Assessing the impact of zero and low emissions control interventions upon air quality in Oxford City; baseline data collection and feasibility study (OxAria)

Study Protocol v2.0

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Protocol Amendment History

Protocol version	Date	Summary of Changes
Detailed project plan	10/10/2018	N/A
Version 1.0	10/10/2018	**1. Background and Scientific Rationale (Section 1)**: Introduction of Zero and Low Emission Zones (ZEZ/LEZ) changed to 'from 2020', replacing 'January 2020', in response to updated policy information received from Oxford City Council. **2. Data Collection:** Air quality monitors confirmed as Praxis units, developed and assembled by South Coast Science [datasheet available at: https://www.southcoastscience.com/wp-content/uploads/2018/01/Praxis_datasheet_online.pdf] A total of 8 air quality (AQ) sensors were available for purchase within allocated project budget, reflecting a reduction from 20 units in the original research plan. **3. Data Collection:** Following discussions with Oxfordshire County Council, we agreed to enhance available AQ data with information obtained from 14 Zephyr (Earthsense) sensors, to be installed in January 2020 within the Network Emissions Vehicle Flow Management Adjustment Study (NEVFMA) funded by Highways England. Arising data will be included within the proposed data sharing agreement, between University of Birmingham (UoB) and Oxfordshire County Council. **4. Study Design (Data Collection):** Traffic flow removed as a secondary outcome measure with the intention of inclusion only within a full evaluation. **5. Dissemination and Legacy activities:** We now include the potential to integrate our findings with those arising from previous and ongoing NIHR research investigating the effectiveness of emissions control measures in other UK cities.
Version 2.0	**05/01/2019**	**1. Study title:** amended to include 'OxAria', the designated acronym. **2. Study Design (3.4.1 AQ Sensor - Network Deployment):** Device locations updated to include other public or private sector assets, reflecting findings of study site visit held on 22 November 2019. **3. Study Design (3.4.1 AQ Sensor - Network Deployment):** Time duration for continuous monitoring amended to 3 months from 4 months duration in the original research plan. This revised timescale reflects the need for production, assembly, and delivery of AQ monitoring equipment, with planned operation from late January 2020. **4. Study Design (3.5 Data Collection – Meteorological Assessment):** Timescale revised to 3-month period in accordance with revision for AQ assessment (point 3). **5. Study Design (3.6 Data Collection – Transport Data):** We now include active travel and road traffic data within the proposed data-

		sharing agreement between UoB and Oxfordshire County Council. **6. Study Design (3.8 Outcome Measures):** We have revised the primary outcome to include different sizes of PM (i.e. PM1, 2.5, 10), reflecting the capability of our AQ monitoring equipment to detect these sizes. **7. Study Design (3.9 Data Analysis).** In response to NIHR PHR feedback on our submitted protocol, we now provide additional details concerning the approach to statistical analyses. We now define how processed AQ data at each measurement location will be adjusted for environmental (temperature, humidity) influences and used to calculate time-series analyses and to compare with legal limit values to assess frequency of exceedances. In response to specialised statistical advice, we now plan to explore the feasibility of applying probabilistic determination of pollutant exposure levels within the proposed full evaluation. In addition, we describe detailed analyses to identify temporal changes and correlations with traffic count information (vehicle number and type). All our observed concentrations will be compared between intervention (ZEZ/LEZ) and control wards, where relevant data is available. **8. Study Design (3.10 Scenario Modelling):** This section has been expanded to include details of scenarios which may be modelled within a full evaluation. These comprise a comparison of AQ changes observe to those predicted by AQ modelling performed within the LEZ/ZEZ design process (also updated in Section 9) and to estimate arising health benefits arising at 1, 5 and 10 years post intervention implementation. **9. Data Protection and Security Standards (4):** Updated to reflect 2018 Data Protection Act and EU General Data Protection Regulations (GDPR) and footnote inserted for reference to the UoB Data Protection Policy. **10. Public Involvement and Engagement (6):** We initially intended to hold a series of three citizen panel events, comprising a demographically and socially representative sample of 12 Oxford residents within the baseline study. However, through piloting of this approach in the Defra funded 'OxAir study' we have come to understand that we would be unlikely to meet our target recruitment, particularly for young males and ethnic minority groups. We have therefore revised our involvement approach to comprise three roundtable events with specific population groups who will be affected by the planned emissions control changes: pedestrians, cyclists and bus drivers. Within the roundtable sessions, we will seek input to the location of AQ sensors and selection of outcome measures for the proposed full evaluation. In addition, we will utilise two engagement opportunities to increase awareness of air quality and health research in Oxford City. **11. Project Management and Governance (8):** We have revised project meetings to occur on a monthly basis (increased from every two months). The Study Steering Committee membership has been updated to include a City Council representative (Cabinet

		Member for Zero Carbon Oxford), to reflect the policy leadership model for the emissions control intervention measures. **12. Dissemination and Legacy Activities (9):** Updated to reflect the above changes and to provide clarity as to planned activities within the existing baseline study and full evaluation respectively.

