Project Document

Our Question: What is the impact of air pollution and how can we improve air quality in the London Borough of Hammersmith and Fulham?

Introduction

Air pollution is a significant issue in London due to the threat it poses to both public health and the environment. Daily exposure to high levels of pollutants such as particulate matter (PM2.5 and PM10), and nitrogen oxides (NOx) can diminish one's quality of life and lead to respiratory and cardiovascular diseases, diseases that disproportionately affect vulnerable populations such as children and the elderly the most. Additionally, policymakers and governments are now in a position where they must implement stringent regulations to mitigate pollution levels and deal with the monetary impact on services such as the NHS. Addressing air pollution in London is critical for safeguarding the well-being of all its residents and ensuring a sustainable urban environment.

Aims and objectives

The primary goal of our project is to inform and advise Hammersmith and Fulham Council and community leaders on improving air pollution management across the borough. We aim to address the question: "What is the impact of air pollution, and how can we improve air quality in Hammersmith and Fulham?". Our focus on this area stems from research indicating it is one of the most polluted boroughs in London, with several schools near busy roads.

To address this question, we divided it into three sub-questions:

1. What are the main causes of air pollution in the borough, and what factors influence pollutant levels?
2. What impact have schemes like ULEZ and traffic reducing events like COVID-19 had on reducing air pollution, and how can this inform future policies?
3. What is the impact of air pollution on health and the NHS?

Our project objectives are:

1. Collect data from various sources, such as APIs and government datasets, on air pollutant levels, pollution sources, health data, and factors like traffic and weather.
2. Analyse this data to identify the main causes of air pollution, trends between pollution and health outcomes, and the influence of time and environmental variables.
3. Provide recommendations on reducing air pollution in the borough based on our findings.

Roadmap of the report

To provide a clear structure for understanding our methods and findings, this report is organised as follows:

- Background: Details the project's purpose, explaining why this topic was chosen and what will be investigated.
- Specification and Design: Outlines technical requirements (data, tools, technologies) and non-technical requirements (accessibility), and explains the project's design and architecture.
- Implementation and Execution: Describes the project execution, development approach, data sources and collection, and tools and libraries used for analysis and visualisation.
- Results: Presents the results for our main research questions.
- Conclusion: Summarises key findings and offers new recommendations for tackling air pollution, including insights into the effectiveness of current measures and suggestions for improvement.

Background

In recent years, air pollution has become a significant concern in urban areas worldwide. In London, Hammersmith and Fulham is one of many boroughs experiencing high levels of pollution, which is particularly alarming given the high concentration of schools in the area. This project aims to understand the main causes and factors contributing to air pollution in Hammersmith and its impact on public health services, especially the NHS. Through this analysis, we aim to provide data-driven recommendations to help reduce pollution levels and mitigate health risks.

Although our project is distinct, it aligns with broader government initiatives aimed at monitoring and reducing air pollution in London. Previous research emphasises the importance of localised data collection and analysis in understanding pollution patterns. Our project contributes by conducting a thorough examination of pollutant levels specifically within Hammersmith and Fulham using government and non-government data sources, thus enriching the ongoing discourse on urban air quality management.

Hammersmith and Fulham, with its heavy traffic and dense urban environment, faces serious air pollution challenges. Measures like the Ultra Low Emission Zone (ULEZ) have been implemented to combat this issue, and the Covid-19 lockdowns have highlighted the significant impact of road traffic on air quality. Our project analyses pollutant levels before and after these two major events to measure the impact of Covid-19 and assess the effectiveness of ULEZ and suggest possible new strategies for improving air quality.

Despite these efforts, pollutant levels in Hammersmith and Fulham often surpass WHO and UK Governments limits, posing significant health risks, especially to vulnerable groups. Of particular concern are nitrogen dioxide ($NO_{2)}$ and particulate matter that is 2.5 microns or less in diameter (PM2.5), which have been linked to respiratory and cardiovascular diseases, as well as adverse effects on children's development and the health of the elderly. Addressing this issue requires continuous involvement and commitment of key stakeholders, including local authorities, school boards, and community members, to improve public health outcomes.

Operating within the urban landscape of Hammersmith and Fulham, our project considers various regulatory frameworks, collects data from monitoring sites across the borough and uses existing datasets and health data models. By offering insights into air pollution patterns and their impact on health outcomes, we aim to inform future efforts to enhance air quality and public health in the area.

