# CLEANER TRAVEL ACCESS FUND CAMPAIGN – ECONOMIC MODELLING RESEARCH

## Technical Report

Report for: Asthma + Lung UK

Ricardo ref. ED18300100 Issue: 2 11 October 2023

Ricardo Energy & Environment, Gemini Building, Fermi Avenue, Harwell, Oxfordshire, OX11 0QR, UK | +44(0)1235 75 3000 | ee.ricardo.com
Registered company no. 08229264 | VAT no. GB 212 8365 24

Customer:
Asthma + Lung UK

Customer reference:
ED18300100

Confidentiality, copyright and reproduction:

This report is the Copyright of Asthma + Lung UK and has been prepared by Ricardo Energy & Environment, a trading name of Ricardo-AEA Ltd under contract CN03167 dated 05/06/2022. The contents of this report may not be reproduced, in whole or in part, nor passed to any organisation or person without the specific prior written permission of Asthma + Lung UK. Ricardo Energy & Environment accepts no liability whatsoever to any third party for any loss or damage arising from any interpretation or use of the information contained in this report, or reliance on any views expressed therein, other than the liability that is agreed in the said contract.

Ricardo reference:
ED18300100

Contact:
Thomas Adams, Gemini Building, Fermi Avenue, Harwell, Didcot, OX11 0QR, UK

T: +44 (0) 1235 753 517
E: Thomas.Adams@ricardo.com

Author:
Thomas Adams, David Birchby, Charlotte Day, James Southgate, Joe Hague

Approved by:
David Birchby

Date:
11 October 2023

Ricardo is certified to ISO9001, ISO14001, ISO27001 and ISO45001.

Ricardo, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to as the ‘Ricardo Group’. The Ricardo Group assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Ricardo Group entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

# CONTENTS

# 1. INTRODUCTION

Exposure to air pollutants can have a harmful effect on human and environmental health, in particular on the most vulnerable groups in society. Air pollution has been associated with a shortening of life and a range of morbidity effects – these effects present a cost to UK society, not just from the intrinsic loss of wellbeing and enjoyment of life (the utility effect) suffered by the individual, but also in terms of costs to health and social care services and lost productivity (e.g. where people participate in formal – i.e. paid employment – or informal – i.e. unpaid activities, such as caring – activities which provide a value for the economy and society as a whole). It is estimated that air pollution in the UK reduces the life expectancy of every person by an average of 7 – 8 months, with an associated cost of up to £20 billion each year.[1]

## 1.1 TACKLING EMISSIONS FROM ROAD TRANSPORT: CLEAN AIR ZONES

Road transport remains an important source of some of the most harmful air pollutants and in particular is responsible for significant contributions to emissions of nitrogen oxides ($NO_X$) and particulate matter (PM), in particular in the centre of towns and cities.

In its 2017 $NO_2$ plan[2], UK government identified a number of cities and towns across the UK at risk of being in exceedance of legal limits of $NO_2$, and required them to assess and consider the introduction of a Clean Air Zone (CAZ) in order to reduce $NO_2$ to levels to below legal limits as soon as possible. In the years since, many cities and towns have implemented CAZs, or will do so in the near future. These city-level measures work alongside a range of national targets and measures to reduce air pollution: more recently the UK government has set targets to phase out the sale of new petrol and diesel vehicles by 2030.

There are currently nine CAZs (or equivalent charging measures) in England: Bath[3] (CAZ C), Birmingham[4] (CAZ D), Bradford[5] (CAZ C+), Bristol[6] (CAZ D), London[7] (Ultra-Low Emission Zone (ULEZ)), Newcastle[8] (CAZ C), Oxford[9] (Zero-Emission Zone (ZEZ)), and Portsmouth[10] (CAZ B) – three of these charge private cars.

The evidence on the monetary impacts generated by clean air zones is limited, there are only a few reports that have modelled the estimated economic benefits. Some examples of predicted benefits of CAZ implementation include:

- **Greater Manchester**'s original plan for a CAZ (which changed as a result of the pandemic) aimed to implement a CAZ B by 2021, and a CAZ C by 2023. The assessment showed that, in its first year of operation, the zone could have led to almost £25 million worth of health and environmental benefits and, in 2022, the value of the scheme (even taking into account the running costs), could have reached £5.5 million as a result of improved local health and environment. This figure was estimated to rise to almost £40 million in 2030.[11]
- **Birmingham'**s impact assessment of its CAZ D proposal found that the health and environmental benefits for 2020 alone would have equated to over £50 million.[12]
- **Bristol** Council undertook modelling which showed that the financial benefits for a Class D CAZ could be five times greater in comparison to implementation of a Class C CAZ. Total benefits as the result

---

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf

[2] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

[3] https://beta.bathnes.gov.uk/bath-clean-air-zone

[4] https://www.birmingham.gov.uk/info/20076/pollution/1763/a_clean_air_zone_for_birmingham

[5] https://www.bradford.gov.uk/breathe-better-bradford/where-is-the-clean-air-zone/where-is-the-clean-air-zone/

[6] https://www.bristol.gov.uk/residents/streets-travel/bristols-caz

[7] https://tfl.gov.uk/modes/driving/ultra-low-emission-zone

[8] https://www.newcastle.gov.uk/our-city/transport-improvements/transport-and-air-quality/newcastle-and-gateshead-clean-air-zone

[9] https://www.oxford.gov.uk/zez

[10] https://cleanerairportsmouth.co.uk/

[11] Transport for Greater Manchester, February 2019, Greater Manchester's outline business case to tackle nitrogen dioxide exceedances at the roadside: E2 modelling report; the monetised benefits are discounted to 2018 prices.

[12] Birmingham City Council, November 2018, Birmingham Clean Air Zone feasibility study

of reduced $CO_2$, and $NO_2$ and $PM_{2.5}$ pollution, shorter journey times, fewer accidents and more active travel were estimated to contribute up to £142 million[13], without measuring direct public health impacts.

## 1.2 THE CLEANER TRAVEL ACCESS FUND CAMPAIGN

Although CAZs are relatively simple and low-cost for a local authority to put in place, the more significant costs of compliance fall on vehicle owners and operators. Furthermore, there is a risk of a strong, negative distributional effect, as older more polluting vehicles that would be non-compliant with a CAZ are more frequently owned by poorer individuals in society or smaller businesses (a risk often highlighted in the Distributional Analysis undertaken by Ricardo in its support to multiple CAZ feasibility studies, e.g. in Staffordshire[14] and Southampton[15]). However, little funding has been provided for private individuals to make the switch. Asthma + Lung UK estimate that only 20% of scrappage funding has been distributed to individuals, with most going to businesses and taxis. This has played a part in many CAZs being delayed or even shelved, as highlighted by Asthma + Lung UK's (referred to from here as A+LUK) 'Zoning in on Clean air' report[16].

In April 2023, A+LUK launched the 'Putting the brakes on toxic air' policy report[17], which set out the barriers and enablers to transitioning to cleaner modes of transport and demonstrated public support for a number of policy enablers to encourage the transition. One of the four recommendations resulting from this research was to establish a Cleaner Travel Access Fund (CTAF), a scrappage scheme for people on low incomes and people with long term health conditions. The intention is to target such funding particularly at those cities considering a CAZ (D). Although the CTAF directly targets the removal of older, more polluting vehicles, the intention is that this would sit as part of a wider push to encourage more sustainable and active travel. The CTAF offers targeted, financial support to those who would face the most difficulty in complying with the CAZ – namely the poorest households, who frequently rely on their vehicle as a means of travel to work, school, healthcare, and other critical activities. The CTAF therefore helps to overcome a potential unequal burden on these groups, but also mitigate the knock-on effects on the local society and economies (e.g. avoiding people cancelling trips to work and urban centres).

The key features of the proposed CTAF scheme, as outlined in A+LUK's 'Putting the brakes on toxic air' policy report, are:

- It is targeted towards people on lower incomes and people with long-term health conditions that affect their mobility;
- The funding would come from central government for communities that implement a class D CAZ, to help with the financial cost of strong clean air policies;
- The scheme should support people to use the cleanest modes of transport that they can access; and
- Consumer choice should be a key principle, allowing those eligible to access a combination of grants for active travel, public transport, and electric vehicles.

As outlined in Section 1.1, there are already a range of CAZs of different class / specification in place across England and these schemes are predicted to have (or are already having) a positive impact on air quality in the respective cities. However, a CAZ D is often found during feasibility studies to have the greatest estimated impact on air pollution levels. As the CTAF provides a scrappage scheme for private cars, it would primarily target those cities who have implemented or are considering a CAZ D (or similar scheme that provides restrictions for cars). In addition, it is hoped that the scheme would allow further cities to consider implementing a CAZ D as the CTAF helps to mitigate the financial burden of CAZ implementation on those who live and work within the CAZ – often one of the major factors in cities opting for a less-stringent class of CAZ.

## 1.3 AIMS AND OBJECTIVES OF THIS STUDY

Asthma + Lung UK (A+LUK) is the UK's lung charity with a vision for a world where everyone has healthy lungs. The key objective of this study is to develop a robust assessment of the health and economic benefits of the Cleaner Travel Access Fund. This will focus on the impacts on human health, exploring both the overall

---

[13] Bristol City Council Clean Air Plan: Outline Business Case – Economic Case, January 2019, https://democracy.bristol.gov.uk/documents/s32874/OBC-5%20%20BCC%20CAZ%20OBC%20Economic%20case%20310119.pdf

[14] https://moderngov.newcastle-staffs.gov.uk/documents/s34196/Appendix%2036%20-%20E3%20Distributional%20Analysis.pdf

[15] https://www.southampton.gov.uk/moderngov/documents/s39084/E3%20Distributional%20Analysis.pdf

[16] https://www.asthmaandlung.org.uk/zoning-in-on-clean-air

[17] https://www.asthmaandlung.org.uk/putting-brakes-toxic-air

quantified and monetised impact which can be compared to the estimated costs of the scheme (£777million based on the eligibility criteria and the areas with illegal levels of pollution expected under a class D CAZ), but also the varying contributing effects which may be of greater interest to different audiences – e.g. impacts on productivity, children, and educational attainment, on health inequalities, etc.

The scope of the appraisal is England-wide, but study provides additional detailed modelling for four focus areas: Liverpool City Region, Greater Manchester, West Yorkshire, and the West Midlands.

# 2. METHODOLOGY AND INPUTS

This section provides an overview of the methodology and data inputs that informed the analysis. The analysis of the scheme can be grouped into three sections: air quality modelling, health impact assessment, and distributional analysis.

## 2.1 AIR QUALITY MODELLING

### 2.1.1 Overview

The potential air quality improvements that could be achieved as a result of implementing a CAZ D[18] vehicle scrappage scheme have been modelled in detail for four regions in England, and wider uptake of the scheme across England has also been estimated. The modelling results are representative of implementation of the proposed Cleaner Travel Access Fund (CTAF) in isolation, and do not include the estimated impact of implementing CAZ D restrictions in any city.

The potential air quality improvements as a result of the implementation of the proposed CTAF have been quantified in terms of both total annual emissions reductions of $NO_X$, $PM_{10}$, $PM_{2.5}$, and $CO_2$, and annual mean concentration improvements of $NO_2$, $PM_{10}$, and $PM_{2.5}$.

To quantify the potential air quality improvements that could be achieved as a result of implementing the proposed CTAF, we have modelled two road transport emissions scenarios:

1. 2019 Baseline – Representative of road transport emissions in 2019 with no changes applied; this scenario is used to provide a baseline situation from which to assess the impact of the proposed CTAF.
2. 2019 CTAF – Representative of emissions in 2019 with the CTAF in place; this scenario is the same as the 'Baseline' scenario, but with assumptions applied to represent implementation of the CTAF. This scenario does not represent implementation of a CAZ D across the city, but rather the vehicles removed and/or upgraded to electric vehicles (EVs) as a result of implementing the CTAF in isolation.

The estimated impact of the CTAF scheme is therefore the difference between scenarios 1 and 2.

To generate the 'CTAF' scenario, scaling factors were calculated by modelling total annual emissions on major roads in four cities within each detailed model region, under both the 'Baseline' and 'CTAF' scenarios. The main input to the emissions and air dispersion modelling is the UK National Atmospheric Emissions Inventory (NAEI) emissions maps for 2019[19] for the road transport sector, which are available at a 1 km x 1 km resolution. An appropriate scaling factor for each city / pollutant was applied to each 1 km grid square in the Baseline emissions map, to generate a 'CTAF' emissions map.

The RapidAIR[20] modelling software was used to model annual average concentrations of $NO_2$, $PM_{10}$, and $PM_{2.5}$ at a 1 km x 1 km resolution across the four detailed model regions, for each scenario, using the Baseline and scaled CTAF emissions maps. This enabled the change in annual average concentrations for each pollutant to be estimated as a result of implementation of the proposed CTAF.

More information on each step in the air quality modelling methodology is provided in the sections below.

### 2.1.2 Development of CTAF scaling factors

Scaling factors were developed for each pollutant ($NO_x$, $PM_{10}$, $PM_{2.5}$, and $CO_2$) for Birmingham (applied across West Midlands), Bradford (applied across West Yorkshire), Liverpool (applied across Liverpool City Region), and Manchester (applied across Greater Manchester) and applied to scale the 2019 Baseline emissions in each of the four regions to produce the 2019 CTAF emissions maps. Separate England-wide scaling factors were also developed to model the impact of the scheme on cities outside of the four detailed model regions. These were calculated as the mean scaling factor for each pollutant across the four regions.

---

[18] CAZ D restrictions apply to buses, coaches, taxis, private hire vehicles, heavy goods vehicles, vans, minibuses, cars, and the local authority has the option to include motorcycles.

[19] https://naei.beis.gov.uk/data/mapping-archive

[20] https://www.rapidair.co.uk/?gclid=CjwKCAjwtuOlBhBREiwA7agf1thNa-nndgR3uuJT1WHHiUFT_Gh6ptlkF2SEZeTKc5o_VgTMupe6mhoCgv4QAvD_BwE

To generate scaling factors for each city and pollutant, the total annual emissions of $NO_X$, $PM_{10}$, $PM_{2.5}$, and $CO_2$ on major roads within the four detailed study cities were calculated for both the ‘Baseline’ and ‘CTAF’ scenarios using the latest available version of Defra’s Emissions Factors Toolkit (EFT) v11.0[21].

The datasets informing the modelling of the Baseline emissions included:

- National activity data from the Department for Transport (DfT) on the number of vehicles travelling on major roads in the study cities[22] (annual average daily traffic (AADT));
- City-specific Euro fleet compositions taken from existing CAZ feasibility studies, where possible:
    - Birmingham – Birmingham Clean Air Zone Feasibility Study Full Business Case Air Quality Modelling Report[23]
    - Bradford – Bradford Clean Air Zone Feasibility Study[24]
    - Liverpool – Targeted Feasibility Study to deliver Nitrogen Dioxide Concentration Compliance in the Shortest Possible Time[25]
    - Manchester – Case for a new Greater Manchester Clean Air Plan[26], Local Plan Transport Modelling Methodology Report (T3)[27], Note 5: GM CAP ANPR Surveys: Summary of Initial Findings[28], Note 37: Vehicle Population Estimates[29];
- National (COPERT 5.3) emissions factors were used, as incorporated into the EFT;
- Assumptions regarding average speed on road links were made by road type (A roads, and motorways), using DfT data for 2019[30],[31].

The extent to which the CTAF scheme would likely be applied in each city was determined by considering eligibility for the CTAF and the likelihood of eligible households making use of the scheme. Assumptions regarding this were made using the following datasets and applied in four steps:

1. The CTAF scheme is targeted towards people on lower incomes and people with long-term health conditions that impact their mobility. The percentage of households eligible for the CTAF scheme was determined using national datasets:
    - The proportion of the population that are Blue Badge Holders (BBHs) in England[32] (4.2% in 2021) was used to determine the proportion households that were eligible for the CTAF due to long-term health conditions that impact their mobility.

---

[21] EFT v11.0, November 2021, https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/

[22] https://storage.googleapis.com/dft-statistics/road-traffic/downloads/data-gov-uk/dft_traffic_counts_aadf.zip

[23] Birmingham Clean Air Zone Feasibility Study, Full Business Case Air Quality Modelling Report, Air Quality Consultants and Birmingham City Council, December 2018, https://www.birmingham.gov.uk/downloads/file/11353/aq3_-_birmingham_caz_fbc_report-_air_quality_v3_4-12-18

[24] Bradford Air Quality Modelling Methodology Report (AQ2), Bradford CAZ Feasibility Study, Ricardo Energy & Environment, November 2019 (not available online)

[25] Targeted Feasibility Study to deliver Nitrogen Dioxide Concentration Compliance in the Shortest Possible Time, Liverpool City Council, 2018, https://uk-air.defra.gov.uk/library/assets/documents/no2ten/Liverpool_FINAL.pdf

[26] Case for a new Greater Manchester Clean Air Plan Technical Documents, https://cleanairgm.com/technical-documents/

[27] Greater Manchester’s Outline Business Case to tackle Nitrogen Dioxide Exceedances at the Roadside, Local Plan Transport Modelling Methodology Report (T3), Transport for Greater Manchester, February 2019, https://assets.ctfassets.net/tlpgbvy1k6h2/4wJPXXo6dWJKFOmDTaogHu/9a9084f3f7c73e567bb1f85f50818010/T3_Local_Plan_Transport_Modelling_Methodology_Report.pdf

[28] Greater Manchester’s Clean Air Plan to tackle Nitrogen Dioxide Exceedances at the Roadside, Note 5: GM CAP ANPR Surveys: Summary of Initial Findings, Transport for Greater Manchester, July 2019, https://assets.ctfassets.net/tlpgbvy1k6h2/38IyhvA990fFePykExrZPo/d1abf9e1b3d627f0260a3bbf09aa5ea8/5_-_GM_CAP_ANPR_Surveys_Summary_of_Initial_Findings.pdf

[29] Greater Manchester’s Clean Air Plan to tackle Nitrogen Dioxide Exceedances at the Roadside, Note 37: Vehicle Population Estimates, Transport for Greater Manchester, August 2020, https://assets.ctfassets.net/tlpgbvy1k6h2/3fR4HEB016Z572elRIs8wx/ddfa01e92fb972d2d5297e04c78f046a/37_-_GM_CAP_Vehicle_population_estimates.pdf

[30] Average speed on local ‘A’ roads (CGN0501a) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1040430/cgn0501.ods

[31] Average speed on the Strategic Road Network in England (CGN0404a) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1162487/cgn0404.ods

[32] Blue Badge scheme statistics: 2021, Department for Transport, January 2022, https://www.gov.uk/government/statistics/blue-badge-scheme-statistics-2021

    - Household income data for the UK[33] was used to determine the proportion households that were eligible for the CTAF due to low household income (<£20,800 per year, based on weekly income figures).
    - To avoid any double counting, the proportion of BBHs were removed from the proportion of households that were eligible based on household income level.
2. The proportion of CTAF-eligible households with car availability was determined using household car availability by household income quintile,[34] considering households in the second income quintile or below (up to an annual household income of £20,500) with access to one or more cars/vans.
3. The percentages of conventional (petrol and diesel) cars that would be classed as non-compliant if a CAZ D were implemented in the relevant city were determined for each city using the city-specific fleet information gathered from the aforementioned CAZ feasibility studies.
4. Assumptions to establish the proportion of eligible vehicles that would switch mode or upgrade as a result of the CTAF implementation were informed by survey data from the Joint Air Quality Unit (JAQU) CAZ Appraisal Guidance[35], applied to previous UK CAZ feasibility study projects.

The above assumptions were applied in sequence to determine a ‘CTAF uptake factor’ for each of the four study cities. The CTAF uptake factor refers to the percentage of conventional cars that would take part in the CTAF scheme using the options outlined in Section 1.1: by either being removed from the road network (if the vehicle owner switched to public transport or active travel) or be replaced by an electric vehicle (EV). It was assumed that, as the majority of households eligible for the CTAF scheme had eligibility based on low household income, these households would choose to switch mode to public transport or active travel, rather than purchasing an EV. However, for households eligible for the CTAF based on long-term health conditions that impact their mobility, switching to these modes of transport may not be feasible and so they may be more likely to use the grant to upgrade their vehicle to an EV. It was therefore assumed that, of the total proportion of cars taking part in the CTAF scheme, 4.2% of these (the national proportion of BBHs) would upgrade to an EV, and the remainder of cars would be removed from the road network as their household switched to another mode of transport.

While many of the datasets used to determine the CTAF uptake factors were national datasets, as the ‘Baseline’ fleet is different for each of the study cities, a different scaling factor was generated for each city, as well as each pollutant. Table 2-1 provides a summary of the scaling factors developed for NOx, $PM_{10}$, $PM_{2.5}$ and $CO_2$ in the four detailed model regions, as well as the average scaling factors applied to cities elsewhere in England (taken as the mean of the four scaling factors developed for each pollutant). For example, the CTAF scheme is predicted to remove 2.3% of total road transport emissions across Greater Manchester and hence the CTAF scheme emissions are 97.7% of the Baseline (scaling factor = 0.977).

The West Midlands (based on fleet data for Birmingham) had the highest scaling factors across all pollutants, i.e. closest to 1. This reflects the vehicle fleet in Birmingham being slightly newer and more CAZ-compliant than in the other cities, and consequently a smaller proportion of emissions were removed when the CTAF uptake assumptions were applied. On the other end of the scale, West Yorkshire (based on fleet data for Bradford) had the lowest scaling factors across all pollutants, meaning the vehicle fleet in Bradford is older than that the other three cities, and therefore more cars would be non-compliant in a CAZ D situation and so eligible for the CTAF.