Contents

1. Background and Scientific Rationale

Poor air quality (AQ) is the largest environmental risk to human health in the UK.[1] It imposes direct and indirect health, environmental and economic costs upon city-regions, public and private sector organisations. The estimated mortality burden from ambient air pollution (AP) exposure is equivalent to 28,000-36,000 deaths per year,[2] with economic costs of over £20Bn.[3] AP is consistently ranked in the top five causes of death in urban areas, ahead of road traffic accidents, excess winter deaths and communicable diseases.[4]

Road transport is the major AP emissions source within urban areas in the UK. Vehicle emissions control measures, which restrict or impose a charge for the most polluting vehicles, are a key policy option for improving urban AQ. In 2017, the Government published a framework to support local authorities to reduce roadside Nitrogen Dioxide (NO_2) levels to below EU legal limits [40 μgm^{-3} annual mean][5,6] in the shortest possible timeframe. Despite widespread problems in achieving NO_2 compliance, Particulate Matter (PM) levels remain largely within legal limits, although exceed WHO guideline values [10 μgm^{-3} annual mean], in >40 UK cities, including Oxford.[7]

In response to these challenges, Oxford City Council declared the city an Air Quality Management Area (AQMA) in 2010 and introduced a bus-based central Low Emission Zone in 2014. Air quality data from the City's AP monitoring locations has shown that between 2016 and 2017, levels of NO_2 fell by an average of 22.7%; however, in 2018 average NO_2 levels remained above legal limits at four central locations.

In this context, Oxford City Council and Oxfordshire County Council have recently developed joint proposals for the introduction of a Zero Emission Zone (ZEZ) and upgraded bus and taxi LEZ, by phased implementation from 2020.[8] Although primarily focused upon achieving legal compliance with NO_2 EU legal limit values, these changes are widely expected to yield public health and societal benefits.

Despite these activities and similar interventions in many UK cities, the effectiveness of emission controls schemes to improve air quality, population health and wellbeing remains poorly defined in the UK. Existing evaluations have been concentrated upon larger cities[9], with limited knowledge of the effectiveness of such measures in small and medium-sized urban settings.

The introduction of these measures in Oxford City provides a unique opportunity to evaluate multiple impacts upon air quality, transportation, health and wellbeing including an economic assessment of cost-effectiveness. To achieve a robust evaluation, immediate baseline data collection is essential to establish current (baseline) in ambient pollution levels and environmental and health impacts, both within and outside planned intervention areas prior to implementation. Therefore, this will enable prospective evaluation of intervention impacts arising from the scheme, including assessment of co- and dis-benefits and unintended consequences.

2. Study Aims and Objectives

2.1 Study Aim

To assess the feasibility of deploying a low-cost wireless AQ sensor network in Oxford City Centre to facilitate the capture of baseline quantitative environmental and health data for emissions control intervention impact assessment.

2.2 Objectives

1) To assess low-cost AQ sensor network performance against reference standards for assessment of urban air quality.

2) To capture high spatial resolution AQ data (primarily NO_2 and PM) across intervention and control sites, thereby generating validated, processed baseline data prior to introduction of emissions control intervention measures.

3) To estimate ward-level population level impacts of AP exposure upon premature mortality and lifetime economic costs among those living in Oxford City.

3. Study Design

We will undertake a cross-sectional study over a six-month period (Nov 2019 to April 2020), to generate baseline data for a full evaluation of a traffic emissions control interventions in Oxford City.