Specifications and design

<u>Technical requirements</u>

Data requirements

1. **Data sources:**
   We need a range of data sources to answer each of our questions:
   - Weather data from an API.
   - Air quality, emissions, and health data from csv files.
2. **Data types:**
   - Data on PM2.5 and NO_2 levels.
   - Data covering same periods to enable merging.
   - Data from pre and post ULEZ.
   - Recent data as well as some historical data.
3. **Data quality:**
   The quality of data must be good so that we can ensure accuracy of findings and recommendations:
   - Check data for completeness, accuracy, and consistency.
   - Handle missing values.
4. **Data storage:**
   - Divide data into ‘clean’ and ‘unclean’ folders.
   - Store datasets in folders within a GitHub repository.
   - Once ‘unclean’ data is ‘cleaned,’ save it as a CSV.
5. **Data integration:**
   - Data must be organised with datetime for merging and combining

Tools and technologies

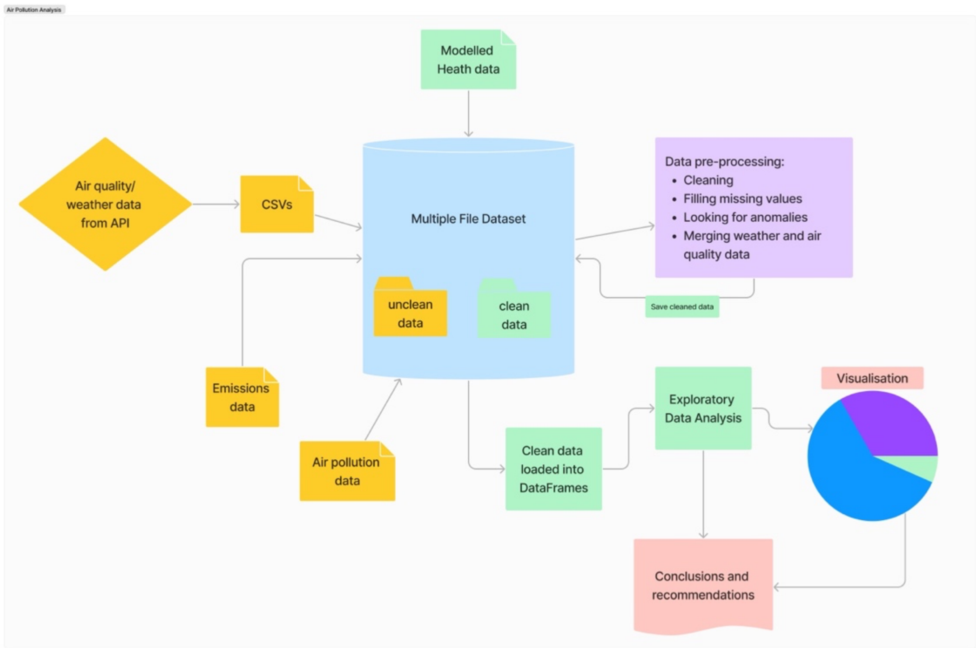
Programming language:	**Software and libraries:**	**Version control:**
Python	• Pandas • NumPy • Matplotlib • Seaborn • Jupyter Notebook	git and GitHub for managing data and code versions.

<u>Non-technical requirements</u>

Accessibility

1. **User-friendly interface:**
   - Our recommendations will be for local government
   - Visualizations will be mainly bar charts so they can be easily understood
2. **Documentation:**
   - Readme will give instructions for running the analysis notebook
   - Observations and notes within the notebook to explain findings and visualisations
3. **Transparency and fairness:**
   - All findings and observations will be noted and reported
   - Open questions used to guide the project and avoid bias

Design and architecture



Implementation and Execution

Our project was conducted with a highly collaborative approach. Each team member took on specific responsibilities related to data mining, cleaning, and analysis, focusing on different aspects of the project. This division of work was pre-agreed and aligned with individual strengths and expertise which was discovered during SWOT analysis. To ensure cohesiveness and integration across various tasks, we conducted regular progress meetings. During these sessions, we reviewed our progress on each dataset. These meetings were crucial for maintaining alignment and facilitating the smooth merging of different datasets in GitHub. At the project's conclusion, we reviewed the final code and contributed to different sections of the report.