The scaling factors for Manchester and Liverpool are very similar, and somewhere in-between the situations of Bradford and Birmingham in terms of vehicle fleet age. However, it should be noted that there was little fleet information available online for Liverpool, so fleet information for Manchester was used for most vehicle types (including cars) – hence the scaling factors are very similar.

---

[33] Household income, Ethnicity facts and figures, September 2022, https://www.ethnicity-facts-figures.service.gov.uk/work-pay-and-benefits/pay-and-income/household-income/latest#download-the-data

[34] Household car availability by household income quintile: England, from 2002 (NTS0703), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1101101/nts0703.ods

[35] Assumptions based on London ULEZ data (Ref: JAQU CAZ Appraisal Guidance 2019)

Table 2-1 Summary of scaling factors applied to 2019 Baseline (NAEI) road transport emissions maps for NOx, $PM_{10}$, $PM_{2.5}$ and $CO_2$ in the four detailed model regions, and the average scaling factors applied to cities elsewhere in England

| Region | Scaling factor | | | |
|---|---|---|---|---|
| | NOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Greater Manchester** | 0.977 | 0.971 | 0.972 | 0.972 |
| **Liverpool City Region** | 0.978 | 0.971 | 0.972 | 0.971 |
| **West Midlands** | 0.985 | 0.982 | 0.982 | 0.984 |
| **West Yorkshire** | 0.972 | 0.966 | 0.966 | 0.967 |
| **England-wide** | 0.978 | 0.973 | 0.973 | 0.973 |

The city-specific scaling factors were subsequently applied to the NAEI emissions maps for the road transport sector, to generate 'CTAF' emissions maps, representing application of the CTAF scheme in each region.

### 2.1.3 Emissions modelling

The main input to the emissions modelling, the UK NAEI emissions maps for 2019 for the road transport sector, are available at a 1 km x 1 km resolution. The year 2019 was chosen for the study as this is the most recent year that the emissions maps are available for, that is not impacted by the COVID-19 pandemic.

The appropriate scaling factor for each city / pollutant was applied to each 1 km grid square in the Baseline emissions map, to generate 'CTAF' emissions maps representing application of the CTAF scheme in each region. The main outputs of this task were maps of total annual emissions (in tonnes) for $NO_X$, $PM_{10}$, $PM_{2.5}$, and $CO_2$ for the 'Baseline' and 'CTAF' scenarios for the four study cities.

### 2.1.4 Air dispersion modelling

#### *2.1.4.1 Model scenarios*

We have provided $NO_2$, $PM_{10}$ and $PM_{2.5}$ annual mean concentration outputs at a 1 km x 1 km resolution for the following scenarios:

1. 2019 Baseline: road transport contributions modelled using NAEI emissions maps[36] and all other sources provided by DEFRA background mapping data[37]
2. 2019 Greater Manchester CTAF: road transport contributions modelled using NAEI emissions maps with Manchester CTAF scaling factor applied (Section 2.1.2) and all other sources provided by DEFRA background mapping data
3. 2019 Liverpool City Region CTAF: road transport contributions modelled using NAEI emissions maps with Liverpool CTAF scaling factor applied (Section 2.1.2) and all other sources provided by DEFRA background mapping data
4. 2019 West Midlands CTAF: road transport contributions modelled using NAEI emissions maps with Birmingham CTAF scaling factor applied (Section 2.1.2) and all other sources provided by DEFRA background mapping data
5. 2019 West Yorkshire CTAF: road transport contributions modelled using NAEI emissions maps with Bradford CTAF scaling factor applied (Section 2.1.2) and all other sources provided by DEFRA background mapping data

#### *2.1.4.2 Model selection*

The RapidAIR©[38] Urban Air Quality Modelling Platform was used to predict air pollutant concentrations for this study. This is Ricardo Energy & Environment's proprietary modelling system developed for urban air pollution assessment. The model approach is based on loose coupling of two elements:

---

[36] https://naei.beis.gov.uk/data/mapping

[37] https://uk-air.defra.gov.uk/data/laqm-background-home

[38] https://www.rapidair.co.uk/what-is-rapidair/

- Convolution of an emissions grid with dispersion kernels derived from the USEPA AERMOD[39] model
- The kernel based RapidAIR model running in GIS software to prepare dispersion fields of concentration for further analysis with a set of decision support tools coded in Python/arcpy

A traffic flow diurnal profile was applied as time varying emissions in AERMOD when creating the RapidAIR dispersion kernel. The profile was developed using UK Department for Transport statistics[40].

#### *2.1.4.3 Meteorology*

RapidAIR includes an automated meteorological processor based on AERMET, which obtains and processes meteorological data of a format suitable for use in AERMOD. Surface meteorological data for the year 2019 was obtained from three surface meteorological stations (Manchester, Rostherne, and Emley Moor) and upper air meteorological data was obtained from two upper air meteorological stations (Nottingham and Larkhill). RapidMet was used to carry out data filling where necessary according to methodology[41] provided by the USEPA Meteorological Monitoring Guidance for Regulatory Modelling Applications.

#### *2.1.4.4 Background concentrations*

The focus of the modelling study is road traffic emissions. Emissions from sources not included in the model were estimated using data from the most recently available DEFRA background mapping data[42] for 2019 (2018-based).

#### *2.1.4.5 Emissions inputs*

Road transport emissions were provided by the NAEI emissions maps[43] at a resolution of at a 1 km x 1 km.

#### *2.1.4.6 NOx/$NO_2$ emissions assumptions*

NOx to $NO_2$ chemistry was modelled using the Defra NOx to $NO_2$ calculator (v8.1)[44] using inputs which were determined to best replicate the background conditions in the modelled regions. Modelled annual mean road NOx concentrations were combined with background NOx concentrations to calculate $NO_2$ annual mean concentrations. Where $NO_2$ concentration maps were required, total $NO_2$ was derived from background NOx and road NOx concentrations using a specific polynomial equation.

## 2.2 HEALTH IMPACT ASSESSMENT

The health impact analysis is split into four separate work-strands, as set out in the following sections.

### 2.2.1 Health impact assessment (following the Defra/IGCB approach)

To assess the impacts of the proposal on human health via changes in exposure to air pollution, we have undertaken a quantitative assessment following two separate (but fundamentally linked) approaches:

- For the 'detailed modelling' domain, we have deployed the Impact Pathway Approach (IPA).
- For the 'cost' and 'England-wide' domains, we have used damage costs.[45]

The IPA is a logical, step-by-step process through which human health impacts are calculated and monetised. The IPA differs in approach to applying the damage costs directly, in that it allows a more nuanced assessment. Damage costs (expressed in terms of a £/tonne estimate) calculate and assess the same impacts as those covered by the IPA, and indeed the IPA is followed to generate damage costs. However, damage costs are applied directly to a change in tonnes of emissions to directly calculate the monetary effect, but in doing so implicitly assume a fixed relationship between pollutant emission, change in concentration and exposure. Given that under the air quality modelling we explored a change in air pollutant concentrations for the detailed modelling domain, we can apply the more detailed IPA to produce a more tailored assessment to the effects

---

[39] https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

[40] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/801205/tra0307.ods

[41] https://www.epa.gov/sites/default/files/2020-10/documents/mmgrma_0.pdf

[42] https://uk-air.defra.gov.uk/data/laqm-background-home

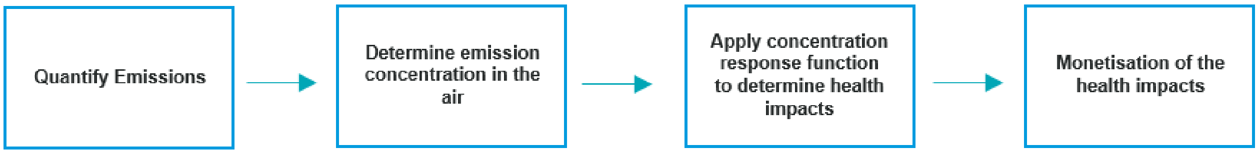
[43] https://naei.beis.gov.uk/data/mapping

[44] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/nox-to-no2-calculator/

[45] Please see the Glossary in Appendix 1 for a definition of damage costs

of the proposal being considered – i.e. better reflecting the change in exposure specifically associated with the scrappage of older vehicles in the CAZ D cities.

Figure 2-1 Schematic of the Impact Pathway Approach



For the 'cost' and 'England-wide' analysis, we have deployed the damage costs from Defra's latest Damage Cost 2023 update[46].

Where we have applied the IPA to the 'detailed modelling' domain, we have followed Defra's guidance for UK appraisal for the assessment of air pollution effects, taking into account recent changes as captured in the Damage Cost 2023 update. We have replicated the health pathways selected, underlying data sources used (e.g. to depict baseline incidence of health outcomes), assumptions and methodological choices (e.g. accounting for overlaps between different pathways or pollutants, and around the strength of the underlying evidence of different effects), and unit values deployed in generating Defra's 2023 damage costs.

To follow the IPA, first, we overlaid gridded annual average modelled air pollutant concentrations with population grids to calculate population weighted concentrations. Changes in concentration exposure are linked to health impacts through concentration response functions (CRFs). The analysis captured a range of health impact pathways, as captured by the Defra damage costs. Note: the pathways captured only represent those for which a robust, quantitative relationship between a change in exposure to a specific air pollutant and health impact exist – in practice, there may be other health impacts associated with the pollutants assessed and otherwise which cannot yet be confidently captured quantitatively in appraisal. The list of impacts captured in our analysis (and captured in the Defra damage costs) covers:

- Mortality associated with long-term exposure ($PM_{2.5}$ and $NO_2$)
- Respiratory hospital admissions associated with acute exposure ($PM_{2.5}$ and $NO_2$)
- Ischemic heart disease ($PM_{2.5}$)
- Stroke ($PM_{2.5}$)
- Lung cancer ($PM_{2.5}$ and $NO_2$)
- Asthma in children ($PM_{2.5}$ and $NO_2$).

Changes in concentrations and CRFs were combined with local population data and baseline data on health outcomes to estimate quantified health effects (e.g. number of deaths per annum associated with solid fuel burning). The output is a quantified effect of the proposal on the number of detrimental health outcomes associated with exposure to air pollution (e.g. change in hospital admissions), presenting the change in 'attributable' health outcomes.

**Information Box: 'Attributable' health impacts**

It is very challenging to estimate the impacts of a change in air pollution on health impacts. The methods deployed produce a quantitative estimate of a change in health outcomes, but these should not be understood as a prediction of a change that would be observed in the real world. In practice, changes in air pollution would manifest in different ways – e.g. changes in incidence and prevalence of disease, but also a change in severity of cases. These outcomes would depend on a wider range of parameters, e.g. the underlying health of the individual and pre-disposition to being susceptible to the effects of air pollution exposure. The underlying HIA methodologies do not allow prediction of effects with high certainty. Instead, they produce what is referred to as an 'attributable' (or equivalent) effects which can be considered broadly representative of the overall effect of a change in air pollution, for use in economic appraisal. In practice, the effect may be quite different, for example contributing a smaller impact on a much wider number of people or cases, or more severe effect on fewer individuals.

The health impacts are then monetised to present the 'economic' benefits – this captures a range of effects, such as the direct impact on the utility of the affected individual (commonly captured by the 'willingness-to-pay'

---

[46] https://uk-air.defra.gov.uk/library/reports?report_id=1103

of the individual to avoid the detrimental health outcome), impacts on productivity and a reduction in medical costs. The monetary values used will align with those deployed in Defra's damage cost estimation.

### 2.2.2 Productivity

Air pollution can have a range of impacts on 'productivity' through its effects on human health, either removing people's ability to participate in formal (i.e. paid) or informal (i.e. unpaid – e.g. volunteering or caring) activities that provide a benefit for society.

As noted above, the Defra damage costs capture some impacts that are defined explicitly as productivity impacts – namely impacts on Work Days Lost, Restricted Activity Days, minor Restricted Activity Days, and the effects on both paid and unpaid activities. These relationships are drawn from underlying work by Ricardo[47] which explored the links between air pollutant exposure and productivity. However, the published damage costs do not include all of the impact pathways identified and quantified in the under lying Ricardo report – some were excluded from the damage cost estimation given risk of overlap with the valuation of impacts already included in the damage costs (e.g. the damage costs already included an estimate of the impacts of exposure on mortality, which are monetised based on estimates of willingness-to-pay for additional life years. Mortality will also impact in some cases on productivity, in particular where affected individuals are still present in the labour force, but these impacts are not captured in the damage costs to avoid risk of double counting with the mortality effects already monetised).

For this study, we produced three estimates of productivity effects for consideration:

1. **Damage cost pathways:** Splitting out the productivity pathways included in the Defra damage costs (e.g. work-loss days) – this forms the most robust, but somewhat incomplete assessment of productivity impacts directly.
2. **Complete bottom-up**: In addition to the pathways captured in the damage costs, we have also added on all other pathways considered in Ricardo's original productivity study for Defra, but not included in the damage costs given overlaps with other pathways – this forms a more complete estimation which could still be viewed as robust as based on the study published by Defra.
3. **Top-down estimation:** deploying the EU-approach adopted by the EU to estimate overall productivity effects (for example, as was deployed in a study to support the impact assessment for proposal to revise the EU's Ambient Air Quality Directive[48]). The empirical basis stems from recent OECD work[49] that quantifies the causal impact of $PM_{2.5}$ pollution on productivity in the EU for the period 2000-2015. In doing so, this produces a more complete assessment of productivity effects, which has credibility as it follows a method deployed by the EU, but is not an approach commonly applied in the UK.

By splitting out the pathways which are part of the 'formal' paid economy, we can also isolate an impact on GDP.

### 2.2.3 Impacts on children and educational attainment

Children and young people are particularly susceptible to the detrimental effects of air pollution, as exposure has a damaging effect during the development of their respiratory and cardio-vascular systems. Defra's damage costs capture several impacts on children specifically – school days lost (SDL), and asthma in children. To explore the effects on children and educational attainment, we have split these out from the core health impact assessment.

The estimation of SDL under this work-strand is linked to the estimation of SDL under the 'productivity' strand of the analysis, but with some key differences. Under this strand, given the focus is on the impacts on children, the output metric is the quantity of school days lost (SDL), which is felt by the child. Under productivity, the focus is instead on the productivity impact of SDL, as hence the output metric is instead work days lost (WDL), which are a knock on effect of the SDL. Not all SDL will result in WDL, as there may be alternative arrangements that can be made which do not interrupt the working patterns of parents and carers. As such, there are additional steps in the calculation of WDL to account for this, in particular adjusting for the proportion

---

[47] https://uk-air.defra.gov.uk/library/reports?report_id=832
[48] https://op.europa.eu/en/publication-detail/-/publication/a05c2e91-54db-11ed-92ed-01aa75ed71a1/language-en
[49] https://one.oecd.org/document/ECO/WKP(2019)54/En/pdf

of households with children where not all adult members work, and a further adjustment drawing on published sources[50] exploring how many SDL translate into WDL for working families.

As noted above, Defra's damage costs present one summary view of the effects of air pollution on health. There are a wide range of effects for which quantitative estimates have not been made, and/or quantitative estimates are not considered robust enough to be included in the damage costs, for example impacts on IQ in children[51] and emerging evidence around the link to mental health[52]. To broaden the narrative, we have undertaken a targeted literature review to elaborate qualitatively these additional links between exposure to air pollution and health effects in children. This includes also elaborating on the link between school absence or 'presenteeism' (where a child attends school, but not in full health and hence impacting their ability to concentrate) with educational attainment.

### 2.2.4 Comparing costs and benefits

This final work-strand draws together the quantification and monetisation of effects for comparison to the costs of the proposal, as estimated in Asthma + Lung UK's 'Putting the brakes on toxic air' report[53]. We have reviewed these estimates to ensure they are expressed in the same price year and discounting to present a consistent comparison to the estimated economic benefits of the proposal.

To complement the comparison, we have also produced a high-level estimate of the fuel saving and GHG emission reduction benefits associated with removing these vehicles from the roads. To do so we have deployed data and assumptions used to estimate the economic effects of Clean Air Zones in the UK as part of several feasibility studies supported by Ricardo[54]. Both GHG emissions and fuel cost impacts are valued using carbon and fuel prices from BEIS' supplementary Green Book guidance[55].

## 2.3 DISTRIBUTIONAL IMPACT ASSESSMENT AND HEALTH INEQUALITIES

There is also a growing awareness of health inequalities in the UK. Health inequalities can be defined in different ways, but a helpful, comprehensive definition is provided by the Kings Fund[56] as presented in the following Box.

**Information Box – definition of health inequalities (Kings Fund)**

Health inequalities are ultimately about differences in the status of people's health. But the term is also used to refer to differences in the care that people receive and the opportunities that they have to lead healthy lives – both of which can contribute to their health status. Health inequalities can therefore involve differences in:

- health status, for example, life expectancy
- access to care, for example, availability of given services
- quality and experience of care, for example, levels of patient satisfaction
- behavioural risks to health, for example, smoking rates
- wider determinants of health, for example, quality of housing.

Health inequalities can manifest themselves in different ways for different groups, for example:

- Difference in life expectancy, associated with variance in income or 'index of deprivation' (the so called 'social gradient in health')[57], or amongst groups with learning disabilities, and different ethnic groups

---

[50] See: Palmer L. et al (2010): 'Effect of influenza-like illness and other wintertime respiratory illnesses on worker productivity: The child and household influenza-illness and employee function (CHIEF) study'; Vaccine. 2010 Jul 12;28(31):5049-56

[51] https://pubmed.ncbi.nlm.nih.gov/31229778/

[52] https://www.psychiatry.org/news-room/apa-blogs/air-pollution%E2%80%99s-impact-on-mental-health#:~:text=Past%20research%20has%20associated%20air,people%20with%20serious%20mental%20illness.

[53] https://www.asthmaandlung.org.uk/putting-brakes-toxic-air

[54] See for example, the '*NORTH STAFFORDSHIRE LOCAL AIR QUALITY PLAN UNAPPROVED OUTLINE BUSINESS CASE APPENDIX 34 – E1 Economic Modelling Report'* which sets out further detail on the approach and data sources used in the CAZ modelling: https://moderngov.staffordshire.gov.uk/documents/s141330/Appendix%2034%20-%20E1%20Economic%20Modelling%20Report.pdf

[55] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[56] https://www.kingsfund.org.uk/publications/what-are-health-inequalities

[57] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthinequalities

- Variance in the prevalence of long-term health conditions, again associated with variance in income or ‘index of deprivation’[58], and ethnic group
- Variation in prevalence of mental health conditions, again associated with variance in income or ‘index of deprivation’, and ethnic group, but also sexuality and gender, and disability status
- Difference in access to healthcare services, again associated with variance in income or ‘index of deprivation’, which can be observed in fewer GP visits per head and/or lower rates of admission to elective care. People living in areas of high deprivation, those from Black, Asian and minority ethnic communities and those from inclusion health group, for example the homeless, are most at risk of experiencing these inequalities[59].

For air pollution specifically, inequalities manifest themselves in terms of exposure and susceptibility to harmful levels of air pollution. For example, higher levels of air pollution are often present in inner-city urban areas, which can also be where a higher level of social or lower-value housing is located. Likewise, certain characteristics make particular segments of society more vulnerable to its effects – e.g. age (young and old), disability status and existence of pre-existing conditions, some of which in turn are linked to other demographic factors (e.g. high levels of deprivation are linked to lower levels of baseline health due to lifestyle factors, which in turn are linked to higher levels of pre-existing conditions which drive higher susceptibility to the effects of air pollution).

Aggregate estimates of financial or health impacts (such as those that will be undertaken in the HIA as explored above) are useful, but would overlook potentially important underlying trends in the impacts across societal groups, in particular those more at risk of health inequalities. Hence we have complemented the HIA with Distributional Analysis, which seeks to explore further any sub-trends in the effects of the CTAF, to understand if any one group in society may be more affected than any other.

We applied the recommended approach detailed within the DfT’s Transport Analysis Guidance (TAG) unit A4-2: The guidance recommends that the scope of the distribution impact assessment covers:

- Areas with a low/high level of income distribution; and
- Areas with a low/high proportion of children (citizens under the age of 16).

Additionally, this analysis also included a review of the potential impacts of the changes in annual average $NO_2$ concentrations in:

- Areas with a low/high proportion of adults over the age of 65.

This was included in recognition that this group are particularly vulnerable to air pollution exposure, and the deterioration of air quality in areas with a high proportion of this sensitive demographic could lead to large increases in hospital admissions and health-related care.

For simplicity, the three groups used in the distributional impact assessment are hereon referred to as IMD (Index of Multiple Deprivation, representing income distribution), children (representing citizens under the age of 16) and elderly citizens (representing citizens over the age of 65).

The analysis evaluates the relationship between the presence of different demographic groups in a given area and against the corresponding change in $NO_2$ concentrations. The change in annual average $NO_2$ pollutant was calculated by first calculating the average concentration of $NO_2$ across a spatial area from the modelling outputs for both the baseline and the CTAF scenarios. The calculated value for the CTAF scenario was then deducted from the baseline scenario to calculate the average concentration change across each of the spatial regions used.

$NO_2$ was selected as the pollutant for analysis (as opposed to $PM_{2.5}$ which was also assessed in detail) as it was considered that given that the issues and impacts associated with $NO_2$ are more local to the source of emissions, it was considered that any distributional trends would be more significant (and hence more apparent) relative to those associated with $PM_{2.5}$.