3.1 Setting

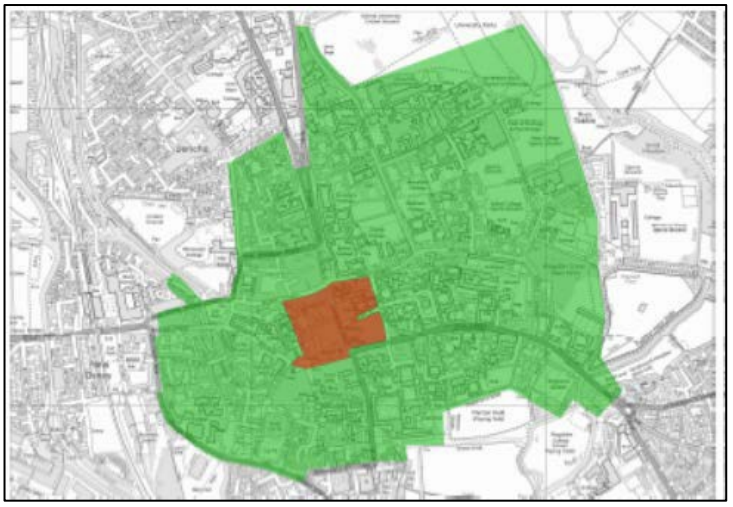
The historic City of Oxford has an estimated population of 154,600 residents (ONS 2017 mid-year estimate), ~34,000 students enrolled (FT) at two universities and 46,000 daily inbound commuters.[10]

3.2 Study Population

Residents living within: intervention wards (Carfax, pop.~6,700; Holywell, pop.~6,200) and comparator wards (North, ~5,900; Hinksey Park~5,800)

3.3 Intervention Measures

Planned Interventions (Fig.1): Two emissions control interventions are planned for central Oxford:



A. Zero Emissions Zone: (red zone) a central area within which vehicles are required to be zero-emissions capable to be permitted to park or load on the street at certain times.

B. Enhanced Low Emissions Zone (green zone): a wider area within which (a) all licensed bus services are required to meet Euro VI requirements for NO_2 emissions; and (b) all Hackney carriages must meet Euro IV standard (renewals); or be Euro VI/zero-emission capable (new vehicles). Emergency vehicles and Blue Badge holders will be exempt from the requirements.

3.4 Data Collection – AQ Assessment

3.4.1 AQ Sensor - Network Deployment

We will deploy multiple urban AQ sensor systems (*Praxis, South Coast Science*) comprising an Optical Particle Counter (Alphasense OPC-N3) and electrochemical sensor (Alphasense NO2-A43F). These devices will measure PM (PM_1, $PM_{2.5}$, PM_{10}) and NO_2 concentrations at selected locations across intervention and control zones over a 3-month period from January 2020. To provide a high-density observational network we will deploy a fixed-site monitoring network within the central ZEZ (red zone) enhanced LEZ (green zone), including a co-located monitor alongside the regulatory station (UKA00258, St Aldates), for calibration purposes. To supplement AQ data measured by this network, we will integrate AQ data arising from a network of 14 AQ monitors [*Zephyr, Earthsense*] deployed by Oxfordshire County Council within the Network Emissions Vehicle Flow Management Adjustment (NEVFMA) study, funded by Highways England. The NEVFMA network will provide observational capability at key highway intersections, perimeter locations and comparator wards (North, Hinksey Park), including urban background sites. AQ monitor units will be mounted upon University of Oxford, Oxford City Council or Oxfordshire County Council or other private or public sector assets All relevant written permissions will be obtained from asset owners prior to installation.

3.4.2 AQ Sensor – Field Trial Acceptance Testing

Each sensor system will undergo acceptance testing to ensure comparable performance. To promote rigour and internal consistency in our observational data we have agreed with our sensor manufacturer for the exchange of sensors, which may pass manufacturer quality control standards but fail our field trial validation tests.

3.4.3 AQ Sensor – Data Extraction and Processing

All AQ monitors will have cellular (4G) communications or WiFi capability linked to the University WiFi network, thereby providing wireless infrastructure for remote data retrieval, aggregation in a cloud environment, prior to automated and supervised processing.

3.5 Data Collection – Meteorological Assessment

To allow for seasonal variation in pollutant levels at baseline, we will perform AQ monitoring for a continuous 3-month period in early spring (2020). Integrated temperature and humidity sensors will also provide high-resolution parameters for the correction of the main interferences for the sensor systems. In addition, we will access meteorological data obtained from the Radcliffe Meteorological Station, for additional contextual support.