The project team initially identified the research questions and objectives, which guided the selection of appropriate datasets. After choosing the topic related to air pollution, weather patterns, and health impacts, the team explored various data sources, including APIs, government repositories, and research databases, to acquire relevant datasets.

Data gathering involved retrieving datasets from multiple sources, including the Open Weather API, Open Meteo, Air Quality Monitoring databases (such as the Diffusion Tube Results), Air Quality England data for ULEZ policy analysis, the London Atmospheric Emissions Inventory (LAEI), and health and traffic data from the UK government website. This step required collecting historical weather data, air quality measurements, health impact data, and details on policy interventions like the Ultra Low Emission Zone (ULEZ). Subsequently, data cleaning procedures were applied to address missing values, outliers, and inconsistencies in the datasets, ensuring data quality and integrity for subsequent analysis.

After cleaning the datasets, the team integrated different datasets, merging them based on common variables such as time, geographic locations, and pollutant measurements. This step facilitated the creation of comprehensive datasets that combined information on weather conditions, pollutant levels, health outcomes, and policy interventions. Additionally, pre-processing techniques were applied to prepare the datasets for analysis.

Exploratory Data Analysis involved visualising and exploring the datasets to identify patterns, trends, and relationships between variables. This process included generating summary statistics, distribution plots, correlation matrices, and time series plots to gain insights into the factors influencing air quality, health outcomes, and the effectiveness of policy measures.

Using tools such as Jupyter Notebook and Python libraries (e.g., Pandas, Matplotlib, Seaborn), the team conducted various analyses, including statistical analysis, time series, and correlation analysis. These analyses focused on assessing the impact of weather conditions, traffic volume, and policy interventions on air pollution levels and health outcomes. Additionally, we used modelled data to forecast future air quality trends, health and NHS cost impacts based on historical data.

The findings and insights derived from the analysis were documented in this report, presentation, and visualisations to communicate the results. This communication process involved creating data visualisations and charts to present the key findings in a clear and accessible manner. Additionally, the project team have engaged in discussions on the implications of the findings to explore potential recommendations.

The results of the analyses were interpreted to provide meaningful insights specifically for the Hammersmith and Fulham community. This involved identifying key findings, trends, and correlations within the data, leading to actionable recommendations. These insights shed light on the effectiveness of policy measures like the Ultra Low Emission Zone (ULEZ), the impact of COVID-19 lockdowns on local air quality, and the long-term health implications of air pollution in the borough.

Results

Air Pollution Sources

Our analysis has shown that although transport is the main source of air pollution in London overall, the main source of air pollutants in Hammersmith & Fulham is industrial and commercial processes, with heat and power generation being the largest contributors of NO_x and Carbon Monoxide (CO) pollution as shown in figure 1. The construction industry and commercial cooking are the biggest sources of particulate matter (PM2.5 and PM10, respectively). The second largest source of pollution is transport, with road transportation being the primary emitter of NOx and particulate matter. Among road vehicles, diesel vehicles are the largest polluters, though petrol cars also significantly contribute to particulate matter levels (figure 2).

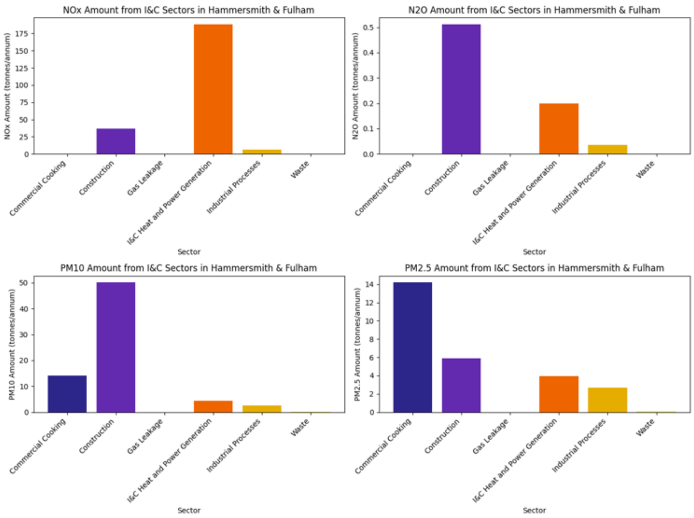


Figure 1 - Total amount of pollutants (tonnes/annum) produced by each industrial and commercial purpose in Hammersmith & Fulham