Lower Super Output Areas (LSOAs) were used to define the spatial regions applied to the analysis. These spatial regions were selected as it was the highest spatial resolution that could be used alongside publicly

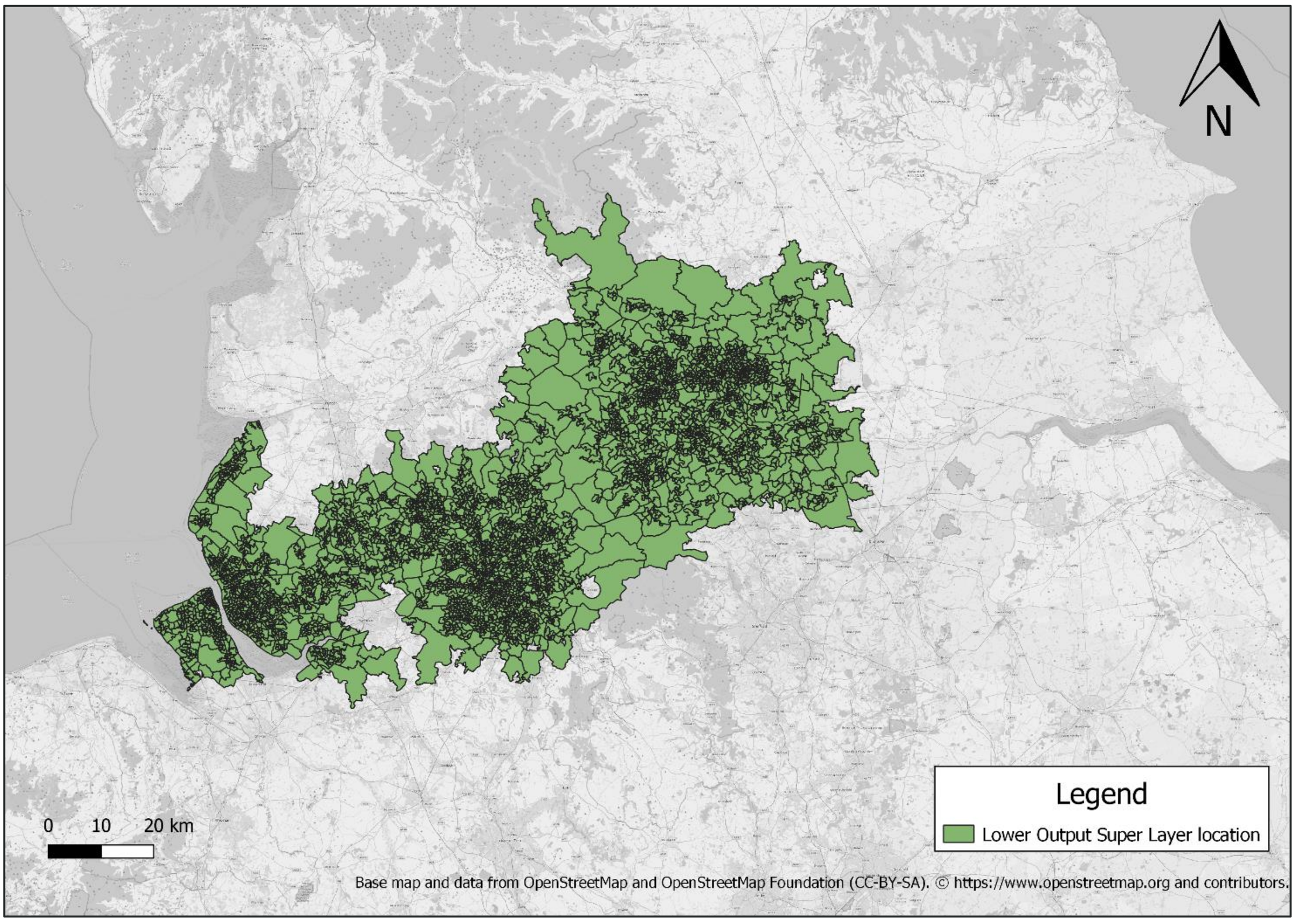
---

[58] https://www.health.org.uk/news-and-comment/news/major-study-outlines-wide-health-inequalities-in-england

[59] https://www.england.nhs.uk/about/equality/equality-hub/national-healthcare-inequalities-improvement-programme/what-are-healthcare-inequalities/

available demographic datasets. An example of the size and number of LSOAs used in this analysis is provided in Figure 2-2.

Figure 2-2 Visualisation of the 4176 LSOAs used to evaluate the distributional impacts across Liverpool, Manchester and the West Yorkshire domains



Base map and data from OpenStreetMap and OpenStreetMap Foundation (CC-BY-SA). © https://www.openstreetmap.org and contributors.

Demographic datasets which provided insights into the level of deprivation (a metric which represents the level of income and access to key services) of each LSOA and those which detailed the number of citizens within each age group were used to rank each LSOA against all other LSOAs within England. The ranking position for each assessment class (level of deprivation, proportion of children, and citizens over the age of 65), was used to assign each LSOA to a quintile class.

The analysis considered the mean change in $NO_2$ concentrations within LSOAs of each quintile class and then compared these changes to understand whether any quintile classes were likely to disproportionately benefit from the implementation of the CTAF scheme in comparison to the others (e.g., if areas with a low population of children experience a greater reduction in annual mean $NO_2$ concentrations overall compared to areas with a high proportion of children within its population).

# 3. RESULTS

This section provides the results of the CTAF scheme assessment and predicts its impacts in terms of air quality, economics, and human health.

## 3.1 AIR QUALITY MODELLING

### 3.1.1 CTAF uptake scenarios

Three CTAF uptake domains were developed to investigate the potential impacts of the CTAF scheme being applied across a smaller or larger number of cities in England:

- "Cost" uptake domain – estimates the impacts of applying the CTAF scheme in four local authorities: Birmingham, Leeds, Liverpool, and Nottingham. This scenario aims to estimate the impacts of applying the CTAF scheme as costed in A+LUK's "Putting the brakes on toxic air" report[60] (Appendix 3 – Policy costing methodology).
- "Detailed model" domain – estimates the impacts of applying the CTAF scheme in 28 local authorities: those within Greater Manchester, Liverpool City Region, West Midlands, and West Yorkshire. A full list of these local authorities is provided in Appendix 2 of this report.
- "England-wide" domain – estimates the impacts of applying the CTAF scheme in 89 local authorities: those within the 'Detailed regions' uptake scenario, plus any others that were exceeding the annual mean $NO_2$ standard in 2019, according to Defra data[61]. A full list of these local authorities is provided in Appendix 2 of this report.

### 3.1.2 Change in annual emissions

Table 3-1 provides a summary of the reduction in total annual emissions (in tonnes) of NOx, $PM_{10}$, $PM_{2.5}$, and $CO_2$ from the road transport sector as a result of the CTAF being applied across the "Cost", "Detailed model", and "England-wide" domains. The reduction in emissions is the difference between the total emissions from road transport from all the 1 km x 1 km grid squares within the relevant CTAF uptake domain, under the Baseline and CTAF scenarios.

The reduction in emissions increases with the size of the CTAF uptake domain, from the "Cost" domain (four local authorities) to the "Detailed model" domain (28 local authorities) and the "England-wide" domain (89 local authorities). Emissions of particulate matter from road transport are generally lower than emissions of NOx, and emissions of $CO_2$ tend to be much greater than emissions of NOx / PM. Therefore, the emissions reductions from PM are the lowest for each domain, followed by NOx, and the greatest reduction in emissions (in tonnes) is attributed to $CO_2$.

Table 3-1 Summary of total annual emissions reductions (in tonnes) of NOx, $PM_{10}$, $PM_{2.5}$, and $CO_2$, from the road transport sector, under the three CTAF uptake scenarios, compared to baseline emissions

| CTAF uptake domain | Annual emissions reduction (tonnes) | | | |
|---|---|---|---|---|
| | NOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Cost (4 LAs)** | 190 | 18.3 | 11.6 | 92,600 |
| **Detailed model (four city regions – 28 LAs)** | 734 | 67.9 | 43.3 | 357,000 |
| **England-wide (89 LAs)** | 1,670 | 158 | 99.9 | 802,000 |

Table 3-2 provides a summary of the reduction in total annual emissions, as a proportion of the baseline emissions from the road transport sector, as a result of the CTAF being applied across the "Cost", "Detailed model", and "England-wide" domains.

---

[60] https://www.asthmaandlung.org.uk/putting-brakes-toxic-air

[61] Air Pollution in the UK 2019, Compliance Assessment Summary, Defra, September 2020. https://uk-air.defra.gov.uk/library/annualreport/assets/documents/annualreport/air_pollution_uk_2019_Compliance_Assessment_Summary_Issue1.pdf

The percentage reduction in emissions across all three CTAF uptake domains were broadly similar; this was expected as the scaling factors applied to the baseline emissions maps were similar between the detailed model regions, and an average of those scaling factors was applied to any local authority within the CTAF uptake domain that was outside of those regions. However, it can be seen that there are some differences between pollutants; the percentage reduction in emissions from NOx is the smallest, as the scaling factors were closer to 1 (between 0.972-0.985) meaning fewer emissions were removed. Greater reductions in emissions were seen for $CO_2$ (slightly smaller scaling factors, between 0.967-0.984). The scaling factors for $PM_{10}$ and $PM_{2.5}$ were very similar, but the greatest percentage reductions in emissions are attributed to $PM_{10}$ (with the smallest scaling factors, between 0.966-0.982).

Table 3-2 Summary of total annual emissions reductions (%) of NOx, $PM_{10}$, $PM_{2.5}$, and $CO_2$, from the road transport sector, under the three CTAF uptake scenarios, compared to baseline emissions

| CTAF uptake domain | Annual emissions reduction (%) | | | |
|---|---|---|---|---|
| | NOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Cost (4 LAs)** | 2.22% | 2.68% | 2.67% | 2.60% |
| **Detailed model (four city regions – 28 LAs)** | 2.21% | 2.72% | 2.69% | 2.64% |
| **England-wide (89 LAs)** | 2.20% | 2.73% | 2.70% | 2.65% |

The main emissions modelling using the NAEI 1 km x 1 km emissions maps accounted for road transport emissions changes for the 1 km grid squares within the relevant local authorities' boundaries; this can be considered to be the 'city emissions' removed as a result of CTAF implementation in those local authorities. However, there are also likely to be additional wider impacts of the CTAF from removal of vehicles travelling outside the local authority boundaries, i.e., 'all emissions' removed as a result of the CTAF. Additional emissions calculations were carried out to attempt to estimate the potential wider impact of the CTAF on emissions (i.e., from vehicles travelling outside the local authority boundaries).

These calculations were carried out by modelling the emissions of a specified number of CAZ non-compliant petrol and diesel cars[62] travelling an assumed 13,000 km per annum[63]. The number of vehicles taking part in the scheme for each CTAF uptake scenario was determined using the methodology applied in A+LUK's "Putting the brakes on toxic air" report (Appendix 3) to determine the cost of the CTAF. The emissions from the specified number of vehicles and their associated vehicle kilometres (vkm) for the "Cost", "Detailed model", and "England-wide" uptake scenarios were assumed to be completely removed as a result of the CTAF implementation.

Table 3-3 presents the results of the emissions calculations for the "Cost", "Detailed model", and "England-wide" uptake scenarios for this approach. For the "Cost" and "Detailed model" uptake scenarios, the reduction in road transport emissions of NOx, $PM_{10}$ and $PM_{2.5}$ are approximately six times greater considering 'all emissions' than when 'city emissions' are considered. For $CO_2$, this is higher at around seven to eight times greater. For the "England-wide" uptake scenario, the reduction in road transport emissions of NOx, $PM_{10}$ and $PM_{2.5}$ are approximately eight times greater and for $CO_2$ the reduction is around nine times greater, considering 'all emissions' than when 'city emissions' are considered.

Table 3-3. Summary of total annual emissions reductions (in tonnes) of NOx, $PM_{10}$, $PM_{2.5}$, and $CO_2$, from removal of emissions from a specified number of CAZ non-compliant cars as a result of the CTAF, under the three CTAF uptake scenarios

| Scenario | No. cars assumed | Annual emissions reduction (tonnes) | | | |
|---|---|---|---|---|---|
| | | NOx | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ |
| **Cost (4 LAs)** | 259,000 | 1,220 | 111 | 67.1 | 608,000 |
| **Detailed model (four city regions – 28 LAs)** | 1,190,000 | 5,580 | 509 | 307 | 2,780,000 |
| **England-wide (89 LAs)** | 3,020,000 | 14,200 | 1,290 | 782 | 7,070,000 |

---

[62] The proportion of petrol and diesel cars was taken as the national average for 2019, from NAEI data. To model CAZ non-compliant vehicles only, the non-compliant Euro standards from the default NAEI Euro standards for petrol/diesel cars for 2019 were normalised and applied in the EFT.

[63] Based on Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished), and as deployed in multiple Clean Air Zone feasibility studies undertaken by Ricardo

### 3.1.3 Change in annual mean concentrations

#### *3.1.3.1 Annual mean concentration maps*

The following maps show the difference in modelled $NO_2$ and $PM_{2.5}$ annual mean concentrations across the four detailed model domains (Greater Manchester, Liverpool City Region, West Midlands, and West Yorkshire) for the 2019 Baseline and CTAF scenarios.

Figure 3-1 Annual mean $NO_2$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across Greater Manchester

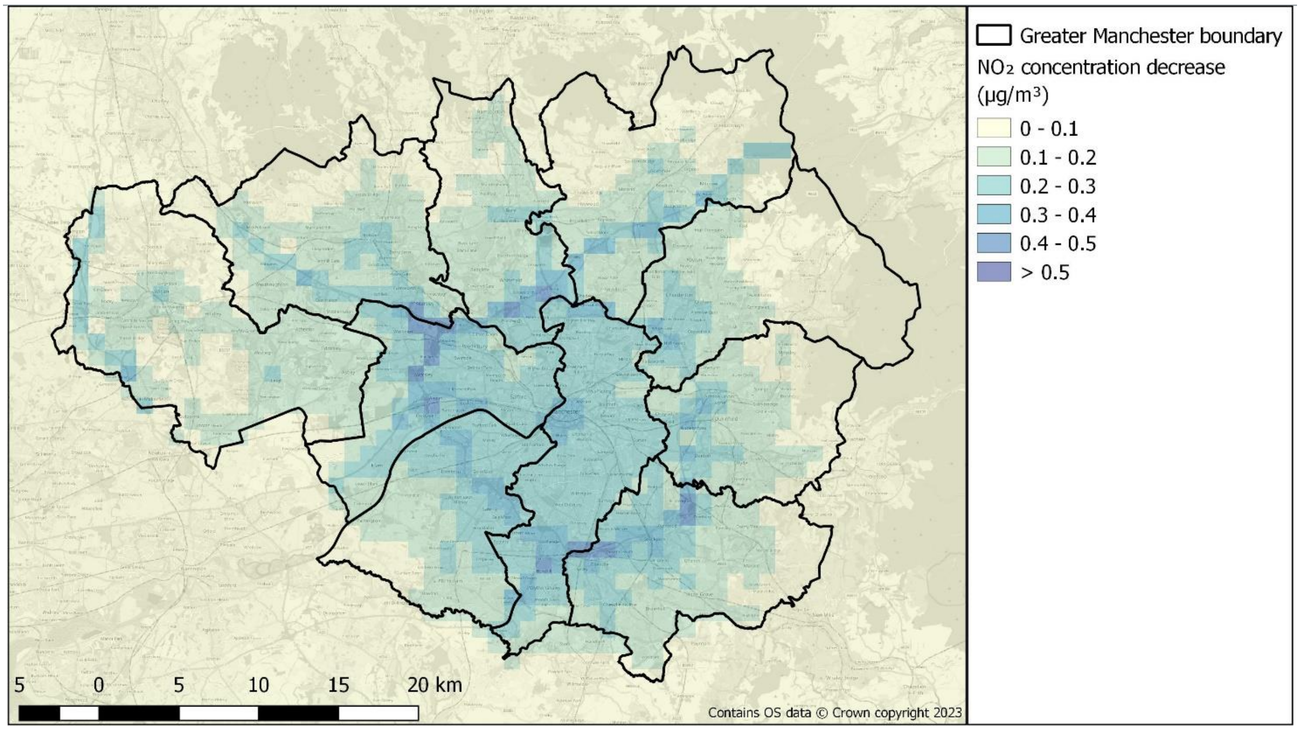


Figure 3-2 Annual mean $NO_2$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across Liverpool City Region

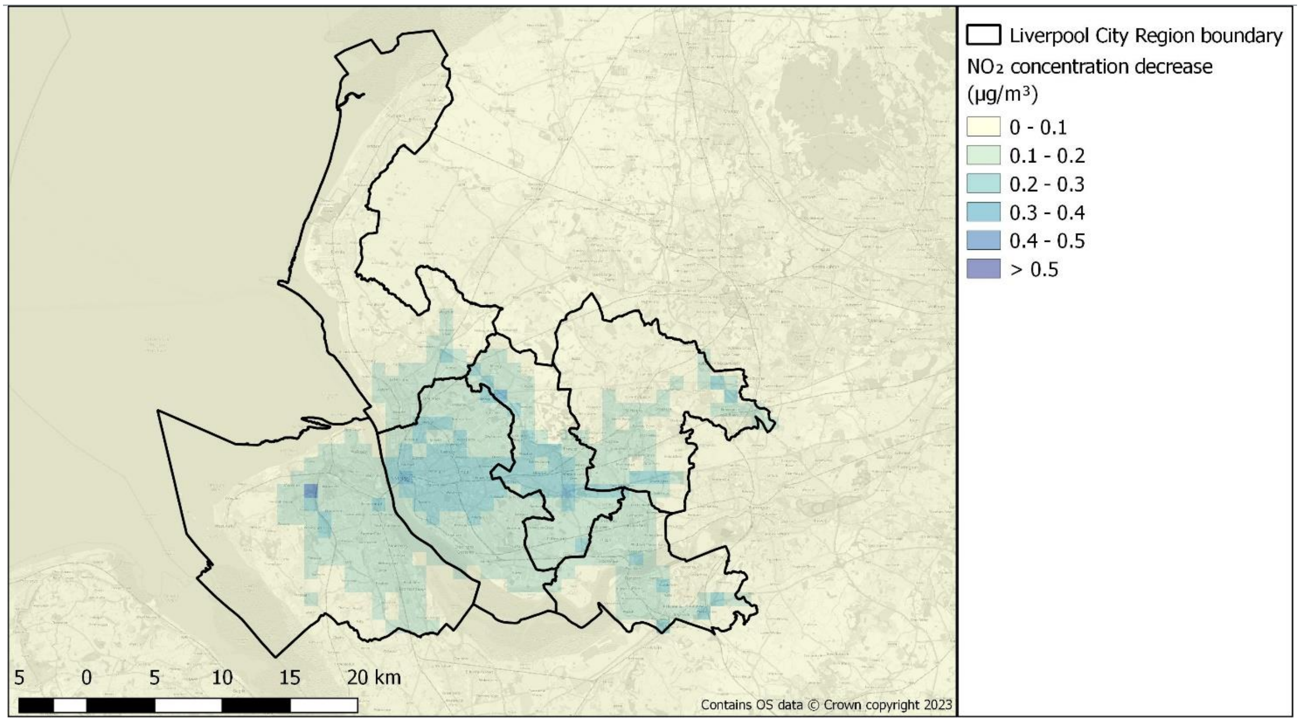


Figure 3-3 Annual mean $NO_2$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across the West Midlands

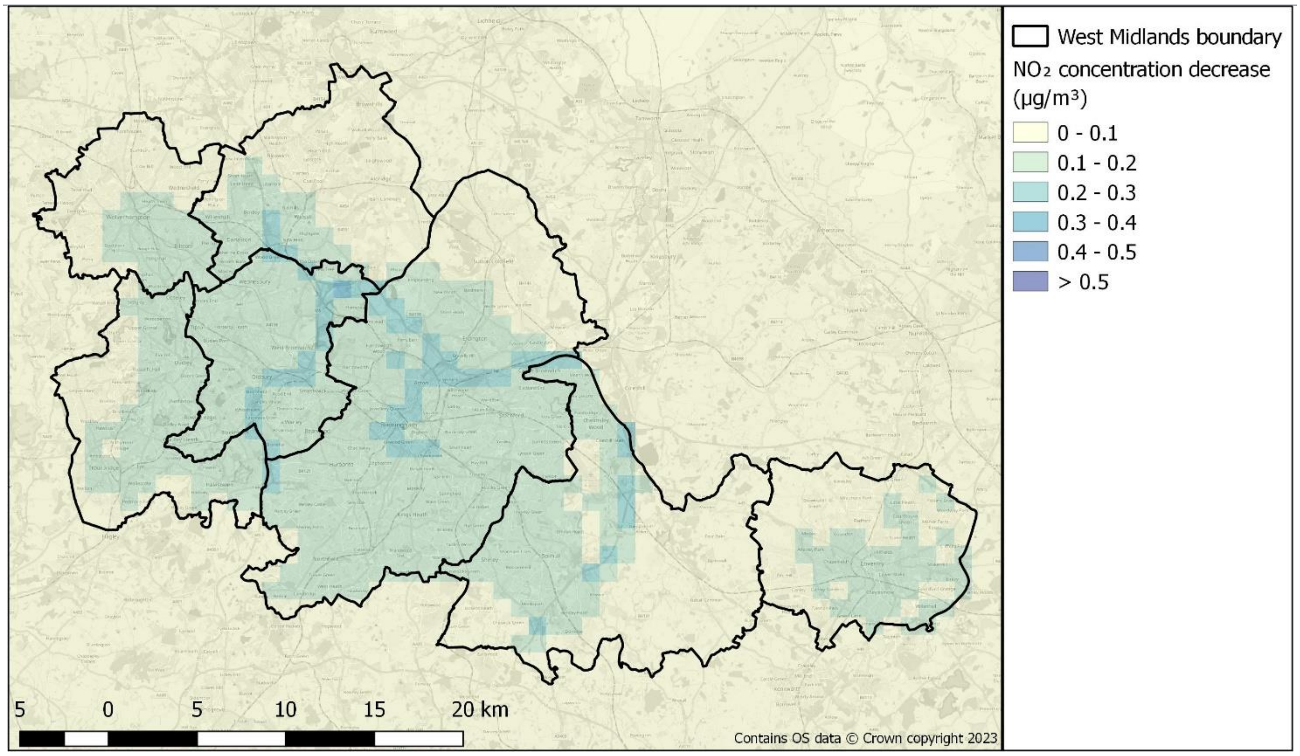


Figure 3-4 Annual mean $NO_2$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across West Yorkshire