3.6 Data Collection – Transport Data

Aggregate data generated from motion sensors, comprising counts by transport mode (i.e. car, van, HGV, pedestrian, cyclist) at key City Centre roadside locations active travel sensors will be obtained from Oxfordshire County Council, in accordance with a data-sharing agreement. Data will be processed to produce summary statistics and enable subsequent assessment of traffic displacement and active travel modal shift within a future full evaluation.

3.7 Data Collection - Health and Demographic information

We will obtain ward level population data (Office of National Statistics) and standardised (all-cause) mortality data (Public Health England). Data will be synthesised to produce summary population health statistics and for modelling AP health and economic impacts at baseline, and to enable assessment of future impacts following introduction of emissions control measures.

3.8 Outcome Measures

- Primary outcomes (baseline): NO_2 and PM (1, 2.5, 10) concentrations at study baseline
- Secondary outcomes (baseline): premature mortality (life years lost), lifetime economic costs (annualised average) (ward level), daily traffic flow, daily active travel trips

3.9 Data Analysis

AQ data will be cleaned, processed and adjusted for local meteorological effects (temperature and humidity interferences) using open source Python libraries. We will calculate a time series of pollutant concentrations and particle numbers at 10 second interval and short-term aggregated statistics relevant to each pollutant. We will also compare these data with EU legal limit and WHO health-based standards to assess the frequency of threshold exceedances. NB. This may not imply

compliance (or otherwise) with relevant legal limits owing to the duration of the feasibility study. We propose to explore the frequency distribution of measured pollutant concentrations by time of day in order to assess the feasibility of probabilistic determination of the range of pollutant exposure within the full-scale evaluation. AQ and traffic count frequency distributions will also be analysed for correlations in amplitude, temporal correlation, temporal offsets, and day of week seasonal effects. A robust analysis of diurnal, weekly and seasonal simple statistics (minima, maxima etc.) and frequency distributions will be essential for the quantitative identification of the impacts of interventions, with a future full evaluation.

In addition, we will calculate spatially-weighted concentrations (annual, daily and 8-hr mean, minimum and maximum values), for intervention and control wards, using current electoral ward boundaries.[11] We will also create a raster layer of selected short and long-term aggregated statistics for each pollutant using a GIS package or Python libraries

We will calculate, population level mortality impacts using existing published concentration response functions, thereby providing independent and combined estimates of loss of all-cause life expectancy for each pollutant of interest.

3.10 Scenario Modelling

We will use these data and parameter estimates to model future impacts of the LEZ/ZEZ measures and compare these to those performed within the emissions control intervention design process. In addition, we will calculate impacts upon upon all-cause mortality within intervention and control zone areas, comparing planned measures at 1, 5 and 10 years to a business-as-usual scenario. Finally, we will undertake a monetary valuation of the average annual economic costs of AP exposure at ward level, applying standard damage cost estimates.[12] The R software will be used for handling of health and demographic data and for future scenario modelling purposes.

4. Data Protection and Security Standards

The UK Data Protection Act 2018 and the EU General Data Protection Regulations ('GDPR') will apply to all data collected within the study activities. All data will be retained on password protected secure computer files in accordance with University of Birmingham and University of Oxford Data Protection Policy requirements.[1]

5. Data Sharing and Access

The proposed study aims to gather base line data collected prior to the implementation of traffic

[1] Available at: https://www.birmingham.ac.uk/university/governance/policies-regs/data-protection.aspx

emissions control interventions in Oxford City. A data-sharing agreement will be sought between collaborating institutions/organisations and with Oxfordshire County Council for sharing of AQ data arising from the Innovate-UK funded NEVFMA study investigate the impact of different traffic management strategies in real-time on the Oxford City road network. All arising data will be retained to enable further analyses if additional funding is secured for a full evaluation, to comprise additional data collection activities peri- and post-implementation of intervention measures.

6. Public Involvement and Engagement

We will conduct a series of public-facing activities within the 6-month baseline study period. The purpose of these will be firstly involvement: (i) to provide input to selection of AQ sensor location and (ii) to identify research priorities for the full evaluation. We will also perform public engagement activities: (i) to raise knowledge and awareness of air quality and health research; (ii) to disseminate our baseline study findings. The involvement events will comprise three roundtable events held with members of population sub-groups (e.g. pedestrians, cyclists, bus drivers), in addition to input provided by two representation of two members of the public on the OxAria Study Steering Group. Engagement activities will comprise a poster exhibition at the Oxford Air Quality Meeting (January 2020) and presentation at the Coalition of Healthy Streets and Active Travel public forum (Feb/March 2020).