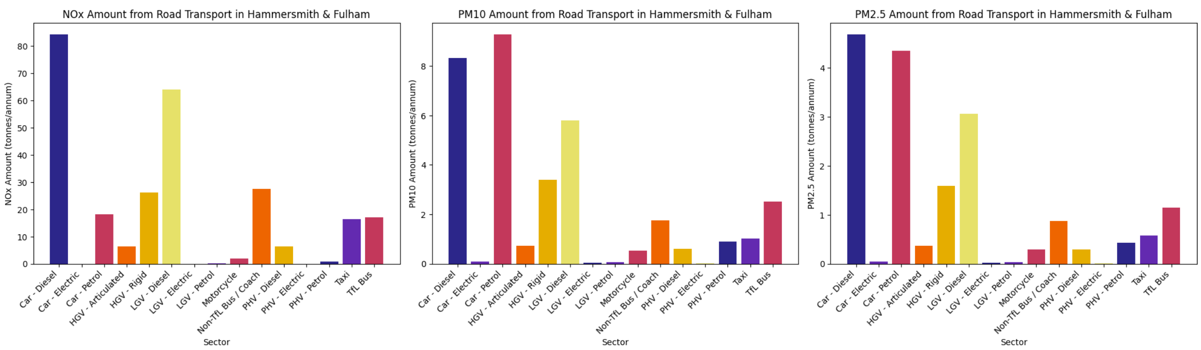


Figure 2 - Total amount of pollutants (tonnes/annum) produced by Road Transportation in Hammersmith & Fulham

Impact of Other Factors on Air Pollution

We found that most pollutants have little to no correlation with weather conditions, except for ozone (O_3), which is not directly related to transport in the borough. Figure 3 demonstrates that NO_2 levels peak during the morning (7am -8am) and evening (5pm - 6pm) rush hours in London. Although levels dip during the day (9am to 4pm), they remain above the legal limit. PM2.5 levels follow a similar pattern.

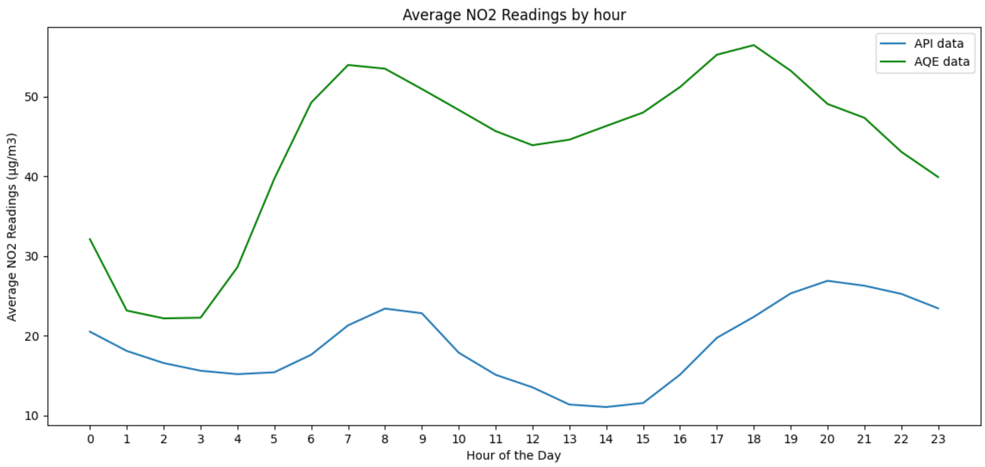


Figure 3 - Average NO_2 readings across 24-hour period in Hammersmith & Fulham

According to Air Quality England, NO_2 levels are lowest in July and August and highest in April and September, varying by monitoring location. NO_2 levels are higher on weekdays and lowest on Sundays as shown in figure 4, with roadside levels significantly exceeding background measurements overall (figure 5, often hitting the legal limit of 40 µg/m³. In 2016, several schools in Hammersmith and Fulham exceeded the legal limit for NO_2 (more current data was unavailable).