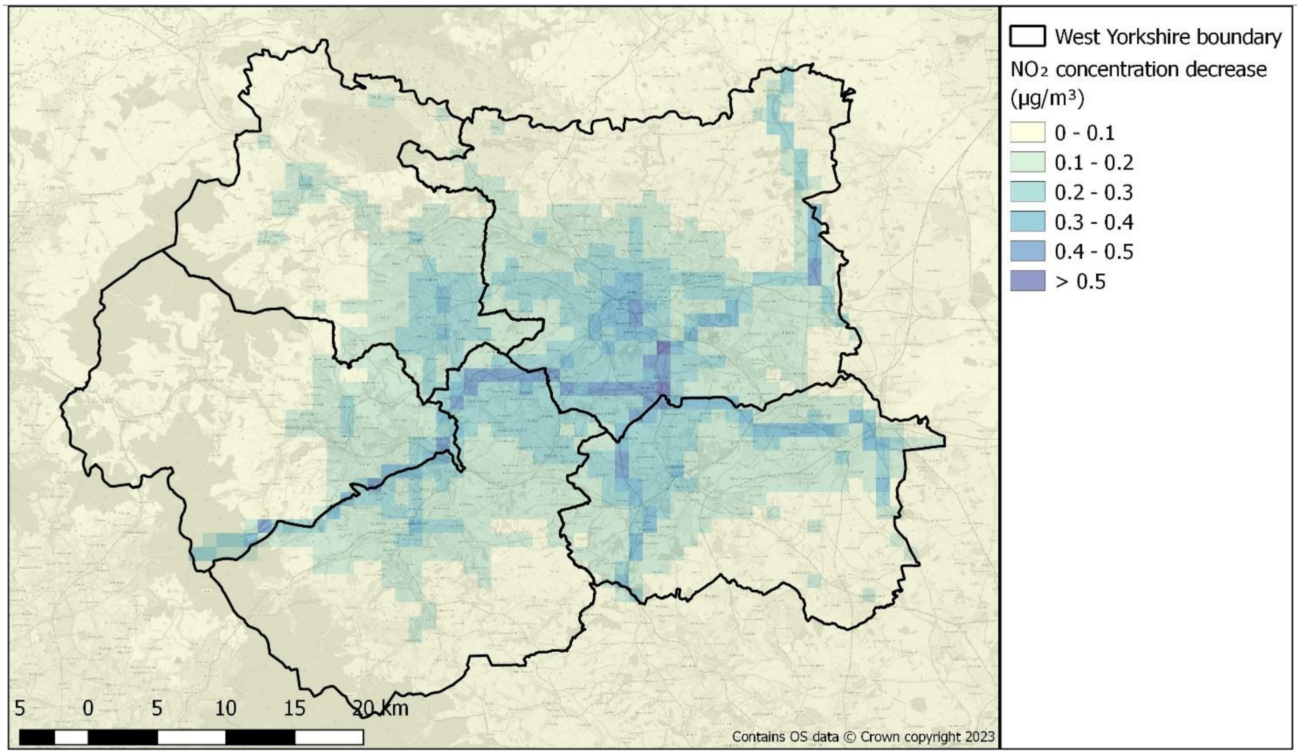


Figure 3-5 Annual mean $PM_{2.5}$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across Greater Manchester

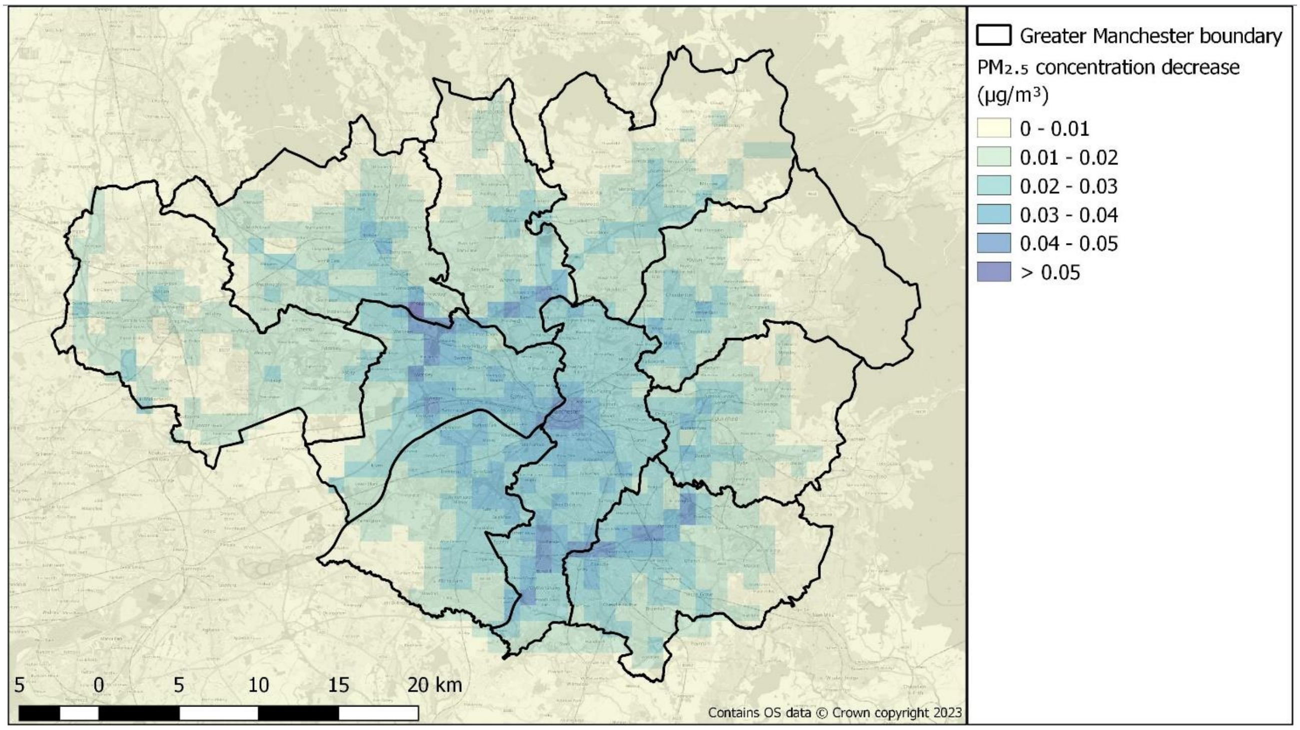


Figure 3-6 Annual mean $PM_{2.5}$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across Liverpool City Region

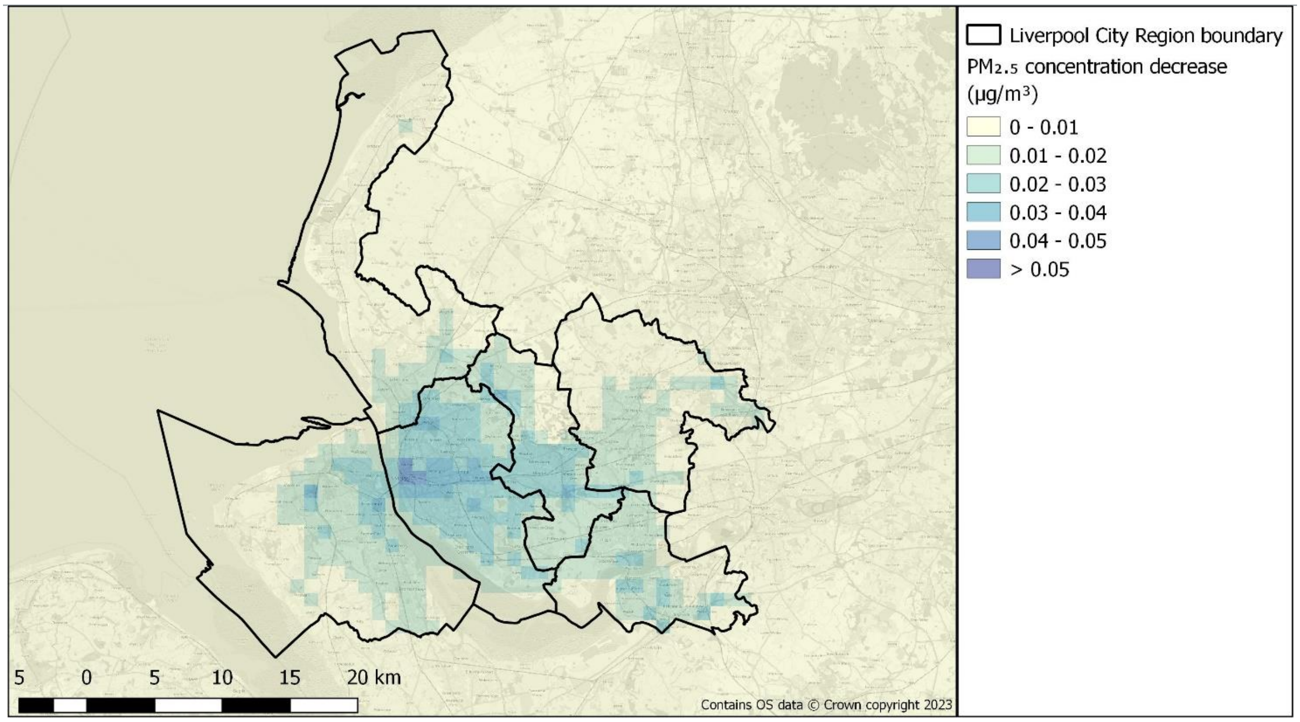


Figure 3-7 Annual mean $PM_{2.5}$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across the West Midlands

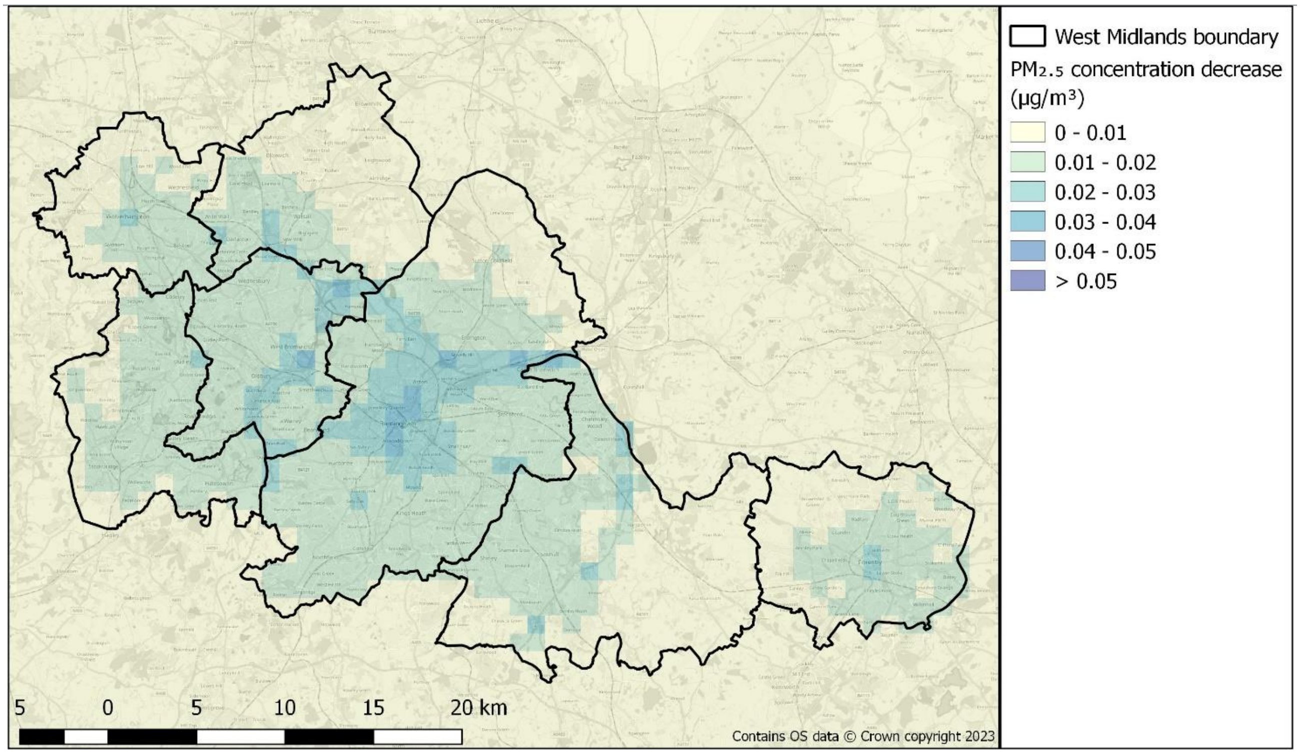
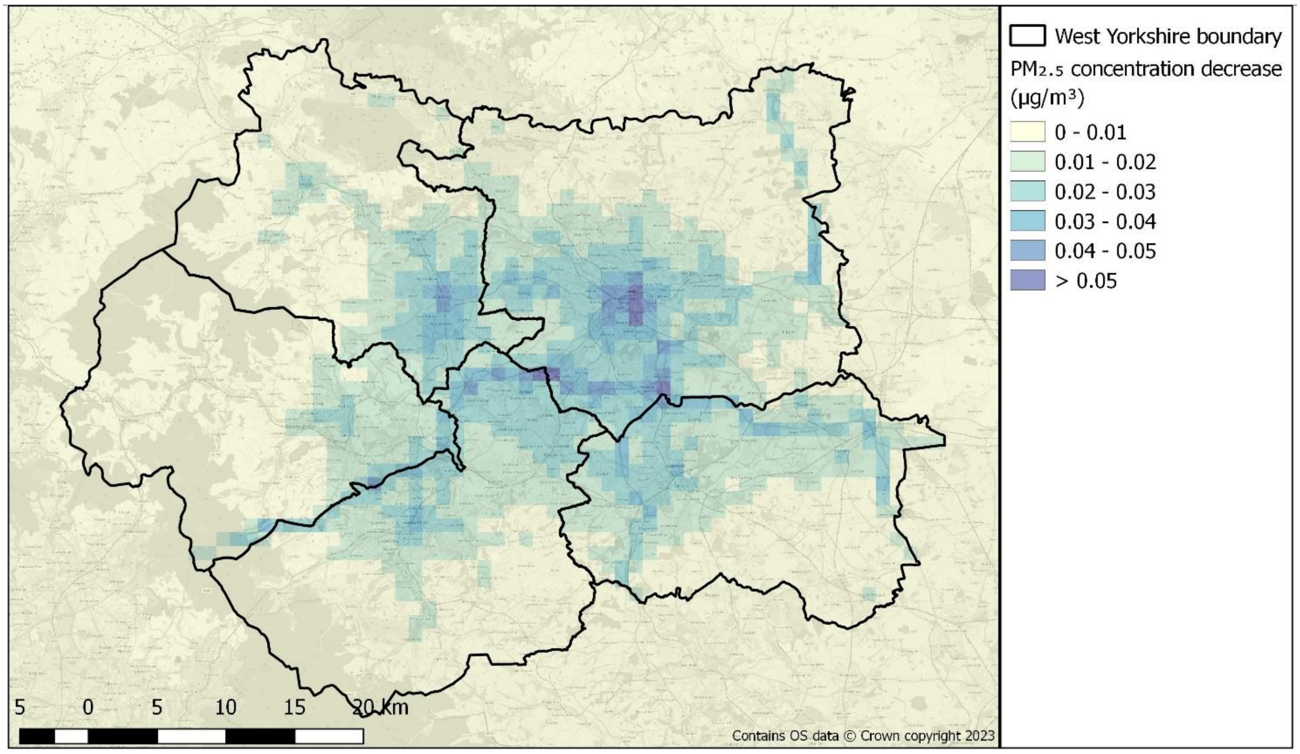


Figure 3-8 Annual mean $PM_{2.5}$ concentration decrease (µg/m$^3$) as a result of the CTAF scheme across West Yorkshire



The following tables show the difference in modelled $NO_2$, $PM_{2.5}$ and $PM_{10}$ annual mean concentrations averaged across the four model domains for the 2019 Baseline and CTAF scenarios. The decrease in pollutant concentrations is presented as total concentration (µg/m$^3$) and percentage of the Baseline concentration.

Table 3-4 Difference in modelled $NO_2$ annual mean concentrations averaged across each of the four model domains for the 2019 Baseline and CTAF scenarios

| Region | Baseline $NO_2$ concentration (µg/m$^3$) | CTAF $NO_2$ concentration (µg/m$^3$) | Difference (µg/m$^3$) | Difference (% of Baseline) |
|---|---|---|---|---|
| Greater Manchester | 16.841 | 16.685 | 0.156 | 0.928% |
| Liverpool City Region | 13.302 | 13.199 | 0.102 | 0.770% |
| West Midlands | 19.603 | 19.489 | 0.114 | 0.581% |
| West Yorkshire | 12.447 | 12.325 | 0.122 | 0.980% |

The largest average change in absolute modelled annual mean $NO_2$ concentrations occurs in Greater Manchester (0.156 µg/m$^3$). The largest percentage change from the Baseline occurs in West Yorkshire (0.980%).

Table 3-5 Difference in modelled $PM_{2.5}$ annual mean concentrations averaged across each of the four model domains for the 2019 Baseline and CTAF scenarios

| Region | Baseline $PM_{2.5}$ concentration (µg/m$^3$) | CTAF $PM_{2.5}$ concentration (µg/m$^3$) | Difference (µg/m$^3$) | Difference (% of Baseline) |
|---|---|---|---|---|
| Greater Manchester | 7.987 | 7.971 | 0.0162 | 0.202% |
| Liverpool City Region | 7.162 | 7.151 | 0.0113 | 0.158% |
| West Midlands | 9.988 | 9.975 | 0.0127 | 0.127% |
| West Yorkshire | 7.558 | 7.546 | 0.0118 | 0.156% |

The largest average change in absolute modelled annual mean $PM_{2.5}$ concentrations also occurs in Greater Manchester (0.0162 µg/m$^3$). The largest percentage change from the Baseline occurs in the Liverpool City Region (0.158%).

Table 3-6 Difference in modelled $PM_{10}$ annual mean concentrations averaged across each of the four model domains for the 2019 Baseline and CTAF scenarios

| Region | Baseline $PM_{10}$ concentration (µg/m$^3$) | CTAF $PM_{10}$ concentration (µg/m$^3$) | Difference (µg/m$^3$) | Difference (% of Baseline) |
|---|---|---|---|---|
| Greater Manchester | 11.996 | 11.970 | 0.0255 | 0.213% |
| Liverpool City Region | 10.803 | 10.785 | 0.0179 | 0.166% |
| West Midlands | 14.961 | 14.941 | 0.0199 | 0.133% |
| West Yorkshire | 11.648 | 11.630 | 0.0183 | 0.157% |

The largest average change in absolute modelled annual mean $PM_{10}$ concentrations again occurs in Greater Manchester (0.0255 µg/m$^3$). The largest percentage change from the Baseline also occurs in Greater Manchester (0.213%).

While the results in Table 3-4, Table 3-5 and Table 3-6 show the average change in annual mean concentrations across the entirety of each region, the impacts of the CTAF are different in each 1 km grid square. The greatest modelled improvements in pollution (in terms of µg/m$^3$) as a result of the CTAF implementation are seen at the following locations:

- Greater Manchester: The strongest improvements in air quality occur in the same 1 km grid square for each pollutant, with centre point 374500,404500 (reduction of 0.49 µg/m$^3$ $NO_2$ (1.2% of the baseline concentration), 0.06 µg/m$^3$ $PM_{2.5}$ (0.5%) and 0.09 µg/m$^3$ $PM_{10}$ (0.6%)). This grid square is located in Bolton, adjacent to the M61 / A666(M) and contains Kearsley Park and parts of Blackreach Country Park, as well as Kearsley Academy and Woodbridge College.
- Liverpool City Region: The greatest improvements in $NO_2$ are estimated to occur in the Wirral within the grid square with centre point 327500,389500, at Junction 2 of the M53 (reduction of 0.40 µg/m$^3$ $NO_2$ (1.4%)). This grid square includes Sandbrook Primary School and Fender Skatepark, as well as

residential and green areas. The greatest improvements in $PM_{10}$ and $PM_{2.5}$ are predicted to occur within the centre of Liverpool itself within the grid square with centre point 334500,390500 (reduction of 0.05 $\mu g/m^3$ $PM_{2.5}$ (0.5%) and 0.07 $\mu g/m^3$ $PM_{10}$ (0.5%)). This grid square contains the Mishra Surgical Center, St. James Park, and numerous shops, restaurants, and hotels.

- West Midlands: The greatest improvements in $NO_2$ are estimated to occur in Sandwell at the grid square with centre point 403500,294500, near Junction 8 of the M6 (reduction of 0.30 $\mu g/m^3$ $NO_2$ (0.8%)). This grid square includes Grove Vale Primary School, as well as much of Red House Park, and a residential area. The greatest improvements in $PM_{10}$ and $PM_{2.5}$ are predicted to occur within Birmingham at the M6 / A38(M) interchange at the grid square with centre point 409500,290500 (reduction of 0.04 $\mu g/m^3$ $PM_{2.5}$ (0.3%) and 0.06 $\mu g/m^3$ $PM_{10}$ (0.3%)). This grid square contains Slade Primary School, Aston Reservoir, other green spaces and residential houses.
- West Yorkshire: The strongest improvements in air quality occur in the same 1 km grid square for each pollutant, with centre point 432500,426500 (reduction of 0.60 $\mu g/m^3$ $NO_2$ (1.6%), 0.07 $\mu g/m^3$ $PM_{2.5}$ (0.6%) and 0.10 $\mu g/m^3$ $PM_{10}$ (0.6%)). This grid square is located in Leeds, at the M1 / M62 interchange and contains Robin Hood Primary School, The Rodillian Academy, green spaces and a residential area.

