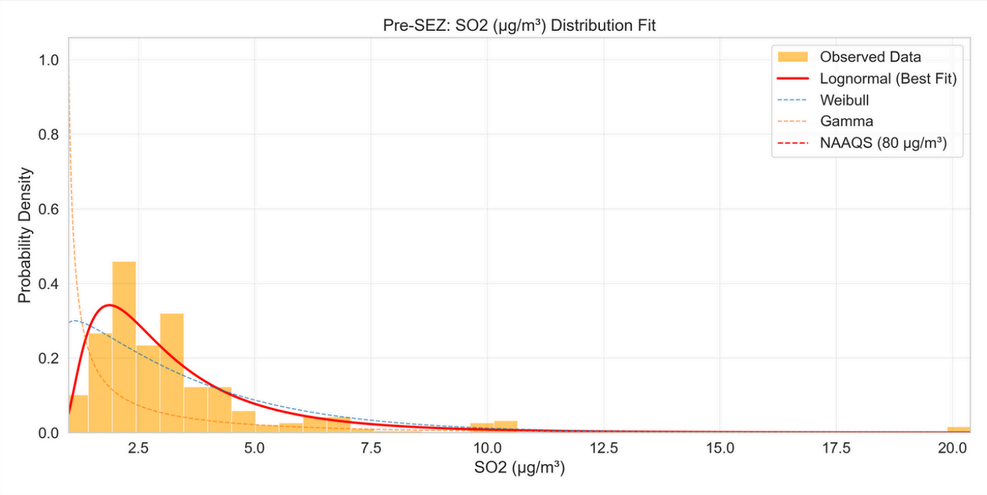

**Pre-SEZ $NO_2$ Distribution Analysis:**

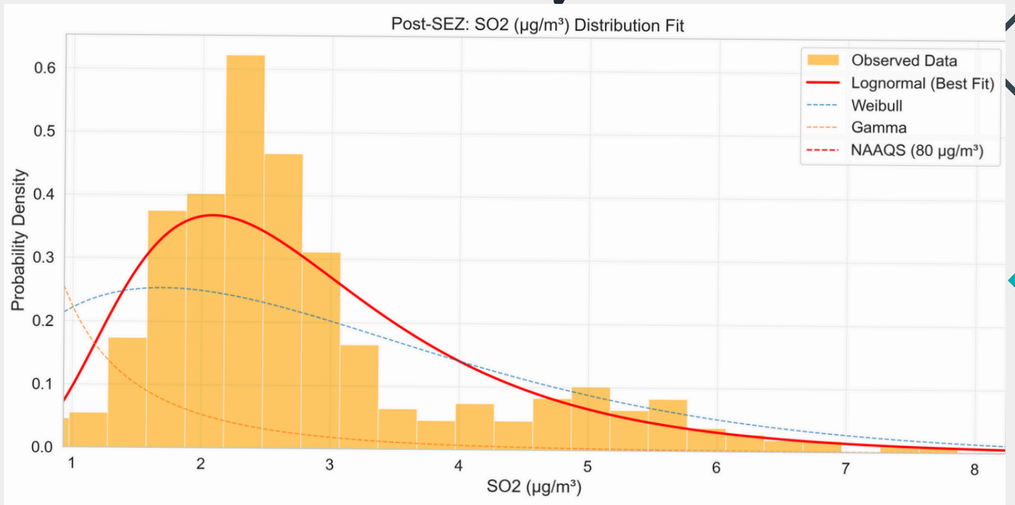
- Best Fit Distribution: Gamma distribution
- Observed $NO_2$ Range is 2 to 37 µg/$m^3$
- Peak Density is observed around 7-10 µg/$m^3$, indicating most frequent values
- Right-skewed distribution, indicating occasional higher values but predominantly lower concentrations
- All observed values are well below the NAAQS limit (80 µg/$m^3$)