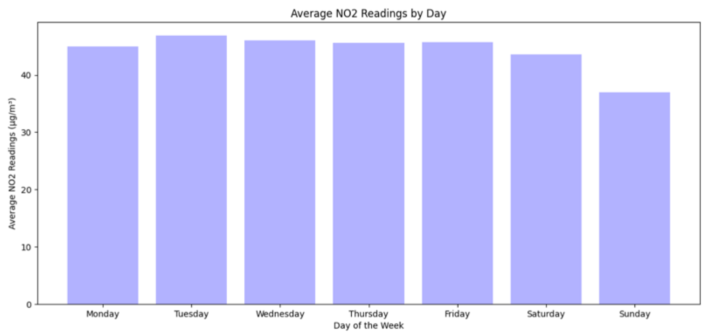


Figure 4 - Average NO_2 per day in Hammersmith & Fulham

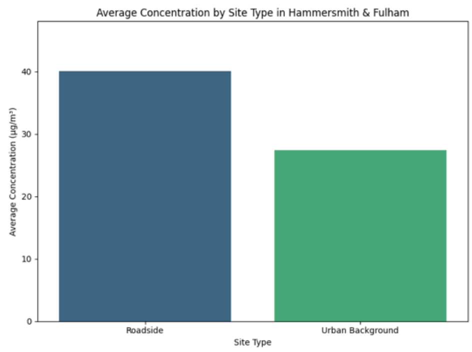


Figure 5 - Average NO_2 concentration for roadside and urban/background areas Hammersmith & Fulham

Impact of ULEZ and COVID-19 on Air Pollution

Figure 6 shows a slight but unsustained reduction in air pollutants following the introduction of the ULEZ scheme. While the rolling average suggests a potential decline in pollutants, a significant portion of data from Air Quality England is missing, and API data intially used proved less reliable.

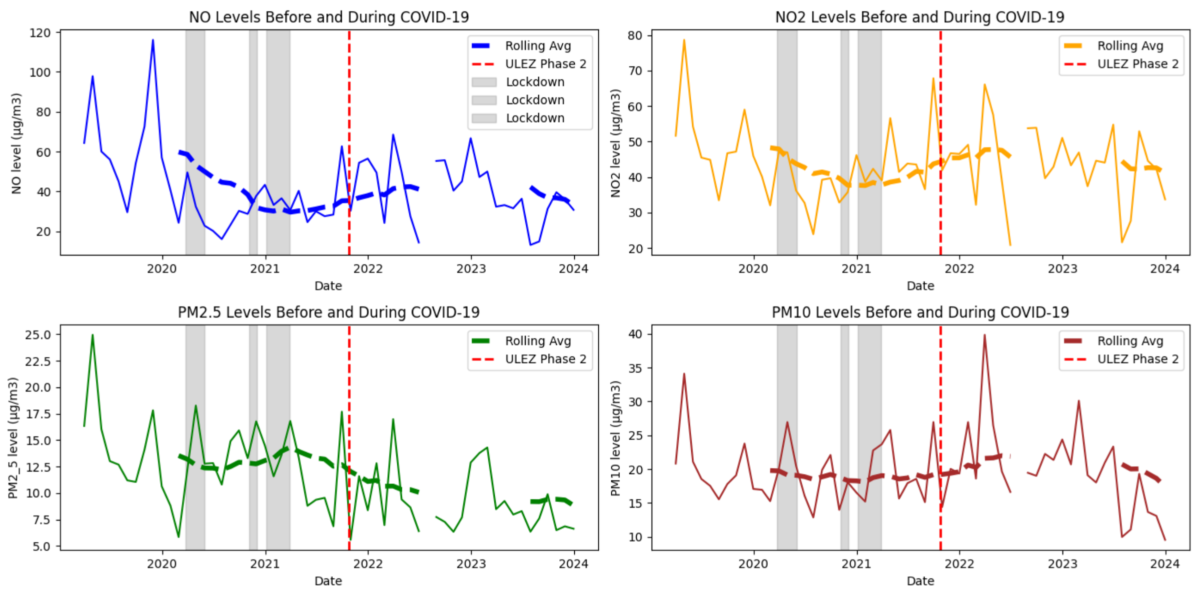


Figure 6 – Hammersmith air pollution levels for four main pollutants before and after COVID with ULEZ introduction marked

The COVID-19 lockdowns in 2020 and 2021 had a greater impact on reducing air pollution than ULEZ, particularly affecting NO and NO_2 levels (figure 7). The overlap of the pre-ULEZ period with the COVID-19 lockdowns means the data from this timeframe may not provide a comprehensive view for Hammersmith however, improvement in PM2_5 level is noticable and can be attibuted to ULEZ introduction.