#### *3.1.3.2 Results summary*

An initial comparison of the 2019 Baseline and CTAF scenario concentration maps shows the impact of the scheme in reducing pollutant concentrations across the four regions. The relative decrease between concentrations for each of the four regions scales with the CTAF scaling factors developed in Section 2.1.2. The largest decreases in concentrations for each region are observed in the areas with the largest proportion of road transport emissions. The decrease in $NO_2$ concentrations is more significant than for PM, as road transport emissions make up a larger proportion of total NOx emissions than total PM emissions.

## 3.2 HEALTH IMPACT ASSESSMENT

### 3.2.1 Health impact assessment

To assess the impacts of the proposal on human health via changes in exposure to air pollution, we have undertaken a quantitative assessment following two different approaches:

- For the detailed modelling domain, we have deployed the Impact Pathway Approach (IPA).
- For the cost and England-wide domains, we have used damage costs. Here we also split the estimation between the impacts associated with a change in emissions within urban centres (or ‘city emissions’) and impacts associated with the overall change in emissions associated with the removal of these vehicles from the roads (or ‘all emissions’), as there will be impacts both within the urban centres where potential CAZs are located, but also outside of these zones.

Health impacts have been quantified both in terms of a change in health outcome, but also as a monetised economic impact. Health outcomes in turn are also expressed in two ways, as a change in health outcome (e.g. number of cases) and health metric (e.g. Quality adjusted life year, or QALY-loss). The results of the analysis are presented in the following tables.

In the *detailed modelling domain*, the changes in air pollution associated with the CTAF are anticipated to deliver:

- A range of human health benefits. This includes: reducing the number of life years lost due to air pollution exposure by 223 life years lost (LYLs) per year – presenting this in another way, CTAF will reduce the number of deaths across the four cities by around 22 each year.

  CTAF is also estimated to reduce the number of hospital admissions for respiratory conditions by around 22 per annum across the four cities.
- A total economic benefit of £21.7m per year across the four urban areas included in the analysis (Greater Manchester, Liverpool City Region, West Midlands, West Yorkshire). The most significant contributor to this is the impact on mortality, of £11.3m per year. This estimation primarily captures the value that individuals place on living longer and in good health, so directly captures the benefits of CTAF for improving quality of life and life satisfaction.

In the *cost and England-wide modelling domain*s, the changes in air pollution associated with the CTAF are anticipated to deliver:

- A smaller total economic benefit of £21.8m per year in the *cost modelling domain* (of which £5.1m per year is associated with emissions reductions in cities – so called ‘city emissions’), rising to £254m per year if CTAF is rolled out more widely across *England* (of which £50.2m per year is associated with reduction in emissions in cities).
- Reducing the mortality impacts of air pollutant exposure in the *cost and England-wide domain* by 226 LYLs and 2,637 LYLs respectively – expressed another way, the CTAF will reduce deaths by 22 and 260 across the *cost and England-wide domains* per annum.
- CTAF is also estimated to reduce the number of hospital admissions for respiratory conditions by around 15 and 174 per annum across the *cost and England-wide domains* respectively.

By way of comparison:

- An assessment of the proposed London-wide ULEZ[64] suggested that scheme could reduce LYL associated with air pollution exposure by 59 LYLs each year, reduce respiratory hospital admissions by 1.4 per year and deliver a total economic benefit of £13.0m per year (2020 prices) across Greater London.
- An earlier assessment of a proposed London ULEZ expansion predicted impacts of a reduction in LYL of 123 per year London-wide, and a reduction in respiratory hospital admissions of 2 per year[65].
- A health impact assessment assessing potential CAZs in Derby predicted an overall gain of 5.6 life years under the preferred scheme, relative to a benefit of 28.8 life years gained per year under a benchmark CAZ D[66].

---

[64] See Appendix 1 here: https://ehq-production-europe.s3.eu-west-1.amazonaws.com/77df043331c0216ccc8d4b941bd8166ade7f1f90/original/1669211507/d98e4423b653b1d331ebffd20480e8d7_appendix-c-integrated-impact-assessment-scheme.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA4KKNQAKICO37GBEP%2F20230811%2Feu-west-1%2Fs3%2Faws4_request&X-Amz-Date=20230811T142231Z&X-Amz-Expires=300&X-Amz-SignedHeaders=host&X-Amz-Signature=c6b75e2d96b56719d67aeeda6941139642fd416bc29830dd3cc4511e2917aaf2

[65] See Appendix 2 here: https://cleanair.london/app/uploads/CAL-294-ULEZ-HIA_Final_ULEZ-consultation_Reduced-size.pdf

[66] https://www.derby.gov.uk/media/derbycitycouncil/contentassets/documents/transport/airqualityplan/finalbusinesscase/Derby-Full-Business-Case-26-March-2019.pdf

Table 3-7 Health and economic benefits of CTAF in detailed modelling domain (IPA)

| | Mortality associated with long-term exposure | Respiratory hospital admission | IHD | Stroke | Lung Cancer | Asthma (Small Children) | Asthma (Older Children) | Productivity | Building soiling | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| **Monetised impact (£2022 prices)** | | | | | | | | | | |
| *Units* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* |
| Greater Manchester | 3,940,000 | 75,300 | 187,000 | 326,000 | 25,000 | 1,560,000 | 1,290,000 | 115,000 | 45,000 | 7,550,000 |
| Liverpool City Region | 1,690,000 | 31,400 | 83,600 | 146,000 | 11,200 | 642,000 | 556,000 | 51,200 | 20,100 | 3,230,000 |
| West Midlands | 2,700,000 | 50,800 | 132,000 | 230,000 | 17,600 | 1,040,000 | 888,000 | 80,900 | 31,700 | 5,180,000 |
| West Yorkshire | 2,980,000 | 57,700 | 139,000 | 241,000 | 18,500 | 1,200,000 | 969,000 | 85,000 | 33,300 | 5,720,000 |
| **TOTAL** | **11,300,000** | **215,000** | **542,000** | **943,000** | **72,200** | **4,450,000** | **3,700,000** | **332,000** | **130,000** | **21,700,000** |
| **Health impacts – metric** | | | | | | | | | | |
| *Units* | *LYL* | *HA* | *QALYLoss* | *QALYLoss* | *QALYLoss* | *QALYLoss* | *QALYLoss* | - | - | - |
| Greater Manchester | 77.8 | 7.7 | 2.6 | 4.5 | 0.3 | 21.6 | 17.8 | - | - | - |
| Liverpool City Region | 33.4 | 3.2 | 1.2 | 2.0 | 0.2 | 8.9 | 7.7 | - | - | - |
| West Midlands | 53.4 | 5.2 | 1.8 | 3.2 | 0.2 | 14.5 | 12.3 | - | - | - |
| West Yorkshire | 58.8 | 5.9 | 1.9 | 3.4 | 0.3 | 16.7 | 13.4 | - | - | - |
| **TOTAL** | **223.0** | **22.0** | **7.5** | **13.1** | **1.0** | **61.7** | **51.3** | - | - | - |
| **Health impacts - cases** | | | | | | | | | | |
| *Units* | *#deaths* | *#HA* | *#cases* | *#cases* | *#cases* | *#cases* | *#cases* | - | - | - |
| Greater Manchester | 7.7 | 7.7 | 0.7 | 0.9 | 0.4 | 2.8 | 2.3 | - | - | - |
| Liverpool City Region | 3.3 | 3.2 | 0.3 | 0.4 | 0.2 | 1.1 | 1.0 | - | - | - |
| West Midlands | 5.3 | 5.2 | 0.5 | 0.6 | 0.3 | 1.9 | 1.6 | - | - | - |
| West Yorkshire | 5.8 | 5.9 | 0.6 | 0.7 | 0.3 | 2.1 | 1.7 | - | - | - |
| **TOTAL** | **22.0** | **22.0** | **2.2** | **2.6** | **1.3** | **7.9** | **6.5** | - | - | - |

Notes: ‘LYL’ = life year lost; ‘HA’ = hospital admission; ‘QALY’ = Quality adjusted life year

Table 3-8 Health and economic benefits of CTAF in cost and England-wide domain (Damage costs)

| Domain | Mortality associated with long-term exposure | Respiratory hospital admission | IHD | Stroke | Lung Cancer | Asthma (all children) | Asthma (Small Children) | Asthma (Older Children) | Productivity | Building soiling | Ecosystems | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monetised impact (£2022 prices)** | | | | | | | | | | | | |
| *Units* | *£* | *£* | *£* | *£* | *£* | | *£* | *£* | *£* | *£* | *£* | *£* |
| Cost (4 LAs) – All emissions | 11,400,000 | 145,000 | 533,000 | 929,000 | 71,200 | 2,150,000 | 4,620,000 | 1,570,000 | 250,000 | 62,100 | 21,600 | 21,800,000 |
| *Cost (4 LAs) – City emissions* | *2,640,000* | *41,000* | *117,000* | *203,000* | *15,600* | *472,000* | *1,120,000* | *380,000* | *59,600* | *21,800* | *3,370* | *5,070,000* |
| England-wide (89 LAs) – all emissions | 133,000,000 | 1,700,000 | 6,210,000 | 10,800,000 | 828,000 | 25,000,000 | 54,000,000 | 18,400,000 | 2,910,000 | 2,466,000 | 252,000 | 254,000,000 |
| *England-wide (89 LAs) – city emissions* | *26,100,000* | *430,000* | *1,100,000* | *1,920,000* | *147,000* | *4,460,000* | *11,400,000* | *3,890,000* | *571,000* | *209,000* | *29,700* | *50,200,000* |
| **Health impacts – metric** | | | | | | | | | | | | |
| *Units* | *LYL* | *HA* | *QALYLoss* | *QALYLoss* | *QALYLoss* | *QALYLoss* | *QALYLoss* | *QALYLoss* | - | - | - | - |
| Cost (4 LAs) – All emissions | 226.00 | 14.90 | 7.40 | 12.90 | 0.99 | 29.90 | 64.10 | 21.80 | - | - | - | - |
| *Cost (4 LAs) – City emissions* | *52.22* | *4.19* | *1.62* | *2.82* | *0.22* | *6.55* | *15.50* | *5.27* | - | - | - | - |
| England-wide (89 LAs) – all emissions | 2,640.00 | 174.00 | 86.10 | 150.00 | 11.50 | 348.00 | 749.00 | 255.00 | - | - | - | - |
| *England-wide (89 LAs) – city emissions* | *515.52* | *43.93* | *15.33* | *2.82* | *0.22* | *6.55* | *15.50* | *5.27* | - | - | - | - |
| **Health impacts - cases** | | | | | | | | | | | | |
| *Units* | *Deaths* | *HA* | *#cases* | *#cases* | *#cases* | *#cases* | *#cases* | *#cases* | - | - | - | - |
| Cost (4 LAs) – All emissions | 22.30 | 14.90 | 2.13 | 2.60 | 1.26 | 3.81 | 8.17 | 2.78 | - | - | - | - |
| *Cost (4 LAs) – City emissions* | *5.15* | *4.19* | *0.47* | *0.57* | *0.28* | *0.83* | *1.98* | *0.67* | - | - | - | - |
| England-wide (89 LAs) – all emissions | 260.00 | 174.00 | 24.80 | 30.30 | 14.60 | 44.30 | 95.50 | 32.50 | - | - | - | - |
| *England-wide (89 LAs) – city emissions* | *50.88* | *43.93* | *4.40* | *0.57* | *0.28* | *0.83* | *1.98* | *0.67* | - | - | - | - |

### 3.2.2 Productivity

For this study, we produced three estimates of productivity effects for consideration:

1. **Damage cost pathways:** Splitting out the productivity pathways in the Defra damage costs.
2. **Complete bottom-up**: In addition to the pathways captured in the damage costs, we have also added on all other pathways considered in Ricardo's original productivity study for Defra to facilitate a more comprehensive assessment.
3. **Top-down estimation:** deploying the approach adopted by the EU (but not commonly applied in the UK) to estimate overall productivity effects based on recent OECD work (Dechezleprêtre, Rivers, & Stadler, 2019).

The results for points 1 and 2 above are presented in the following tables.

Across the *detailed modelling domain* (considering the four urban areas of Greater Manchester, Liverpool City Region, West Midlands and West Yorkshire), CTAF is estimated to deliver:

- a productivity benefit of £340,000 per annum capturing only those pathways included in the Defra damage costs, rising to £948,000 when capturing a broader range of pathways.
- These effects capture a range of underlying impacts on human health which cascade into an impact on productivity, including a reduction in: 16 lost working years (for each year of reduced air pollutant exposure), 2,300 avoided work days lost, 3,900 care hours and 2,900 volunteering hours.
- The majority of these effects would also be reflected directly in a change in GDP, with around £328,000 and £844,000 of the respective estimated effects coming through formal employment.

Across the *cost modelling domain*, CTAF is estimated to deliver:

- A total economic productivity benefit of £256,000 rising to £725,000 where a greater range of pathways are included (or £246,000 to £631,000 in terms of an impact on GDP).
- Each year, avoiding the loss of: 12 work years lost, 1,760 work days, 2,900 care hours and 2,200 volunteer hours.

Across the *England-wide modelling domain*, CTAF is estimated to deliver:

- A total economic productivity benefit of £3.0m rising to £8.4m where a greater range of pathways are included (or £2.9m to £7.3m in terms of an impact on GDP).
- Each year, avoiding the loss of: 136 work years, 20,400 work days, 34,000 care hours, and 25,000 volunteer hours.

Table 3-9 Productivity impacts of CTAF in detailed modelling (IPA) domain

| Domain | Mortality associated with long-term exposure (all employed persons) | Chronic bronchitis (all employed persons) | Work days lost (all employed persons) | School days lost (all employed persons) | (minor) Restricted Activity Days (all employed persons) | Mortality associated with long-term exposure (carers) | Work days lost (carers) | Mortality associated with long-term exposure (volunteers) | Work days lost (volunteers) | TOTAL | TOTAL – DC* | *TOTAL (GDP)* | *TOTAL – DC (GDP)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monetised impact (£2022 prices)** | | | | | | | | | | | | | |
| *Units* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* |
| Greater Manchester | 133,000 | 39,400 | 84,200 | 5,980 | 29,100 | 26,200 | 3,490 | 13,100 | 913 | 335,000 | 118,000 | *291,680* | *113,300* |
| Liverpool City Region | 59,500 | 17,600 | 37,600 | 2,670 | 13,000 | 11,700 | 1,560 | 5,840 | 408 | 145,000 | 52,600 | *130,370* | *50,600* |
| West Midlands | 93,900 | 27,800 | 59,400 | 4,220 | 20,500 | 18,500 | 2,460 | 9,210 | 644 | 228,000 | 83,000 | *205,820* | *79,900* |
| West Yorkshire | 98,600 | 29,200 | 62,400 | 4,430 | 21,500 | 19,400 | 2,580 | 9,680 | 677 | 240,000 | 87,200 | *216,130* | *83,900* |
| **TOTAL** | **385,000** | **114,000** | **244,000** | **17,300** | **84,100** | **75,700** | **10,100** | **37,800** | **2,640** | **948,000** | **340,000** | ***844,400*** | ***328,100*** |
| ***Productivity impacts - metric*** | | | | | | | | | | | | | |
| *Units* | *WYL* | *WYL* | *WDL* | *WDL* | *WDL* | *Care hours* | *Care hours* | *Volunteering hours* | *Volunteering hours* | - | - | - | - |
| Greater Manchester | 4.13 | 1.28 | 572 | 41 | 198 | 1,179 | 154 | 939 | 65 | - | - | - | - |
| Liverpool City Region | 1.84 | 0.57 | 256 | 18. | 88 | 527 | 69 | 419 | 29 | - | - | - | - |
| West Midlands | 2.91 | 0.91 | 404 | 29 | 139 | 831 | 109 | 662 | 46 | - | - | - | - |
| West Yorkshire | 3.06 | 0.95 | 424 | 30 | 146 | 874 | 114 | 696 | 48 | - | - | - | - |
| **TOTAL** | 11.94 | 3.71 | 1,656 | 118 | 571 | 3,410 | 447 | 2,716 | 187 | - | - | - | - |

Notes: *Pathways included in the damage costs are a subset of all pathways shown here. These are denoted by lighter blue in the header row.

Table 3-10 Productivity impacts of CTAF in core and England-wide (damage cost) domains

| **Domain** | **Mortality associated with long-term exposure (all employed persons)** | **Chronic bronchitis (all employed persons)** | **Work days lost (all employed persons)** | **School days lost (all employed persons)** | **(minor) Restricted Activity Days (all employed persons)** | **Mortality associated with long-term exposure (carers)** | **Work days lost (carers)** | **Mortality associated with long-term exposure (volunteers)** | **Work days lost (volunteers)** | **TOTAL – APPROACH 1** | ***TOTAL – APPROACH 1 – GDP ONLY*** | **TOTAL – APPROACH 2** | ***TOTAL – APPROACH 2 (GDP)*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monetised impact (£2022 prices)** | | | | | | | | | | | | | |
| *Units* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* | *£* |
| Cost (4 LAs) – All emissions | 289,000 | 83,000 | 183,000 | 12,600 | 63,100 | 56,800 | 7,570 | 28,400 | 1,980 | 256,000 | 246,100 | 725,000 | 630,700 |
| *Cost (4 LAs) – City emissions* | *69,100* | *20,000* | *43,700* | *3,030* | *15,100* | *13,600* | *1,810* | *6,780* | *474* | *61,100* | *58,800* | *173,000* | *150,930* |
| England-wide (89 LAs) – all emissions | 3,360,000 | 964,000 | 2,130,000 | 146,000 | 734,000 | 661,000 | 88,100 | 330,000 | 23,100 | 2,970,000 | 2,864,000 | 8,440,000 | 7,334,000 |
| *England-wide (89 LAs) – city emissions* | *661,000* | *190,000* | *418,000* | *28,900* | *144,000* | *130,000* | *17,300* | *64,900* | *4,530* | *585,000* | *562,000* | *1,660,000* | *1,441,900* |
| ***Productivity impacts - metric*** | | | | | | | | | | | | | |
| *Units* | *WYL* | *WYL* | *WDL* | *WDL* | *WDL* | *Care hours* | *Care hours* | *Volunteering hours* | *Volunteering hours* | - | - | - | - |
| Cost (4 LAs) – All emissions | 8.96 | 2.71 | 1,243 | 86 | 429 | 2,560 | 335 | 2,039 | 140 | - | - | - | - |
| *Cost (4 LAs) – City emissions* | *2.14* | *0.65* | *297* | *21* | *102* | *612* | *80* | *487* | *33* | - | - | - | - |
| England-wide (89 LAs) – all emissions | 104.26 | 31.45 | 14,458 | 995 | 4,988 | 29,774 | 3,902 | 23,716 | 1,630 | - | - | - | - |
| *England-wide (89 LAs) – city emissions* | *20.50* | *6.21* | *2,843* | *196* | *981* | *5,855* | *767* | *4,664* | *321* | - | - | - | - |

Notes: *Pathways included in the damage costs are a subset of all pathways shown here. These are denoted by lighter blue in the header row.

Our understanding of the impacts of air pollution on productivity (and human health more generally) are constantly evolving, and different analyses often adopt different approaches to assessing such effects (based on the author's view on the robustness of the underlying evidence, the purpose of the analysis, etc). Approach 3 adopts a top-down approach, following a methodology commonly applied at EU-level in analyses of the impacts of air pollution (see for example the Clean Air Outlooks[67] and the support study to the Impact Assessment regarding proposed revisions to the Ambient Air Quality Directives[68] published by DG Environment). These studies draw on an underlying study by Dechezleprêtre et al.[69], which found that for every 1ugm$^{-3}$ change in $PM_{2.5}$, there is a 0.8% reduction in GDP.

Applying this relationship to the estimated changes in $PM_{2.5}$ concentrations as a result of CTAF in the detailed modelling cities, the estimated annual impacts on GDP (as set out in the table below) could be as large as a combined £35.7m benefit per year across the four cities in the *detailed modelling domain*.

This approach is not routinely applied in UK-studies, and has not yet been systematically reviewed by the Committee on the Medical Effects of Air Pollution (or COMEAP[70]) which advises the UK-government on appraisal approaches to assess the impacts of exposure to air pollution. As such the results should be treated with care and should not be considered as robust as the results following Defra's guidance – but these estimates are useful demonstration that following Defra's guidance produces a conservative estimate of the productivity impacts of the CTAF, and the true impacts could be (significantly) greater in practice.

The estimated (smaller) productivity effects following Approaches 1 and 2 (utilising Defra's guidance) are presented below for comparison.

Table 3-11 Estimated overall annual productivity impacts on GDP, applying the Dechezleprêtre et al. relationship to estimated changes in $PM_{2.5}$ concentrations, as a result of CTAF implementation

| Region | Approach 3 – top down approach | *Approach 1 – Defra's guidelines, accounting for overlaps with other effects to be included as part of wider damage costs* | *Approach 2 – Defra's guidelines, unadjusted for overlaps with other effects* |
|---|---|---|---|
| Greater Manchester | 13.4 | *0.12* | *0.34* |
| Liverpool City Region | 4.9 | *0.05* | *0.15* |
| West Midlands | 8.2 | *0.08* | *0.23* |
| West Yorkshire | 9.2 | *0.09* | *0.24* |
| **TOTAL** | **35.7** | *0.34* | *0.95* |

### 3.2.3 Impacts on children and educational attainment

The Defra approach captures specific pathways which quantify particular impacts of air pollution on child health. These are split out in the following table. As can be seen in the table, the change in air pollution emissions and exposure as a consequence of the CTAF scheme can have a positive impact on child health and school attendance, and in turn on educational attainment.