7. Ethical Approval

All planned research will adhere to the UK Policy Framework for Health and Social Care Research. We have obtained confirmation from the University of Birmingham Central Ethics Committee that ethical approval is not required for the baseline study

8. Project Management and Governance

The Project Management Group, comprising the investigator team (lead applicant, co-applicants) will meet in person or by videoconference months. The group will (i) agree protocol methods; (ii) monitor progress against the Project Management Plan; (iii) identify and resolve any practical and methodological issues arising from study conduct; (iv) provide quality assurance and governance for the overall investigation.

The external Study Steering Committee, composed of an independent Chair, GP, two academic experts (statistician, health economist), two County Council representatives, a City Council representative, bus company representative and two members of the public who have direct experience of the topic will provide overall project oversight and scrutiny from a scientific, methodology and governance perspective.

9. Dissemination and Legacy Activities

Our overarching goal is to provide contemporary scientific evidence regarding the effectiveness of transport emissions measures to improve population health and therefore inform future public policy in the UK. Clean Air Zones are already planned or undergoing implementation within a number of UK cities which exceed NO_2 legal limit values and more restrictive 'Zero- emissions' strategies are widely recognised to be essential to achieve more stringent PM emissions targets which may be adopted in the UK. Generating improved evidence on this theme will inform future technical and behavioural change policies to reduce emissions of and exposure to AP, thereby improving public health outcomes. Our findings may be integrated with those arising from previous and ongoing NIHR funded research investigating the effectiveness of emissions control interventions in other UK cities.

This baseline study will provide a contemporary high spatial resolution 'map' of PM and NO_2 roadside pollutant concentrations for Oxford City Centre and estimated premature mortality and economic impacts arising from AP exposure at ward level. Preliminary findings will be documented within a summary report for relevant public agencies, civic and commercial sector organisations and a briefing document for Oxford City and Oxfordshire County Council members, coordinated through joint communication channels. We will also perform a comparison against modelled productions for future NO2/PM in Oxford as performed within the ZEZ/LEZ development process. Study outputs (full evaluation) will include an enhanced AQ sensor network, collection of detailed information on traffic flow, bus and taxi fleet composition (including emissions compliance), assessment of modal share/active travel uptake and shift and change in health status and quality of life at population level and among vulnerable groups. We would also seek to perform a full economic evaluation of cost-effectiveness and the identification of unintended consequences arising from the scheme.

The study will also develop standardised protocols for operation and quality assurance of wireless, network integrated low-cost AQ sensors, which may be further deployed in other urban contexts. We will seek to make the AQ data available to the wider public, practitioners and policymakers through the https://oxfordshire.air-quality.info/ website and Oxford City Council communications channels. Our academic findings will also be presented at relevant conferences, such as the Oxford Air Quality Meeting (January 2020) and published in relevant peer reviewed journals.

10. References

[1] RCP: Every Breath We Take: The lifelong impact of air pollution, Feb 2016.

[2] COMEAP: Associations of long-term average concentrations of nitrogen dioxide with mortality, Aug 2018.

[3] HM Treasury: "Air Quality: Economic Analysis" Green Book, 2015.

[4] PHE: Estimation of costs to the NHS and social care due to the health impacts of air pollution,

May 2018.
[5] Defra/DfT: Clean Air Zone Framework Principles for setting up Clean Air Zones in England, May 2017.
[6] European Commission. Air Quality Standards. Available at: https://ec.europa.eu/environment/air/quality/standards.htm (accessed 31 October 2019)
[7] World Health Organisation Global Ambient Air Quality Database (update 2018). Available at: https://www.who.int/airpollution/data/cities/en/
[8] Oxford City Council. Oxford's Zero Emission Zone. Available at: https://www.oxford.gov.uk/info/20216/air_quality_management/1305/oxford_zero_emission_zone_zez [accessed 31 October 2019]
[9] NIHR Signal London's Low Emission Zone has not been shown to improve children's respiratory health. Feb 2019. doi:10.3310/signal-000733
[10] Oxford City Council: Oxford Profile 2018 [population]. Available at https://www.oxford.gov.uk/info/20131/population [accessed 31 October 2019]
[11] Open Data Portal. https://geoportal.statistics.gov.uk/ [Accessed 31 October 2019]
[12] Walton H et al. Understanding the Health Impacts of Air Pollution in London, King's College London 2015.