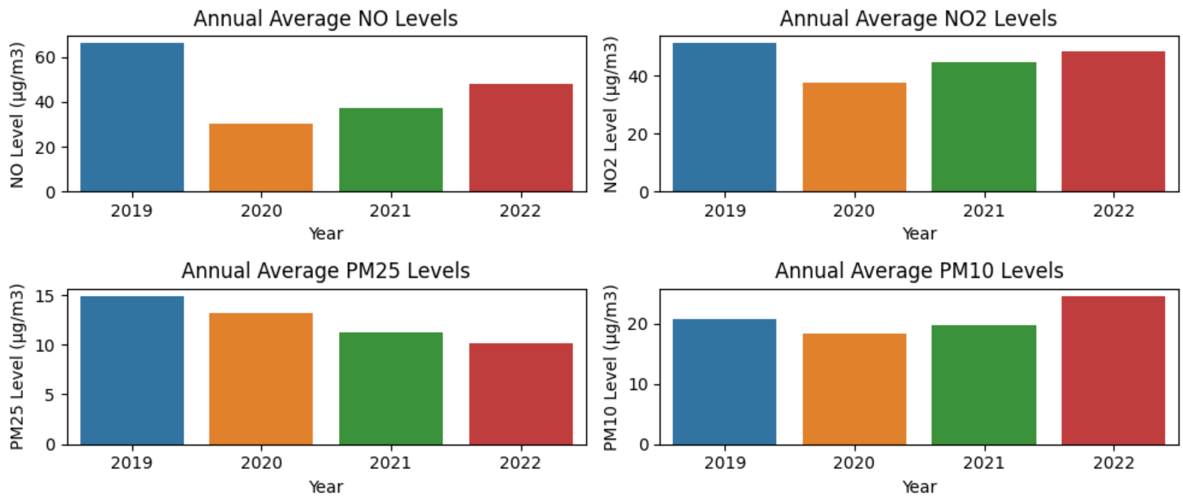


Figure 7 – Average annual air pollutant levels from 2019 to 2022, highlighting impact of COVID on air pollution

Impact of Air Pollution on Health in Hammersmith

The health data utilzed in this section, previously cleaned and used in a report by the Greater London Authority, explores different air quality scenarios:

- Scenario 0: Baseline data from 2016.
- Scenario 2: Government implements the Ultra Low Emission Zone (ULEZ), including modelled improvements from the central ULEZ in 2019, tightening of the Low Emission Zone (LEZ) in 2020, ULEZ expansion in 2021, and additional policy measures from 2016 to 2024.
- Scenario 3: London Environment Strategy, with modelled improvements from ULEZ, LEZ tightening, ULEZ expansion, and additional policies from 2025 to 2050.

Predictive modeling indicates that ULEZ and LEZ schemes will significantly reduce the incidence of several diseases. An example with NO_2 is shown in figure 8. However, diseases such as dementia and lung cancer are expected to rise regardless of air quality strategies, suggesting the need to investigate other contributing factors in the borough. Figure 9 shows that further tightening of ULEZ and LEZ restrictions would have the most substantial impact on preventing disease, potentially saving £2 million per 100,000 residents. Young people would benefit the most from these tighter restrictions, with a higher proportion of avoided hospitalisations.

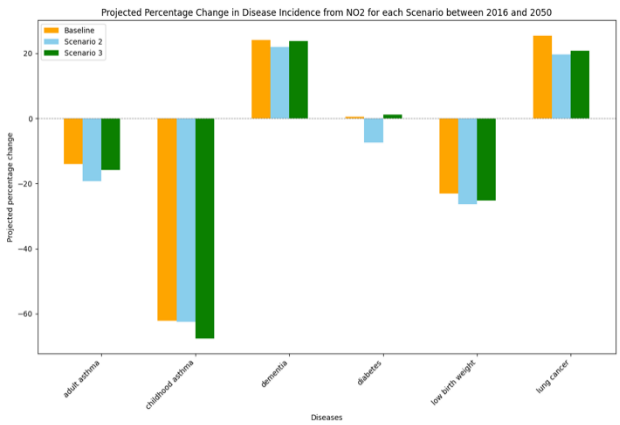


Figure 8 - Predictive modelling showing impact reduction in NO_2 will have on several diseases for all three scenarios