In the *detailed modelling domain* (covering the effects within the four focus urban areas of: Greater Manchester, Liverpool City Region, West Midlands and West Yorkshire), the CTAF scheme is estimated to reduce the number of missed school days (SDL) by 620 per year, and reduce the number of new cases of asthma by around 15 per year (sum of effects across smaller and older children).

In the *cost modelling domain*, the CTAF scheme is estimated to reduce the number of missed school days (SDL) by 570 per year, and reduce the number of new cases of asthma by around 15 per year (sum of effects across smaller and older children).

---

[67] https://environment.ec.europa.eu/topics/air/clean-air-outlook_en

[68] https://environment.ec.europa.eu/publications/revision-eu-ambient-air-quality-legislation_en

[69] https://one.oecd.org/document/ECO/WKP(2019)54/En/pdf

[70] https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

In the *England-wide modelling domain*, the CTAF scheme is estimated to reduce the number of missed school days (SDL) by 6,600 per year, and reduce the number of new cases of asthma by around 172 per year (sum of effects across smaller and older children).

Table 3-12 Impact of CTAF on children in detailed modelling (IPA) domains

| | **School days lost** | **Asthma (Small Children - 0-5)** | **Asthma (Older Children – 6-15)** |
|---|---|---|---|
| Associated pollutant | $PM_{10}$ | $NO_2$ | $NO_2$ and $PM_{2.5}$ |
| ***Monetised impact (£2022 prices)*** | | | |
| *Units* | *£* | *£* | *£* |
| Greater Manchester | 5,980* | 1,560,000 | 1,290,000 |
| Liverpool City Region | 2,670* | 642,000 | 556,000 |
| West Midlands | 4,220* | 1,040,000 | 888,000 |
| West Yorkshire | 4,430* | 1,200,000 | 969,000 |
| **TOTAL** | **17,300*** | **4,450,000** | **3,700,000** |
| ***Educational attainment - metric*** | | | |
| *Units* | *SDL* | #cases | #cases |
| Greater Manchester | 214 | 2.8 | 2.3 |
| Liverpool City Region | 96 | 1.1 | 1.0 |
| West Midlands | 151 | 1.8 | 1.6 |
| West Yorkshire | 159 | 2.1 | 1.7 |
| **TOTAL** | **620** | **7.9** | **6.5** |

Notes: *Impact calculated as a productivity effect through SDL causing WDL.

Table 3-13 Impact of CTAF on children in cost and England-wide (Damage costs) domains

| | **School days lost** | **Asthma (Small Children - 0-5)** | **Asthma (Older Children – 6-15)** |
|---|---|---|---|
| Associated pollutant | $PM_{10}$ | $NO_2$ | $NO_2$ and $PM_{2.5}$ |
| ***Monetised impact (£2022 prices)*** | | | |
| *Units* | *£* | *£* | *£* |
| Cost (4 LAs) – All emissions | 15,900* | 4,620,000 | 3,720,000 |
| *Cost (4 LAs) – City emissions* | *3,500** | *1,120,000* | *852,000* |
| England-wide (89 LAs) – all emissions | 185,000* | 54,000,000 | 43,400,000 |
| *England-wide (89 LAs) – city emissions* | *33,400** | *11,400,000* | *8,340,000* |
| ***Educational attainment - metric*** | | | |
| *Units* | *SDL* | #cases | #cases |
| Cost (4 LAs) – All emissions | 570 | 8.17 | 6.6 |
| *Cost (4 LAs) – City emissions* | *127* | *2.0* | *1.5* |
| England-wide (89 LAs) – all emissions | 6,620 | 95.50 | 76.8 |
| *England-wide (89 LAs) – city emissions* | *1,200* | *20.2* | *14.8* |

Notes: *Impact calculated as a productivity effect through SDL causing WDL.

However, the Defra approach only captures two of an increasing list of impacts that air pollution can have on children, and subsequently on their educational attainment (a broader set of health pathways are not yet included given these have not yet been systematically reviewed by COMEAP, who provide guidance to Defra on the health impacts associated with exposure to air pollution and methodologies to assess them). A number of other effects on children have been linked to exposure to air pollution.

Defra's approach captures the association between exposure and asthma in children, but air pollution is linked generally to the incidence of a ***broader group of acute lower respiratory infections in children***, including acute lower respiratory infections, pneumonia, upper respiratory infections and otitis media[71]. The development of Ottis Media (OM) in children has also been found[72] to be correlated with a short-term increase in PM exposure, with the strongest association found for children aged between 0-2 years of age. Other research[73, 74] has shown a positive association between short term increases in air pollution and paediatric hospitalization (including specifically for pneumonia). Alongside morbidity, acute lower respiratory infections (ALRI) account for nearly one fifth of mortality in young children.

Furthermore, a systematic review[75] of the association between air pollution and childhood leukaemia identified a positive association between benzene (and $NO_2$) and ***childhood leukaemia***.

Air pollution has been found to be linked with a condition known as ***small for gestational age*** (SGA)[76]. A 10 $\mu g/m^3$ increase in $PM_{2.5}$ levels over the entire pregnancy was associated with an 8% increase of SGA. Although there are uncertainties with confounders such as nutrition or social class.

There is growing evidence of a link between air pollutant exposure on brain development and subsequent ***mental health in children and adults***. Research undertaken in Denmark[77] studied the association between four psychiatric disorders (bipolar disorder, schizophrenia, personality disorder, and depression) and the level of childhood exposure to air pollution (between birth and 10 years old). The study found that for all four psychiatric disorders the rate of disorder increased with increasing levels of exposure to air pollution with a statistically significant association. The strongest association was between air pollution and personality disorder which showed a 162% increase in the disorder rate among the category with exposure to the highest levels of air pollution, compared to the lowest. Another study[78] found that children exposed to higher levels of outdoor NOx experienced greater psychopathology at the transition to adulthood, and a third study[79] found that residential exposure to $PM_{2.5}$ and $NO_2$ during childhood was linked to an increased risk of self-harm in later life (ages 10 to 37).

There is a strong amount of research which has identified a relationship between ***exposure to air pollution and IQ loss***. Research[80] was undertaken to assess the impact of prenatal exposure to air pollution on childhood IQ and that the effects vary by maternal and child characteristics, and found that exposure to higher levels of $PM_{10}$ were associated with a lower IQ. Namely, for every 5 $\mu g/m^3$ increase in $PM_{10}$ prenatal exposure,

---

[71] European Environment Agency (2023) Air pollution and children's health. Available at: https://www.eea.europa.eu/publications/air-pollution-and-childrens-health#:~:text=Air%20pollution%20also%20causes%20low,risks%20of%20adult%20chronic%20diseases. (Accessed 21/08/2023)

[72] Lee, S. Y., Jang, M. J., Oh, S. H., Lee, J. H., Suh, M. W., & Park, M. K. (2020). Associations between Particulate Matter and Otitis Media in Children: A Meta-Analysis. International journal of environmental research and public health, 17(12), 4604. https://doi.org/10.3390/ijerph17124604

[73] Nhung, N. T. T., Amini, H., Schindler, C., Kutlar Joss, M., Dien, T. M., Probst-Hensch, N., Perez, L., & Künzli, N. (2017). Short-term association between ambient air pollution and pneumonia in children: A systematic review and meta-analysis of time-series and case-crossover studies. Environmental pollution (Barking, Essex : 1987), 230, 1000–1008. https://doi.org/10.1016/j.envpol.2017.07.063

[74] King, C., Kirkham, J., Hawcutt, D., & Sinha, I. (2018). The effect of outdoor air pollution on the risk of hospitalisation for bronchiolitis in infants: a systematic review. PeerJ, 6, e5352. https://doi.org/10.7717/peerj.5352

[75] Filippini, T., Hatch, E. E., Rothman, K. J., Heck, J. E., Park, A. S., Crippa, A., Orsini, N., & Vinceti, M. (2019). Association between Outdoor Air Pollution and Childhood Leukemia: A Systematic Review and Dose-Response Meta-Analysis. Environmental health perspectives, 127(4), 46002. https://doi.org/10.1289/EHP4381

[76] Pun, V.C., Dowling, R. & Mehta, S. (2021) Ambient and household air pollution on early-life determinants of stunting—a systematic review and meta-analysis. Environ Sci Pollut Res 28, 26404–26412. https://doi.org/10.1007/s11356-021-13719-7

[77] Khan A, Plana-Ripoll O, Antonsen S, Brandt J, Geels C, et al. (2019) Environmental pollution is associated with increased risk of psychiatric disorders in the US and Denmark. PLOS Biology 17(8): e3000353. https://doi.org/10.1371/journal.pbio.3000353

[78] Reuben A, Arseneault L, Beddows A, et al. (2021) Association of Air Pollution Exposure in Childhood and Adolescence With Psychopathology at the Transition to Adulthood. JAMA Netw Open. 4(4):e217508. doi:10.1001/jamanetworkopen.2021.7508

[79] Pearl L.H. Mok, Sussie Antonsen, Esben Agerbo, Jørgen Brandt, Camilla Geels, Jesper H. Christensen, Lise M. Frohn, Carsten B. Pedersen, Roger T. Webb, (2021) Exposure to ambient air pollution during childhood and subsequent risk of self-harm: A national cohort study. Preventive Medicine. Volume 152, Part 1. https://doi.org/10.1016/j.ypmed.2021.106502

[80] Loftus, C. T., Hazlehurst, M. F., Szpiro, A. A., Ni, Y., Tylavsky, F. A., Bush, N. R., Sathyanarayana, S., Carroll, K. N., Karr, C. J., & LeWinn, K. Z. (2019). Prenatal air pollution and childhood IQ: Preliminary evidence of effect modification by folate. Environmental research, 176, 108505. https://doi.org/10.1016/j.envres.2019.05.036

the average IQ was 2.5 points lower. Another study[81] in Southern California found that for children aged 9 to 11, increased exposure to $PM_{2.5}$ was associated with decreased IQ scores, specifically for Performance IQ. Additionally, the effects were found to be 150% greater in low SES families and 89% stronger in males, compared to their counterparts. A further study[82] found that also indoor air quality within schools can also cause a decrease in performance on standardised tests.

The above studies explore the impact of air pollutant exposure on child health. Although it is logical that detrimental health impacts and subsequent school absence will have an ***impact on educational attainment***, fewer studies directly link exposure to education outcomes. That said, there is a growing body of evidence exploring these effects directly. One study[83] analysed this association for 18,241 students aged 15-16 in Cardiff and found a 10 $\mu g/m^3$ increase of exposure to $NO_2$ was associated with a 0.044 reduction of Capped Point Score (CPS, a continuous measure of attainment which is derived from a student's best eight subjects including Mathematics, and English Language or Welsh as a first language). Similarly, a study[84] undertaken in Chile also found a clear relationship in exam results and air pollution exposure. This study found $PM_{10}$ concentrations had the greatest effect, with the results indicating a 10 $\mu g/m^3$ increase is associated with a decline in 0.7 units in test scores. Additionally, it was found that short term exposure to air pollution can have significant effects, particularly elevated levels of PM and NOx. One study[85] undertaken in the USA also found air pollution is associated with lower academic performance among children with relationships identified for $PM_{2.5}$, $NO_2$ and $O_3$. Similarly, a study[86] in China identified a relationship between agricultural fires and cognitive performance on exams.

### 3.2.4 Comparison of costs and benefits

The air pollution benefits delivered by the CTAF are only part of the story. There would be costs to deliver the CTAF, but also additional benefits. This section explores both in further detail, and culminates in a comparison between the two to consider whether the CTAF would deliver an overall net benefit or cost to society.

***Costs:*** As set out in the 'Putting the brakes on toxic air' report, the cost of delivering the CTAF scheme is estimated to be around £777m (based on a grant of £3,000 being made available to 259,000 vehicle owners, or £651m for low-income households and £127m for blue-badge holders).

In the case of those that switch to active or public transport, this cost is assumed complete (i.e. there are no additional costs) as the incentive must be sufficient to enable a switch to these alternative modes, and cover any additional costs of taking active or public transport relative to existing means (e.g. cost of a bike or bus or train fares).

In the case of switch to electric cars however, an additional cost might be incurred. This is because the difference in price between an electric vehicle and an internal-combustion engine (ICE) vehicle is greater than the grant available. This is also recognised in the stakeholder survey undertaken by A+LUK. As such, households would incur an additional cost over and above the grant to switch to an EV.

To capture this additional cost, it is assumed that blue-badge holders upgrade to an EV at the point of purchasing a new vehicle – i.e. their existing ICE vehicle has reached the end of its useful life. As such, the additional cost of the EV is taken as the difference between the cost of buying a new EV versus the cost of a new ICE vehicle. Using cost data as deployed in several CAZ feasibility studies[87], the additional cost (considering only the 'social cost', i.e. excluding taxes and profit) of an EV relative to a petrol ICE vehicle in

---

[81] Wang P, Tuvblad C, Younan D, Franklin M, Lurmann F, et al. (2017) Socioeconomic disparities and sexual dimorphism in neurotoxic effects of ambient fine particles on youth IQ: A longitudinal analysis. PLOS ONE 12(12): e0188731. https://doi.org/10.1371/journal.pone.0188731

[82] Tess M. Stafford. (2015) Indoor air quality and academic performance, Journal of Environmental Economics and Management. Volume 70. Pages 34-50. ISSN 0095-0696. https://doi.org/10.1016/j.jeem.2014.11.002

[83] Amy Mizen, Jane Lyons, Ai Milojevic, Ruth Doherty, Paul Wilkinson, David Carruthers, Ashley Akbari, Iain Lake, Gwyneth A. Davies, Mohammad Al Sallakh, Richard Fry, Lorraine Dearden, Sarah E Rodgers, Impact of air pollution on educational attainment for respiratory health treated students: A cross sectional data linkage study, Health & Place, Volume 63, 2020, 102355, ISSN 1353-8292, https://doi.org/10.1016/j.healthplace.2020.102355

[84] Miller, Sebastián J.; Vela, Mauricio A. (2013) The Effects of Air Pollution on Educational Outcomes: Evidence from Chile.

[85] Lu, W., Hackman, D. A., & Schwartz, J. (2021). Ambient air pollution associated with lower academic achievement among US children: A nationwide panel study of school districts. Environmental epidemiology (Philadelphia, Pa.), 5(6), e174. https://doi.org/10.1097/EE9.0000000000000174

[86] Joshua Graff Zivin, Tong Liu, Yingquan Song, Qu Tang, Peng Zhang. (2020) The unintended impacts of agricultural fires: Human capital in China. Journal of Development Economics, Volume 147. 102560. ISSN 0304-3878. https://doi.org/10.1016/j.jdeveco.2020.102560

[87] In turn taken from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)

2025 is estimated to be around £7,800 (so £4,800 in addition to the grant cost). Combining this with around 42,400 EVs purchased by blue-badge holders, the estimated costs of EVs is around £332m (or an additional £205m on top of the grant fund costs).

It is important to note that the grant and EVs are one-off costs, which will deliver impacts over a number of years. As such, when comparing the upfront one-off cost to ongoing benefits, it is important to annualise the costs so they are comparable – i.e. present these on an equivalent annual basis.

The following table presents the absolute and annualised costs, and the period over which the costs are annualised, for comparison. The table also allocates costs to specific stakeholders.

Table 3-14 Absolute and annualised costs

| Cost category | Cost type | Stakeholder | Absolute cost | Period over which costs are annualised | Annualised costs |
|---|---|---|---|---|---|
| Grant for low-income households switching to AT/PT | Grant | Government | £651m | 5* | £144m |
| Blue-badge holders purchasing EVs | Grant | Government | £127m | 12** | £13m |
|  | *Additional cost of purchasing EV* | Individuals / businesses | £205m |  | £21m |
| **TOTAL** |  |  | **£983m** |  | **£179m** |

Note: *It is assumed that the vehicle owner uses AT or PT for 5 years after receipt of the grant; **average lifetime of a car.

***Benefits:*** As noted above, there would be a range of 'private' (i.e. accruing to the household) benefits from switching to active or public transport, or EVs.

There would be both fuel and operating cost impacts, both from the switch to active travel and public transport (fuel and opex savings), and the switch to EVs (could be a saving or cost depending on the relative costs of running an ICE versus an EV).

To estimate fuel and operating cost changes, we combine average fuel and electricity consumption per km for different vehicle types taken from the CAZ feasibility studies[88]. We combine the total number of vehicles removed with average distance travelled per vehicle per year (assumed to be 13,000km), and split this by petrol and diesel and euro standard according to the fleet split of the four cities. Fuel savings are then combined with fuel costs (Long-run variable costs) taken from BEIS' supplementary green book guidance.

We have also estimated GHG emissions savings from ICE vehicles removed by combined the calculated fuel savings with average GHG emissions factors from BEIS' guidance. We combine this with an estimate of the GHG emissions associated with running around 43,000 new EVs each year (BBHs, based on average electricity consumption per annum and electricity grid GHG emissions factors from BEIS Supplementary Green Book guidance). These are combined with carbon prices also from BEIS guidance.

The fuel, opex and GHG emissions savings are presented in the following table.

Table 3-15 Fuel, opex and GHG emission savings benefits (all impact per annum)

| Impact | Saving | Additional cost | Net impact |
|---|---|---|---|
| Fuel | Fuel savings from removal of 259,000 ICE vehicles:<br>£168m | Electricity cost for additional 42,400 EVs: -£8.8m | £160m saving |
| Opex | Savings from removal of 259,000 ICE vehicles: £90m | Additional opex for 42,400 EVs: -£10.1m | £79m saving |

---

[88] In turn taken from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)

| Impact | Saving | Additional cost | Net impact |
|---|---|---|---|
| GHG | Savings from removal of 259,000 ICE vehicles:<br>618 ktCO2e<br>£181m | Additional emissions for 42,400 EVs (based on grid emissions factors):<br>9.6 ktCO2e<br>-£2.8m | £179m saving |

It is important to note that the analysis has not captured any impacts on travel time, nor any additional risks around safety and security whilst travelling, nor any additional benefit to health through active travel.

***Net present value***: Comparing costs and benefits provides an illustration of the merits of the CTAF scheme. The calculated costs and benefits are presented in the following table.

As can be seen from the table, the CTAF scheme is assessed to deliver a net benefit to society (i.e. it has a positive net present value) of around £261m per year. These benefits would persist over the period where behaviour change to switch to active travel or public transport is maintained, and/or over the lifetime of the EVs purchased. The scheme is estimated to deliver a benefit-to-cost ratio of 2.5 – i.e. for every £1 invested in the scheme, there is a payback of £2.50 for society (this ratio would be even higher when only considering costs incurred by the funder).

There are costs to the scheme, including additional costs of EVs over and above the grant funding provided. However, the switch to active travel, public transport and EVs delivers significant benefits, in particular through fuel and GHG emissions savings which outweigh the costs of the scheme. Air pollution benefits in the urban centres deliver an additional important benefit for the scheme.

Table 3-16 Summary of costs and benefits of the CTAF scheme

| Impact | Estimated value |
|---|---:|
| Grant for low-income households switching to AT/PT | -£144m |
| Blue-badge holders purchasing EVs | -£34m |
| **TOTAL COSTS** | **-£179m** |
| Fuel saving | £160m |
| Opex saving | £79m |
| GHG emission saving | £179m |
| AQ emission saving (See cost scenario – Table 3-7) | £21.8m |
| **TOTAL BENEFITS** | **£440m** |
| **NET PRESENT VALUE** | **£261m** |
| ***BENEFIT-COST RATIO*** | ***2.5*** |

## 3.3 DISTRIBUTIONAL IMPACT ASSESSMENT

Table 3-17: to Table 3-19 provide a summary of the results from distributional impact assessment (a more detailed set of results is presented in Appendix 3). Each results table shows the average reduction of $NO_2$ pollutant for LSOAs within each quintile group.