**Post-SEZ $NO_2$ Distribution Analysis**

- Best Fit Distribution: Lognormal distribution
- Observed $NO_2$ Range is ~5 to 85 µg/$m^3$
- Peak Density is observed around 10-15 µg/$m^3$, with a long tail extending to higher concentrations
- Much wider spread in histogram, showing increased variation and higher $NO_2$ levels
- Some values approach or exceed the NAAQS limit (80 µg/$m^3$), marked with a red vertical lines

# Comparative study



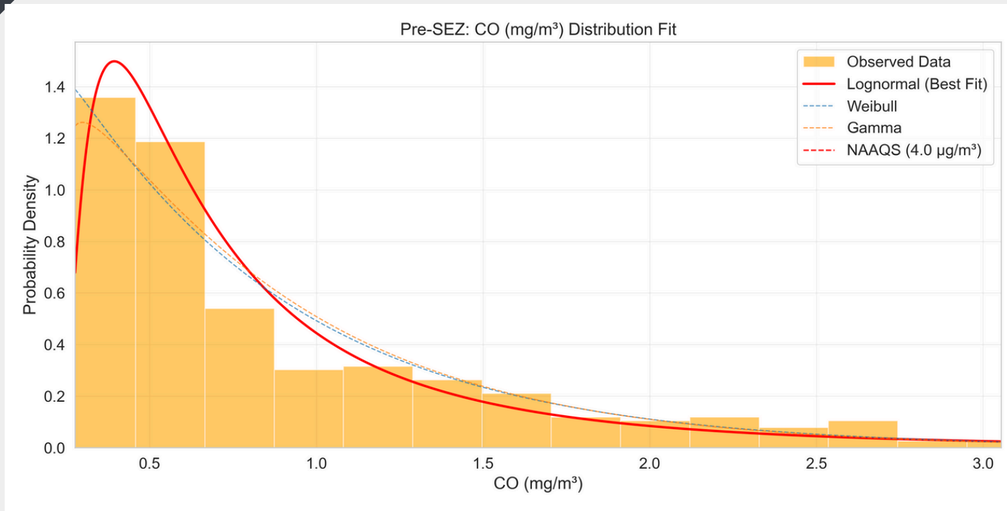

**Pre-SEZ: $SO_2$ Distribution Characteristics**

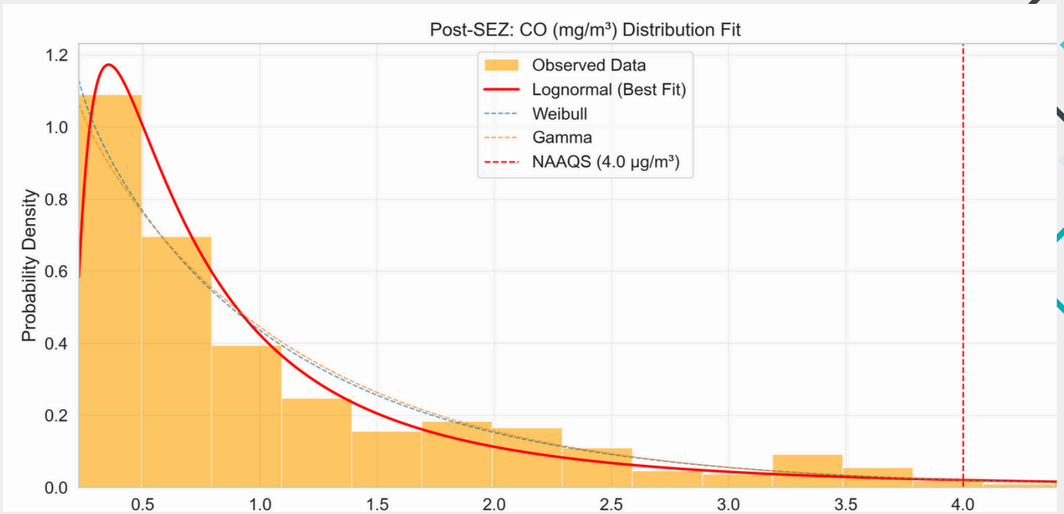
- $SO_2$ concentrations range widely, extending up to nearly 20 µg/m$^3$.
- The distribution is positively skewed, with most values clustered toward the lower end but a long tail toward higher concentrations.
- The lognormal distribution (solid red line) is the best fit.
- The histogram shows a sharper drop-off after the peak, indicating occasional but significant spikes in $SO_2$ levels–likely due to episodic emissions.