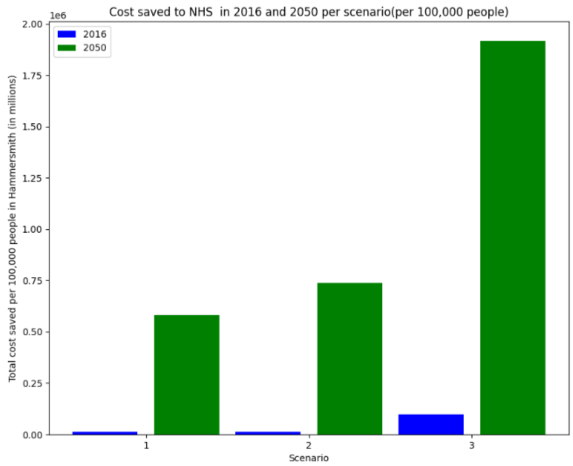


Figure 9 - Predicted cost savings for NHS based on all three scenarios

Conclusion

Throughout this report we have aimed to answer what is the impact of air pollution and how we can improve air quality in the London Borough of Hammersmith and Fulham. Throughout analysis of the data, we have come to the following outcomes with our findings.

Specifically looking at the borough Hammersmith and Fulham, we can conclude that its biggest causes of pollution are road transportation, industrial and commercial businesses, construction and the commercial cooking industry. With a mix of NOx, PM10, PM2.5 and CO all collectively being generated across these different areas, significant changes in practice would need to be undertaken to start reducing overall pollution levels in Hammersmith and Fulham.

We can also conclude that while Ozone (O3) is the only pollutant to see correlation with weather, this is not a direct link to road transport pollution. Peak hours of rush hour traffic between 7am-9am and 4pm-6pm we can conclude as the highest air pollution levels overall on weekdays which further points towards more action is needed in road transportation to make significant change to levels overall.

Throughout our findings we can also confirm that with the introduction of ULEZ there were significant fluctuations with pollutant levels around the introduction date and early 2022. While most pollutants are reduced, with PM10 remaining high due to non-exhaust emissions and construction, further work beyond ULEZ is needed. With COVID-19 having a more significant impact on pollution levels, this further emphasises the need for improving traffic management. If we continue with further ULEZ and LEZ measures, from the predicted data, a potential £0.75m per 100,00 saving could be made to the NHS with a drastic improvement across a range of health conditions affected by air pollution in Hammersmith and Fulham

Recommendations for local government based on report:

- Promote electric and hybrid vehicles through subsidies and incentives.
- Expand charging infrastructure for electric vehicles across the city.
- Improve public transportation frequency, reliability, and coverage.
- Develop cycling and walking infrastructure, including bike-sharing schemes.
- Implement congestion charging with dynamic pricing to reduce traffic during peak times.
- Create car-free zones and days to reduce vehicle traffic in city centres and near schools and hospitals.
- Provide indoor air filtration systems in schools, particularly those near busy roads.
- Encourage telecommuting and flexible working hours to reduce peak-hour traffic.
- Incentivise ridesharing and carpooling with dedicated lanes and reduced parking fees.
- Conduct education and awareness campaigns to promote alternative transportation modes.
- Use technological innovations in traffic management to optimise flow and reduce congestion.
- Conduct regular reviews and updates to emission standards for vehicles within LEZs and ULEZs.
- Support businesses in making buildings more energy efficient to reduce amount of heat and power generation, particularly in the industrial and commercial sector.
- Place air pollution monitors in school and hospital grounds to ensure that there is an up-to-date record of pollutant levels.
- Limit construction near schools, particularly during school opening hours.

Recommendations for school boards based on report:

- Windows should remain closed in classrooms until at least 10am, particularly in the autumnal / winter months where possible.
- Ensure outdoor play times are scheduled between 10am and 3pm.
- Monitor indoor air quality.
- On days where pollution is higher, finding an alternative to outdoor play of students with respiratory conditions.
- Encourage 'walk to school' schemes throughout the local areas to help reduce congestion.
- The use of air purifiers, plants and activated charcoal in classrooms with close proximity to busy roads.
- Traffic limiting measures around the school area throughout the day, not just at the start or end of the day to help with overall traffic in the area of the schools.

References:

https://docs.google.com/document/d/1bcOHYLZiHsn_NPm8CaiRnmmwCjjEiUm5JrAtd2wIk50/edit