Table 3-17: Distribution of the mean change in modelled annual average $NO_2$ concentrations (µg/m$^3$) across the IMD quintile groups as a result of CTAF implementation

| Detailed model region | Lowest level of deprivation | | | | Highest level of deprivation |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Liverpool City Region | -0.08 | -0.12 | -0.13 | -0.14 | -0.17 |
| Greater Manchester | -0.15 | -0.17 | -0.19 | -0.21 | -0.21 |
| West Midlands | -0.09 | -0.10 | -0.12 | -0.13 | -0.14 |
| West Yorkshire | -0.12 | -0.16 | -0.17 | -0.18 | -0.21 |

Table 3-17: shows that:

- For all of the detailed model regions, there is a linear trend between areas with the largest change in modelled annual mean $NO_2$ concentrations and those with the highest level of deprivation. Namely: the introduction of the CTAF scheme will benefit those living in the most deprived areas (Quintile 5) the greatest, whilst those living in the lesser deprived areas will also benefit but by a smaller absolute value relative to those living in Quintile 5 LSOAs.
- Further statistical analysis suggests that this trend is statistically significant (to a 99% level of confidence)

Table 3-18 Distribution of the mean change in modelled annual average $NO_2$ concentrations (µg/m$^3$) across the children quintile groups as a result of CTAF implementation

| Location | Lowest proportion of children | | | | Highest proportion of children |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Liverpool City Region | -0.13 | -0.13 | -0.15 | -0.16 | -0.15 |
| Greater Manchester | -0.19 | -0.16 | -0.18 | -0.21 | -0.21 |
| West Midlands | -0.11 | -0.10 | -0.12 | -0.12 | -0.14 |
| West Yorkshire | -0.18 | -0.16 | -0.16 | -0.18 | -0.21 |

Table 3-18 shows that:

- The change in modelled annual mean $NO_2$ concentrations is reasonably consistent across quintile groups for all the detailed model regions.
- That said, the largest change in modelled annual mean $NO_2$ concentrations tended to correlate with the LSOAs that have higher/highest proportions of children (i.e. those areas with greater/greatest numbers of children may benefit more from the introduction of the CTAF).
- This trend pattern is less distinct (relative to say, the trend based on deprivation). That said, further statistical analysis suggests this trend is (just) statistically significant (to a 99% level of confidence)

Table 3-19 Distribution of the change in modelled annual average $NO_2$ concentrations (µg/$m^3$) across the elderly quintile groups as a result of CTAF implementation

| Location | Lowest proportion of elderly citizens | | | | Highest proportion of elderly citizens |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Liverpool City Region | -0.19 | -0.16 | -0.15 | -0.13 | -0.09 |
| Greater Manchester | -0.23 | -0.21 | -0.18 | -0.16 | -0.14 |
| West Midlands | -0.15 | -0.13 | -0.12 | -0.10 | -0.09 |
| West Yorkshire | -0.23 | -0.19 | -0.17 | -0.14 | -0.14 |

Table 3-19 shows that:

- The largest change in modelled annual mean $NO_2$ concentrations tended to correlate with the LSOAs that have the lowest proportion of elderly citizens.
- Overall, the data suggests that that those living in LSOAs in the lower quintiles (those with the lowest proportion of elderly citizens) will benefit most from the CTAF scheme, relative to areas with a higher populations of older residents.
- Further statistical analysis suggests that this trend is statistically significant (to a 99% level of confidence)

# 4. CONCLUSIONS

This section provides a summary of the outcomes of this assessment, focusing on the health and economic benefits of the Cleaner Travel Access Fund.

Emissions and air dispersion modelling were used to predict the air quality impacts of implementing the CTAF scheme for local authorities in England. Three CTAF uptake domains were developed to investigate the potential impacts of the scheme being implemented by different numbers of cities across England:

- "Cost" uptake domain – to estimate the impacts of applying the CTAF scheme in four local authorities and representative of the CTAF scheme as costed in A+LUK's "Putting the brakes on toxic air" report.
- "Detailed model" domain – to estimate the impacts of applying the CTAF scheme in the 28 local authorities within Greater Manchester, Liverpool City Region, West Midlands, and West Yorkshire.
- "England-wide" domain – to estimate the impacts of applying the CTAF scheme in 89 local authorities exceeding the annual mean $NO_2$ standard in 2019, to represent the potential impacts of wider uptake of the CTAF.

The results showed that the modelled reductions in $NO_2$, particulate matter ($PM_{10}$ and $PM_{2.5}$), and $CO_2$ emissions increased with increased uptake of the CTAF scheme.

Detailed air dispersion modelling was carried out for four focus regions in England: Greater Manchester, Liverpool City Region, West Midlands, and West Yorkshire, providing annual average concentrations of $NO_2$, $PM_{10}$ and $PM_{2.5}$ throughout the regions for the Baseline and CTAF scenarios. The greatest absolute change in pollutant concentrations as a result of the CTAF scheme were seen in Greater Manchester for all three pollutants.

The modelled impacts of the CTAF scheme were observed to vary by location across the four regions, with the strongest impacts observed where road transport emissions were at their highest and up to four to six times greater than the average for the region (depending on the pollutant). The greatest modelled improvements in pollution (in terms of $\mu g/m^3$) as a result of the CTAF implementation were seen at the following locations:

- Greater Manchester: The greatest improvements in $NO_2$, $PM_{2.5}$ and $PM_{10}$ concentrations occurred in Bolton, adjacent to the M61 / A666(M). Nearby locations of human exposure include Kearsley Academy and Woodbridge College, as well as Kearsley Park and parts of Blackreach Country Park.
- Liverpool City Region: The greatest improvements in $NO_2$ were estimated to occur in the Wirral, at Junction 2 of the M53. Nearby are Sandbrook Primary School and Fender Skatepark, as well as residential and green areas. The greatest improvements in $PM_{10}$ and $PM_{2.5}$ were predicted to occur within the centre of Liverpool itself, near to the Mishra Surgical Center, St. James Park, and numerous shops, restaurants, and hotels.
- West Midlands: The greatest improvements in $NO_2$ were estimated to occur in Sandwell, near Junction 8 of the M6. Nearby locations of human exposure include Grove Vale Primary School, as well as much of Red House Park, and a residential area. The greatest improvements in $PM_{10}$ and $PM_{2.5}$ were predicted to occur within Birmingham at the M6 / A38(M) interchange, and near to Slade Primary School, Aston Reservoir, other green spaces and residential houses.
- West Yorkshire: The strongest improvements in $NO_2$, $PM_{2.5}$ and $PM_{10}$ occurred in Leeds, at the M1 / M62 interchange and near to Robin Hood Primary School, The Rodillian Academy, green spaces and a residential area.

The results of the emissions and air dispersion modelling were used to inform the Health Impact Assessment and Distributional Impact Assessment. The analysis shows that the CTAF scheme can deliver significant benefits for health, productivity, and educational attainment, in particular in areas which suffer from higher levels of deprivation.

The results from the distributional impact assessment showed that, across all four detailed model regions, the CTAF scheme is likely to provide a greater improvement in air quality to citizens living within the most deprived LSOAs. The analysis also uncovered evidence to suggest that areas with greater numbers of children could also benefit more so than areas with fewer children (although this result is less clear, relative to the effects for areas with lower/higher levels of deprivation). LSOAs with the highest proportion of elderly citizens were found to benefit the least from the introduction of the CTAF scheme.

Across the four urban areas which were the focus of our analysis (Greater Manchester, Liverpool City Region, West Midlands, West Yorkshire), could deliver a total economic benefit of £21.7m per year (capturing the value that individuals place on living longer an in good health, but also NHS savings of avoided health and social care costs and productivity losses). The CTAF will lead to a range of human health benefits in these cities. Through the air pollution reductions that will be achieved through CTAF, we can avoid 22 early deaths each year, deliver 223 extra years of good health each year, and help all people live well for longer across Greater Manchester, Liverpool City region, West Yorkshire, and the West Midlands. CTAF is also estimated to reduce the number of hospital admissions for respiratory conditions by around 22 per annum across the four cities.

Should the CTAF be rolled out England-wide, the scheme could deliver a total economic benefit of £254m per year (of which £50.2m per year is associated with reduction in emissions in urban centres). This represents a greater achievement of health benefits, equivalent to reducing the mortality impacts of air pollutant exposure by 2,637 LYLs, deaths by 260, and hospital admissions for respiratory conditions by 174 per annum. By way of comparison, an assessment of the proposed London-wide ULEZ[89] suggested that scheme could reduce LYL associated with air pollution exposure by 59 LYLs each year, reduce respiratory hospital admissions by 1.4 per year and deliver a total economic benefit of £13.0m per year (2020 prices) across Greater London.

One of the impacts captured in the comprehensive figures above is an important effect on productivity. Looking at these effects directly, CTAF could deliver a boost to the economy to the tune of £948,000 per annum across the four urban areas of Greater Manchester, Liverpool City Region, West Midlands and West Yorkshire. The majority of these effects would also be reflected directly in a change in GDP (£844,000 of the total). These effects capture a range of underlying impacts on human health which cascade into an impact on productivity, including a reduction in: 16 lost working years (for each year of reduced air pollutant exposure), 2,300 avoided work days lost, 3,900 care hours and 2,900 volunteering hours. If rolled out England-wide, the total benefit could be much greater at around £8.4m benefit per year, of which £7.3m would be directly reflected in GDP. These estimates adopt a bottom-up estimation approach, linking effects to particular pathways. Adopting a 'top-down' approach as commonly used in European studies, in fact the overall productivity impacts could be significantly greater, estimated to be as large as a combined £35.7m benefit per year across the four cities in the detailed modelling domain.

CTAF could also importantly mitigate some of the negative impacts of air pollution on children, school attendance and educational attainment. In the detailed modelling domain (covering the effects within the four focus urban areas of: Greater Manchester, Liverpool City Region, West Midlands and West Yorkshire), the CTAF scheme is estimated to reduce the number of missed school days (SDL) by 620 per year, and reduce the number of new cases of asthma by around 15 per year. England-wide, the scheme could reduce the number of missed school days (SDL) by 6,600 per year, and reduce the number of new cases of asthma by around 172 per year. That said, there would be many more benefits for children that it is currently not possible to quantify (e.g. effects on mental health, IQ, etc).

The analysis has also compared the costs and benefits of CTAF to provide an overall illustration of the merits of the CTAF scheme. The CTAF scheme is assessed to deliver a net benefit to society (i.e. it has a positive net present value) of around £261m per year. These benefits would persist over the period where behaviour change to switch to active travel or public transport is maintained, and/or over the lifetime of the EVs purchased. The scheme is estimated to deliver a benefit-to-cost ratio of 2.5 – i.e. by investing in a fair transition to cleaner modes of travel, the government are getting a 2.5-for-1 deal: for every £1 invested in the scheme, there is a payback of £2.50 for society (this ratio would be even higher when only considering costs incurred by the funder).

An additional benefit captured as part of the comparison of costs and benefits is an additional climate change benefit: CTAF is estimated to deliver 608 ktCO2e of greenhouse gases avoided, helping to protect our planet from climate breakdown.

---

[89] See Appendix 1 here: https://ehq-production-europe.s3.eu-west-1.amazonaws.com/77df043331c0216ccc8d4b941bd8166ade7f1f90/original/1669211507/d98e4423b653b1d331ebffd20480e8d7_appendix-c-integrated-impact-assessment-scheme.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA4KKNQAKICO37GBEP%2F20230811%2Feu-west-1%2Fs3%2Faws4_request&X-Amz-Date=20230811T142231Z&X-Amz-Expires=300&X-Amz-SignedHeaders=host&X-Amz-Signature=c6b75e2d96b56719d67aeeda6941139642fd416bc29830dd3cc4511e2917aaf2

# APPENDICES

# APPENDIX 1 GLOSSARY AND ABBREVIATIONS

| Term | Meaning |
|---|---|
| **A+LUK** | Asthma + Lung UK |
| **AADT** | Annual Average Daily Traffic |
| **Air quality model** | A mathematical simulation of how air pollutants disperse and react in the atmosphere to affect ambient air quality. |
| **Air quality standard** | A statutory limit, usually set as an airborne concentration which should not be exceeded in order to avoid unacceptable risks of air pollution impacts. The standard may be specified to allow a certain number of exceedances of the limit value. |
| **Ambient air quality** | The quality of the outside air that we breathe in terms of the amount of pollutants it contains. |
| **Averaging period** | The time over which a pollutant concentration is measured, modelled and evaluated. Relevant averaging periods range from a few seconds for odours, through 15 minutes for sulfur dioxide, one to twenty-four hours (a wide range of pollutants), to a year (a wide range of pollutants). |
| **BBH** | Blue Badge Holder |
| **CAZ** | Clean Air Zone |
| **CBA** | Cost-Benefit Analysis |
| **CO** | Carbon monoxide (CO) is an air pollutant typically emitted from combustion processes and road traffic. Carbon monoxide can present a risk to health at high concentrations, but is normally less of a concern for urban air pollution than other pollutants. |
| **$CO_2$** | Carbon dioxide ($CO_2$) is a greenhouse gas that traps heat in the atmosphere. It is commonly emitted from the extraction and burning of fossil fuels (such as coal, oil, and natural gas), from wildfires, and natural processes like volcanic eruptions. |
| **CRF** | Concentration response function |
| **CTAF** | Cleaner Travel Access Fund |
| **Damage costs** | Damage costs are summary estimates of the monetized impacts of air pollution, summarized as a cost per tonne emitted. |
| **DfT** | Department for Transport |
| **EFT** | Emissions Factors Toolkit |
| **EI** | An emission inventory (EI) is a listing, by source, of the amounts of pollutants actually or potentially discharged from a defined geographical area. The inventory may be presented as total values, or may be presented geographically as emissions from point sources and/or sub-areas (e.g. a grid of squares or administrative areas within the defined geographical area). |
| **EV** | Electric vehicle |
| **GDP** | Gross Domestic Product, a measure of the monetary value of final goods and services (e.g. of a country). |
| **GHG** | Greenhouse gases (GHGs) are gases in the Earth's atmosphere that trap heat. Greenhouse gases cause the greenhouse effect by absorbing some of the heat a planet's surface radiates in response to light from its host star (e.g., the Sun for planet Earth). |
| **GVA** | Gross Value Added. Gross value added (GVA) is an economic productivity metric that measures the contribution of a corporate subsidiary, company, or municipality to an economy, producer, sector, or region. GVA is the output of the country less the intermediate consumption, which is the difference between gross output and net output. |
| **HA** | Hospital admission |

| Term | Meaning |
|---|---|
| **ICE** | Internal-combustion engine |
| **IGCB** | Interdepartmental Group on Costs and Benefits |
| **IMD** | Index of Multiple Deprivation |
| **IPA** | Impact Pathway Approach |
| **ITs** | Interim targets, set by the World Health Organization in addition to their Guideline Values on air pollutant concentrations. They are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. The targets aim to promote a shift from high air pollutant concentrations, which have acute and serious health consequences, to lower air pollutant concentrations. |
| **JAQU** | Joint Air Quality Unit |
| **LSOA** | Lower Super Output Area |
| **LYLs** | Life years lost is a summary measure of premature mortality. It estimates the years of potential life lost due to premature deaths. |
| **Morbidity** | The annual rate of ill health in a given population (e.g., hospital admissions per 100,000 people) |
| **Mortality** | The annual rate of death in a given population (e.g., deaths per 100,000 people) |
| **MSOA** | Medium Super Output Area |
| **NAEI** | National Atmospheric Emissions Inventory |
| **NO** | Nitric oxide |
| **$NO_2$** | Nitrogen dioxide ($NO_2$) is an air pollutant, typically emitted from combustion processes and road traffic. Nitrogen dioxide reacts reversibly to form nitric oxide and vice versa, by interaction with sunlight, ozone and other oxidants in the atmosphere. At high levels, nitrogen dioxide can have acute effects on health, and long-term exposure can also result in an increase in respiratory and cardiovascular disease, and premature deaths. Deposition of nitrogen dioxide also contributes to acidification and eutrophication. |
| **$NO_x$** | For most practical purposes, oxides of nitrogen (NOx) comprise nitric oxide (NO) and nitrogen dioxide ($NO_2$). |
| **$O_3$** | Ozone ($O_3$) is an air pollutant formed in the atmosphere from complex reactions involving oxides of nitrogen, volatile organic compounds and sunlight. At high levels, ozone can have acute effects on health, and long-term exposure can also result in an increase in respiratory and cardiovascular disease, and premature deaths. Ozone can also have adverse impacts on agricultural crops and natural ecosystems. |
| **OAP** | Old Age Pensioner |
| **OECD** | Organization for Economic Co-operation and Development |
| **Opex** | Ongoing annual operating costs. |
| **PM** | Particulate matter (PM) is an air pollutant, emitted from a wide range of sources, including combustion processes, road traffic, agriculture, construction, and natural sources. Airborne particulate matter can cause a nuisance due to dust deposition, and finer fractions ($PM_{10}$ and $PM_{2.5}$) can have effects on health. |
| **$PM_{10}$** | Particulate matter with a diameter of less than 10 microns ($10 \times 10^{-6}$ meters). At high levels, $PM_{10}$ can have acute effects on health, and long-term exposure can also result in an increase in respiratory and cardiovascular disease, and premature deaths. |
| **$PM_{2.5}$** | Particulate matter with a diameter of less than 2.5 microns ($2.5 \times 10^{-6}$ meters). At high levels, $PM_{2.5}$ can have acute effects on health, and long-term exposure can also result in an increase in respiratory and cardiovascular disease, and premature deaths. |

| Term | Meaning |
|---|---|
| **QALYs** | Quality adjusted life year. The quality-adjusted life year (QALY) is a generic measure of disease burden, including both the quality and the quantity of life lived. One quality-adjusted life year (QALY) is equal to 1 year of life in perfect health. |
| **SDL** | School days lost |
| **Spearman's Rank Correlation Coefficient** | Spearman's Rank correlation coefficient is a technique which can be used to summarise the strength and direction (negative or positive) of a relationship between two variables. The result will always be between 1 and minus 1, where a result of 1 or -1 suggests that two variables are perfectly correlated, and a value of 0 where there is no correlation between two variables. |
| **TAG** | Transport Analysis Guidance |
| **WHO** | World Health Organization |

# APPENDIX 2 LOCAL AUTHORITIES INCLUDED IN CTAF UPTAKE SCENARIOS

Table A- 1. List of local authorities included in the “Cost”, “Detailed model” and “England-wide” CTAF uptake scenarios

| Local authority | Included in CTAF uptake scenario? | | |
|---|---|---|---|
| | Cost (4 LAs) | Detailed model (28 LAs) | England-wide (89 LAs) |
| Barking and Dagenham | | | X |
| Barnet | | | X |
| Basildon | | | X |
| Bexley | | | X |
| Birmingham | X | X | X |
| Bolsover | | | X |
| Bolton | | X | X |
| Bournemouth, Christchurch and Poole | | | X |
| Bradford | | X | X |
| Brent | | | X |
| Bristol, City of | | | X |
| Bury | | X | X |
| Calderdale | | X | X |
| Camden | | | X |
| City of London | | | X |
| County Durham | | | X |
| Coventry | | X | X |
| Crawley | | | X |
| Croydon | | | X |
| Derby | | | X |
| Dudley | | X | X |
| Ealing | | | X |
| Enfield | | | X |
| Fareham | | | X |
| Gateshead | | | X |
| Greenwich | | | X |
| Guildford | | | X |
| Hackney | | | X |
| Halton | | X | X |
| Hammersmith and Fulham | | | X |
| Haringey | | | X |

| Local authority | Included in CTAF uptake scenario? | | |
|---|---|---|---|
| | Cost (4 LAs) | Detailed model (28 LAs) | England-wide (89 LAs) |
| Havant | | | X |
| Havering | | | X |
| Hillingdon | | | X |
| Hounslow | | | X |
| Islington | | | X |
| Kensington and Chelsea | | | X |
| Kingston upon Thames | | | X |
| Kirklees | | X | X |
| Knowsley | | X | X |
| Lambeth | | | X |
| Leeds | X | X | X |
| Leicester | | | X |
| Lewisham | | | X |
| Liverpool | X | X | X |
| Manchester | | X | X |
| Merton | | | X |
| Middlesbrough | | | X |
| New Forest | | | X |
| Newcastle upon Tyne | | | X |
| Newcastle-under-Lyme | | | X |
| Newham | | | X |
| North Tyneside | | | X |
| Nottingham | X | | X |
| Oldham | | X | X |
| Plymouth | | | X |
| Portsmouth | | | X |
| Reading | | | X |
| Redbridge | | | X |
| Richmond upon Thames | | | X |
| Rochdale | | X | X |
| Rochford | | | X |
| Rotherham | | | X |
| Rushmoor | | | X |
| Salford | | X | X |
| Sandwell | | X | X |

| **Local authority** | **Included in CTAF uptake scenario?** | | |
|---|---|---|---|
| | **Cost (4 LAs)** | **Detailed model (28 LAs)** | **England-wide (89 LAs)** |
| Sefton | | X | X |
| Sheffield | | | X |
| Slough | | | X |
| Solihull | | X | X |
| Southampton | | | X |
| Southwark | | | X |
| Spelthorne | | | X |
| St. Helens | | X | X |
| Stockport | | X | X |
| Stoke-on-Trent | | | X |
| Surrey Heath | | | X |
| Tameside | | X | X |
| Tower Hamlets | | | X |
| Trafford | | X | X |
| Wakefield | | X | X |
| Walsall | | X | X |
| Waltham Forest | | | X |
| Wandsworth | | | X |
| West Northamptonshire | | | X |
| Westminster | | | X |
| Wigan | | X | X |
| Wirral | | X | X |
| Wolverhampton | | X | X |
| **Total** | **4** | **28** | **89** |

# APPENDIX 3 DISTRIBUTIONAL IMPACT ASSESSMENT

## A3.1 INTRODUCTION

This section of the report provides full detail of the approach undertaken to assess the distribution of the impacts of the CTAF scheme across areas with a low/high level of sensitivity to changes in the level of air pollution experienced by its inhabitants (i.e. low/high levels of representation across different demographic groups).

## A3.2 APPROACH TO ASSESSING THE DISTRIBUTIONAL IMPACTS

### Overview and output metrics

The DfT's Transport Analysis Guidance (TAG) unit A4-2[90] document was used as the framework for this evaluation. The TAG unit A4-2 document is specifically dedicated to providing advice on how to evaluate the distributional impacts caused by changes to the transport system. The framework states that the following two social demographics should be used to appraise the social impacts caused by changes in $NO_2$ by the implementation of a CAZ type D:

- Areas with a low/high level of income distribution; and
- Areas with a low/high proportion of children (citizens under the age of 16).

A review of available datasets that could be used to evaluate the impacts of the changes in the concentrations of $NO_2$ pollutant determined that both analyses could be undertaken using the Lower Super Output Area layer (LSOA) spatial resolutions[91]. LSOAs are spatial areas that are commonly used in the UK for reporting population statistics. Each LSOA zone comprises of a group of smaller Output Areas (OAs), forming spatial regions which comprise of populations between 1,000 – 3,000 in size. LSOAs were used to compare the changes in the annual average concentrations of $NO_2$ with each demographic variable. Hence this resolution is used to compare the changes in the annual average concentrations of $NO_2$ predicted as a result of CTAF implementation directly to populations given in the datasets identified for each social demographic.