**Pre-SEZ $SO_2$ Distribution Analysis:**

- The $SO_2$ range is now much narrower–mostly concentrated between 1 to 6 µg/m$^3$.
- Once again, the lognormal distribution provides the best fit, but now it's more symmetric, reflecting tighter control and more stable emissions.
- The histogram is more bell-shaped and centered around 2-3 µg/m$^3$, with a higher peak–suggesting most measurements fall in a very narrow range.

# Comparative study



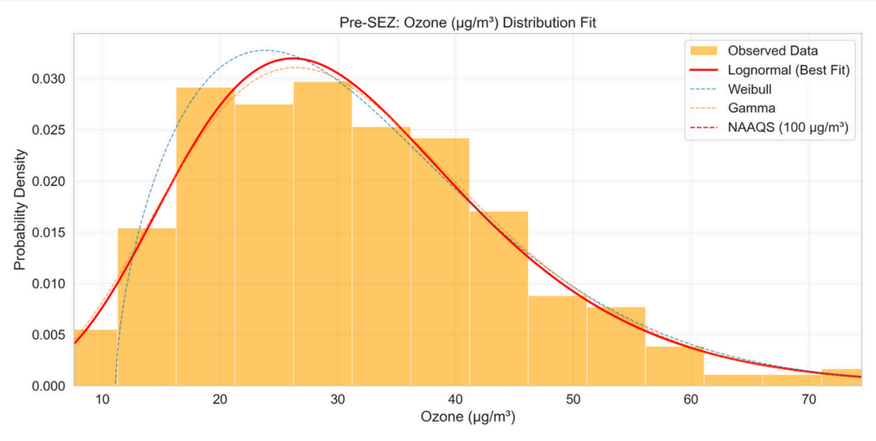

**Pre-SEZ CO Distribution Analysis:**

- The observed data follows a lognormal distribution most closely (red curve).
- CO concentrations remain well below the NAAQS limit (4.0 mg/m$^3$).
- The peak occurs at lower CO levels (~0.4-0.6 mg/m$^3$), indicating relatively clean air.

**Post-SEZ CO Distribution Analysis:**

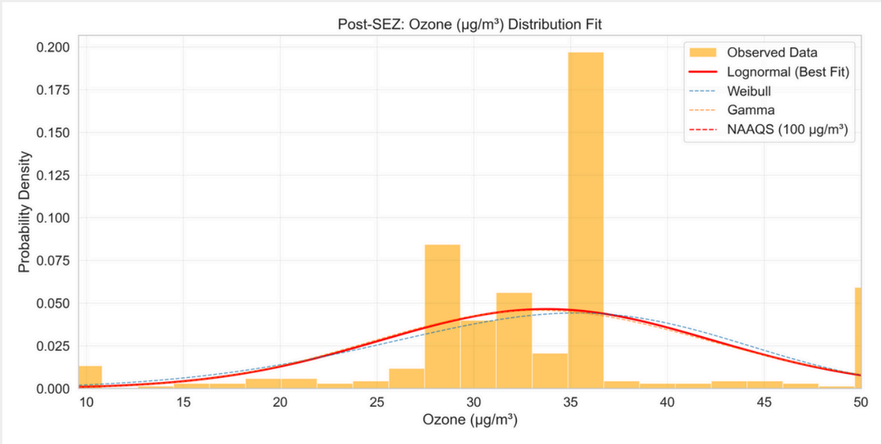
- The lognormal distribution still provides the best fit, but the peak flattens and shifts slightly.
- A wider spread and longer tail toward higher CO values suggests increased variability and more instances of higher concentrations.
- However, most values still stay below the NAAQS threshold.

# Comparative study




## Pre-SEZ Ozone Distribution

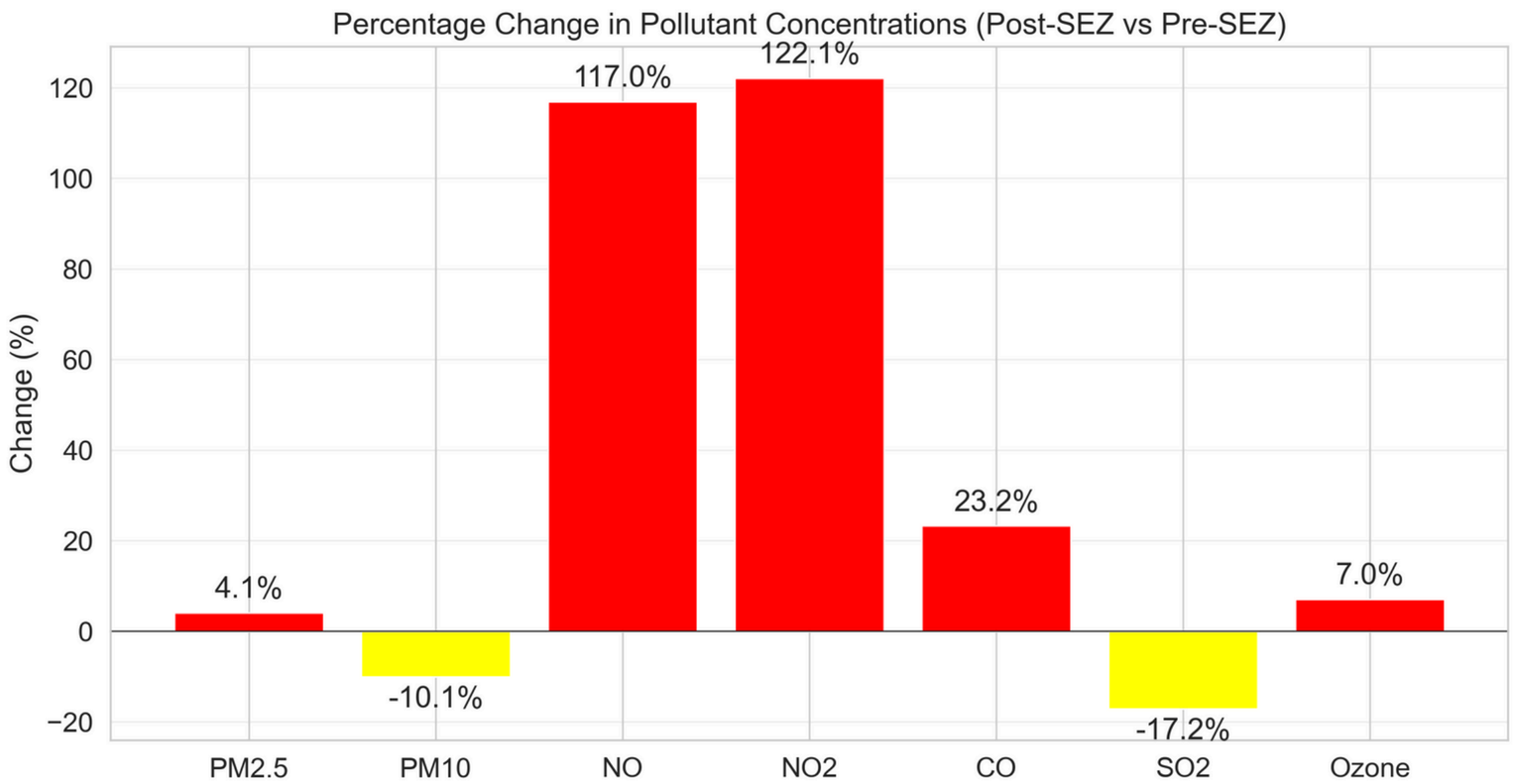
- The distribution has a unimodal peak around 25-35 µg/m$^3$, with most values spread between 10 and 60 µg/m$^3$.
- The lognormal distribution (red curve) is the best fit, capturing the positively skewed nature of the data.
- There's a noticeable right tail extending beyond 60 µg/m.




## Post-SEZ Ozone Distribution

- The distribution becomes bimodal, with notable peaks around 30-35 µg/m$^3$ and again at 50 µg/m$^3$.
- The data is more concentrated and lacks the wider spread seen in the pre-SEZ period. Most values fall in the 30-50 µg/m$^3$ range.
- The lognormal distribution still provides the best fit but the curve becomes slightly flatter, indicating less variation in the data.

# Comparative study



# Overall Summary

| Pollutant | Pre-SEZ Mean | Post-SEZ Mean | Change (%) (Mean) | Pre-SEZ Median | Post-SEZ Median | Change (%) (Median) | Pre-SEZ Distribution | Post-SEZ Distribution | Distribution Changed | Pre-SEZ Exceedance (%) | Post-SEZ Exceedance (%) | Exceedance Change (pp) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PM2.5 | 111.1694 | 115.6959 | 4.071715 | 86.75 | 108.7604 | 25.37224 | Gamma | Lognormal | TRUE | 69.31507 | 85.75342 | 16.43836 |
| PM10 | 218.4817 | 196.4066 | -10.1039 | 205.49 | 184.3594 | -10.283 | Weibull | Gamma | TRUE | 82.73973 | 84.65753 | 1.917808 |
| NO | 8.947671 | 19.41208 | 116.9512 | 7.09 | 10.51476 | 48.30412 | Lognormal | Lognormal | FALSE | 0.273973 | 2.191781 | 1.917808 |
| NO2 | 11.42132 | 25.36755 | 122.1071 | 9.98 | 23.16178 | 132.0819 | Gamma | Lognormal | TRUE | 0 | 1.917808 | 1.917808 |
| CO | 0.924521 | 1.1393 | 23.23144 | 0.64 | 0.736319 | 15.04991 | Lognormal | Lognormal | FALSE | 0 | 1.917808 | 1.917808 |
| SO2 | 3.619178 | 2.997641 | -17.1734 | 2.84 | 2.463333 | -13.2629 | Lognormal | Lognormal | FALSE | 0 | 0 | 0 |
| Ozone | 31.53855 | 33.75994 | 7.043424 | 29.62 | 35.06795 | 18.39281 | Lognormal | Lognormal | FALSE | 0 | 0 | 0 |

# Conclusions

- The SEZ has likely led to increased industrial and vehicular activities, contributing to higher nitrogen oxides (NO, $NO_2$) and CO.
- Some mitigation measures (e.g., for PM10, $SO_2$) may already be in place or more effective.
- The air quality profile has shifted, indicating a need for targeted pollutant control, especially for NOx emissions.

# Conclusions

| Pollutant | % Change | Remarks |
|---|---|---|
| PM10 | -10.1039 | Coarse particulate levels improved, possibly due to dust control measures |
| $SO_2$ | -1717.34% | Reduction suggests cleaner fuel use (e.g., shift from coal to gas) |

Improvements here may reflect better dust suppression systems and fuel switching due to environmental regulations.

# Conclusions

| Pollutant | % Change | Remarks |
|---|---|---|
| $NO_2$ | 122.11% | Significant rise, linked to combustion and traffic activity |
| NO | 116.95% | Indicative of fresh emissions from vehicles and industries |
| CO | 23.23% | Slight increase, suggests incomplete combustion activity |
| PM2.5 | 4.07% | Marginal increase; fine particulates are harder to control |
| Ozone | 7.04% | Photochemical formation likely influenced by NOx increase |

NO and $NO_2$ saw the most dramatic rises, pointing to a surge in industrial emissions, possibly due to SEZ expansion.

# Policy Recommendations

- **Implement NOx Control Strategies:**

Catalytic converters, vehicular emission standards, and industrial scrubbers.

- **Strengthen Monitoring:**

Especially for NO and $NO_2$, given their sharp rise and exceedance risk.

- **Sustain Gains:**

Maintain and expand dust suppression and cleaner fuel policies that improved PM10 and $SO_2$ levels.

# References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# Thank You