Sections A3.4 to A3.6 detail the approaches undertaken to create the variables needed to compare changes in the annual average $NO_2$ concentrations within each LSOA and the relative sensitivity of each LSOA with respect to the two social groups considered. In summary each LSOA was assigned a quintile value to reflect whether it had a low or high proportion of the sensitive social group.

The following two statistical tests were undertaken using the change in annual average $NO_2$ concentrations and social indicator variables:

- Box and whisker plot summaries – box and whisker plots were created for each quintile group; displaying the change in $NO_2$ concentration data. These present the minimum, average, and maximum change in $NO_2$ concentrations for each quintile.
- A Spearman's Rank Correlation Coefficient test[92] – this test provided an overall indicator of whether reductions in the concentration of $NO_2$ pollutant are larger or smaller for certain demographic groups relative to another. The test assesses how correlated two variables are – i.e. how does one variable change when there is change in the other. Where there is strong correlation between the change in air pollution and demographic characteristics, there is stronger evidence that there will be a disproportionate benefit or negative impact on certain demographic groups relative to another.
    - Figure A- 1 displays a visual representation of how the spearman rank correlation score should be interpretated. The correlation coefficient significant value was abstracted from the Kendel significance table which shows that a correlation score is not statistically significant below 0.15 at a 0.005 level of confidence for observations greater than 60[93].

---

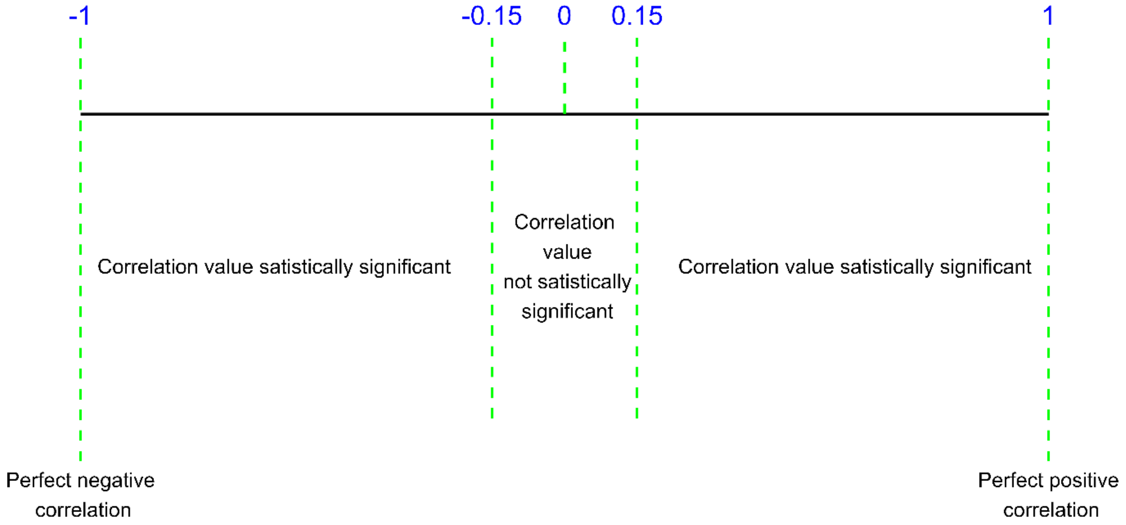
[90] https://www.gov.uk/guidance/transport-analysis-guidance-tag

[91] https://www.data.gov.uk/dataset/fa883558-22fb-4a1a-8529-cffdee47d500/lower-layer-super-output-area-lsoa-boundaries

[92] https://www.rgs.org/CMSPages/GetFile.aspx?nodeguid=882169d2-8f96-4c55-84f5-fbb7614870e9&lang=en-GB

[93] https://www.york.ac.uk/depts/maths/tables/kendall.pdf

Figure A- 1. Interpretation of Spearman's Rank Correlation Coefficients



The figure shows that:

- 1 or -1 representing a perfect linear trend (i.e. a prefect correlation) between the two variables (the quintile grouping, and the pollutant reduction values). The positive or negative value indicates the direction of the trend; a positive value indicates the reduction value will increase in magnitude with each quintile group whilst a negative value represents that the level of reduction reduces with each quintile group).
- A value +/-1 and +/- 0.15 reflects a significant correlation between the two variables.
- A score between -0.15 and 0.15 indicates that the correlation coefficient is too weak to be statistically significant.
- A score close to 0 indicates that the level of reduction in annual average $NO_2$ concentrations is consistent across quintile groups – i.e. there is no correlation between change in air pollution levels and demographic characteristics, and hence all groups in society are impacted broadly equally.

### Approach to assessing changes in the concentration of $NO_2$ pollutant

The $NO_2$ raster outputs from the air quality modelling study were uploaded into GIS software alongside a shapefile containing the spatial extent of all LSOAs located in England.

A GIS tool was used to average the concentrations of each modelled $NO_2$ location within each LSOA. This data was exported from the software as a table which states the LSOA name and the average $NO_2$ concentration value. This process was repeated for each scenario used within this analysis.

To evaluate the impact of the CTAF implementation on each LSOA, the change in the average $NO_2$ concentrations for each LSOA were calculated by subtracting the predicted $NO_2$ concentrations from the CTAF scenario model output from the corresponding LSOA in the baseline scenario model output.

Using this method, a positive figure means there is an improvement in air quality as a result of the introduction of the policy option.

$$(\text{CTAF } NO_2) - (\text{Baseline } NO_2) = (\text{Change in Air Quality})$$

### Approach to assessing the distribution of changes in $NO_2$ pollutant across areas with lower/higher levels of deprivation

The most recent update to the indices of multiple deprivation (IMD) dataset (2019)[94] was used to provide an indication of the overall levels of deprivation in each LSOA. The score given within the dataset takes into consideration several factors including crime and employment. Lower IMD values correspond to areas with higher deprivation.

---

[94] https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

The dataset was restructured so that LSOAs were listed in ascending order of their overall IMD score. Each LSOA was then assigned a quintile value in accordance with its ranking position.

The quintile grouping of each LSOA was cross-referenced with its change in annual average $NO_2$ concentration value as a result of CTAF implementation. The change in $NO_2$ concentration value was also assigned a rank value based on the position of the LSOAs when the level of change in $NO_2$ concentration was ordered in ascending values.

### Approach to assessing the distribution of changes in $NO_2$ pollutant across areas with a low/high proportion of children

The results from the 2021 national census[95] were used to identify the total number within each population within a LSOA to be under the age of 16 years old. This number was then divided by the total population size of the same LSOA to determine the percentage of the LSOA's population that were classified as a child.

Each LSOA within England was then ranked in ascending order by the proportion of children living within each LSOA. This order of ranking was used to assign a quintile grouping number. The quintile grouping number was used to reflect whether the proportion of children within the LSOA was within the lower, medium, or higher quintile groups.

The quintile grouping of each LSOA was cross referenced with its change in $NO_2$ concentration value. The change in $NO_2$ concentration value was also assigned a rank value based on the position of the LSOAs when the level of change in $NO_2$ concentration ordered in ascending values.

### Approach to assessing the distribution of changes in $NO_2$ pollutant across areas with lower/higher levels of elderly citizens

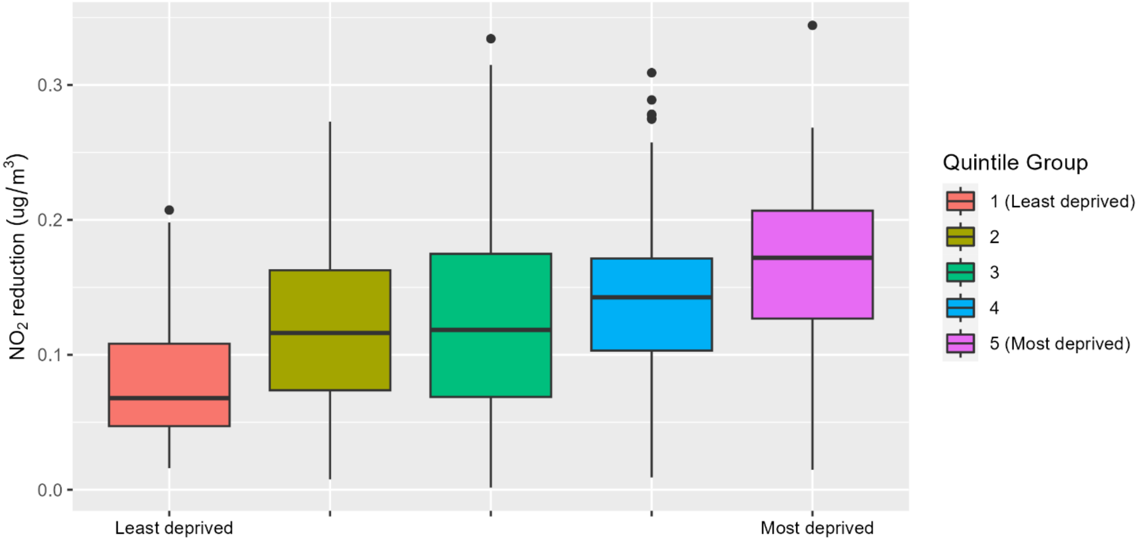
The same approach used in section A3.5 was reapplied for to evaluate the relationship between changes in annual averaged $NO_2$ pollutant and areas with a low/high proportion of elderly citizens. The approach was adapted so the proportion of citizens over the age of 65 was first calculated before a quintile ranking was assigned.

## A3.3 IMPACTS OF THE PROPOSED POLICY ON CONCENTRATION OF $NO_2$ IN AREAS WITH LOW/HIGH LEVEL OF DEPRIVATION

This section details the results from the analysis undertaken to understand the relationship between the changes in $NO_2$ concentration brought by the CTAF scheme and areas of low/high levels of deprivation.

### A3.7.1 Summary of the impacts on IMD quintile groups across the Liverpool City Region

Figure A- 2. Boxplot of the change in $NO_2$ concentration within IMD quintile groups across the Liverpool City Region



---

[95] https://www.ons.gov.uk/census

Table A- 2. Tabulated summary of the impacts within IMD quintile groups across the Liverpool City Region

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 |
| 1st Quartile | 0.05 | 0.07 | 0.07 | 0.10 | 0.13 |
| Median | 0.07 | 0.12 | 0.12 | 0.14 | 0.17 |
| **Mean** | **0.08** | **0.12** | **0.13** | **0.14** | **0.17** |
| 3rd Quartile | 0.11 | 0.16 | 0.17 | 0.17 | 0.21 |
| Max | 0.21 | 0.27 | 0.33 | 0.31 | 0.34 |
| Total population | 123,815 | 225,550, | 253,694 | 262,548 | 751,368 |

The Spearman's Rank Correlation Coefficient for the mean value was calculated as **0.42.**

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the IMD quintile groups.
- There is only a small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing the least deprived LSOAs) and those living in Quintile 5 (representing the most deprived LSOAs). A caveat to this is that those in Quintile 1 – 4 experience a far greater reduction relative to those living in Quintile 5 (as an average), with those living in Quintile 1 predicted to benefit a level of reduction which is double the level of reduction predicted in Quintile 5.

### A3.7.2 Summary of the impacts on IMD quintile groups across Greater Manchester

Figure A- 3. Boxplot of the change in $NO_2$ concentration within IMD quintiles across Greater Manchester

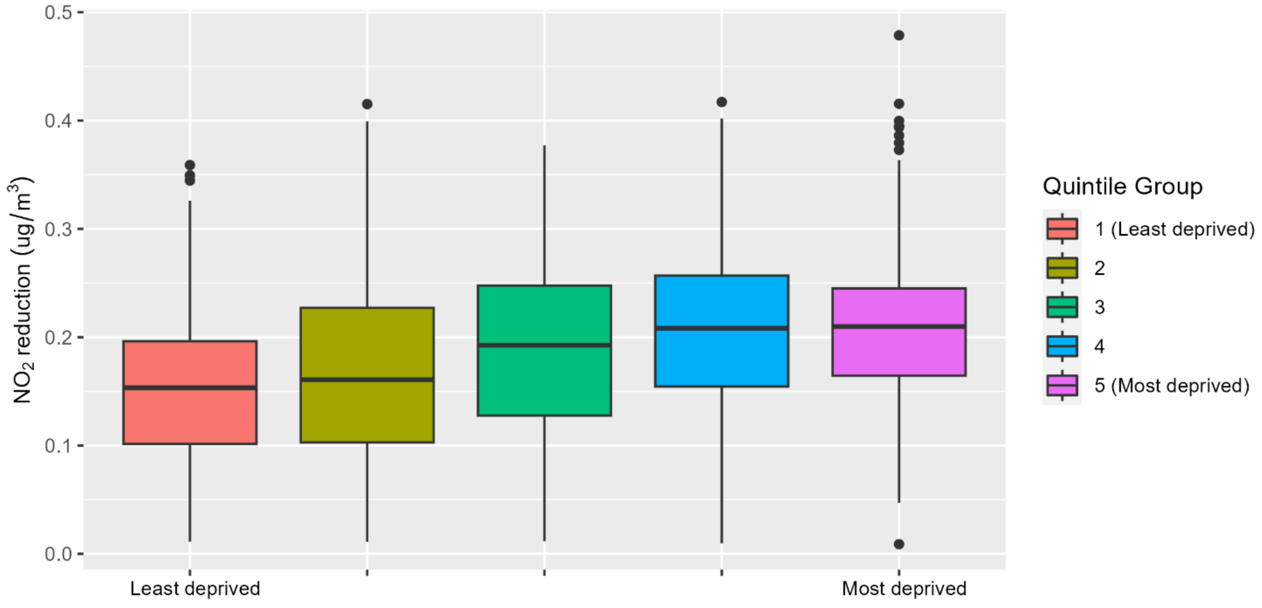


Table A- 3. Tabulated summary of the impacts within IMD quintiles across Greater Manchester Region

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1st Quartile | 0.10 | 0.10 | 0.13 | 0.15 | 0.16 |
| Median | 0.15 | 0.16 | 0.19 | 0.21 | 0.21 |
| **Mean** | **0.15** | **0.17** | **0.19** | **0.21** | **0.21** |
| 3rd Quartile | 0.20 | 0.23 | 0.25 | 0.26 | 0.25 |

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Max | 0.36 | 0.42 | 0.38 | 0.42 | 0.48 |
| Total population | 348,457 | 419,848 | 395,973 | 618,559 | 1,149,417 |

The Spearman's Rank Correlation Coefficient was calculated as **0.25**.

The results show that:

- There is a statistically significant correlation between the level of $NO_2$ reduction and the IMD quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing the least deprived LSOAs) and those living in Quintile 5 (representing the most deprived LSOAs).

### A3.7.3 Summary of the impacts on IMD quintile groups across the West Midlands' Region

Figure A- 4. Boxplot of the change in $NO_2$ concentration with respect to IMD quintiles across the West Midlands' Region

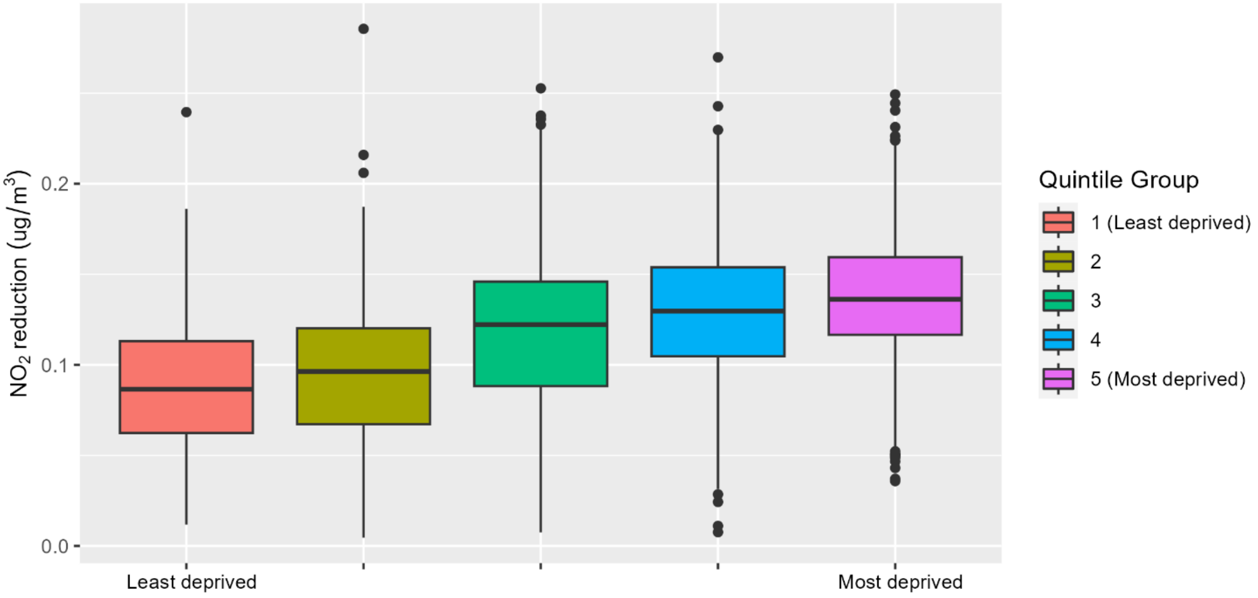


Table A- 4. Tabulated summary of the impacts on IMD quintiles across the West Midlands' Region

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.01 | 0.00 | 0.01 | 0.01 | 0.04 |
| 1st Quartile | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 |
| Median | 0.09 | 0.10 | 0.12 | 0.13 | 0.14 |
| **Mean** | **0.09** | **0.10** | **0.12** | **0.13** | **0.14** |
| 3rd Quartile | 0.11 | 0.12 | 0.15 | 0.15 | 0.16 |
| Max | 0.24 | 0.29 | 0.25 | 0.27 | 0.25 |
| Total population | 273,477 | 325,879 | 454,543 | 614,817 | 1,387,162 |

The Spearman's Rank Correlation Coefficient was calculated as **0.39**.

The results show that:

- There is a statistically significant correlation between the level of $NO_2$ reduction and the IMD quintile groups.

- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing the least deprived LSOAs) and those living in Quintile 5 (representing the most deprived LSOAs).

### A.3.7.4 Summary of the impacts on IMD quintile groups across West Yorkshire

Figure A-4. Boxplot of the change in $NO_2$ concentration within IMD quintile groups across West Yorkshire

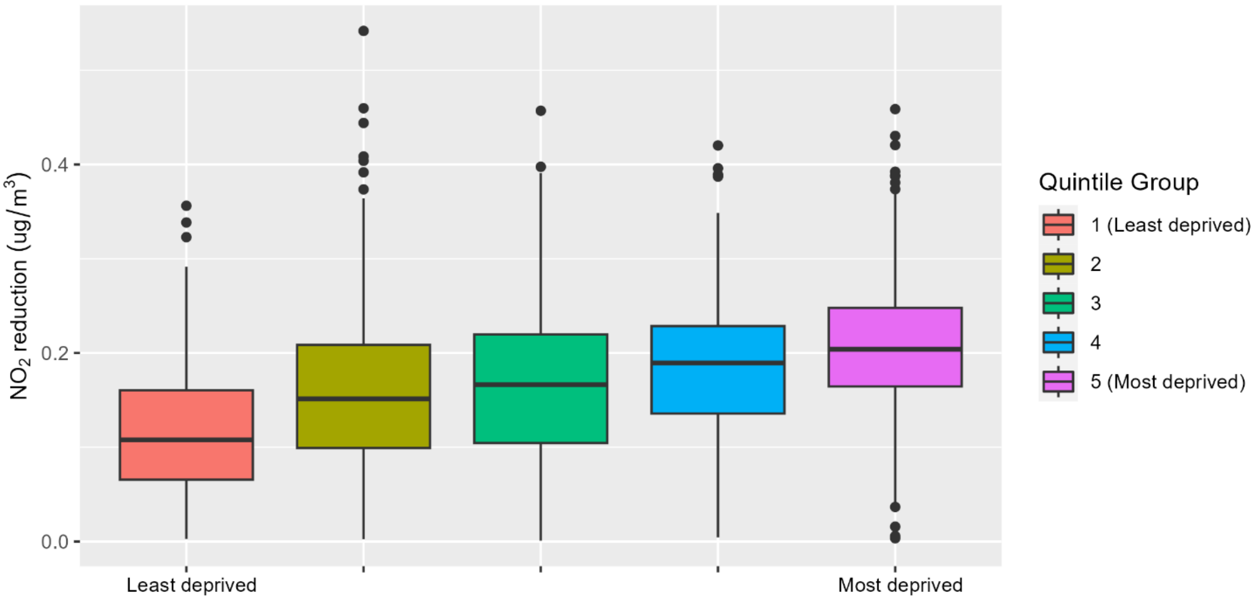


Table A- 5. Tabulated summary of the impacts within IMD quintile groups across West Yorkshire

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1st Quartile | 0.07 | 0.10 | 0.10 | 0.14 | 0.16 |
| Median | 0.11 | 0.15 | 0.17 | 0.19 | 0.20 |
| **Mean** | **0.12** | **0.16** | **0.17** | **0.18** | **0.21** |
| 3rd Quartile | 0.16 | 0.21 | 0.22 | 0.23 | 0.25 |
| Max | 0.36 | 0.54 | 0.46 | 0.42 | 0.46 |
| Total population | 265,117 | 410,885 | 417,708 | 458,585 | 869,801 |

The Spearman's Rank Correlation Coefficient was calculated as **0.33**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the IMD quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing the least deprived LSOAs) and those living in Quintile 5 (representing the most deprived LSOAs).

## A3.8 IMPACTS OF THE PROPOSED POLICY ON THE AVERAGE CONCENTRATION OF $NO_2$ IN AREAS WITH A LOW/HIGH PROPORTION OF CHILDREN

This section details the results from the analysis undertaken to understand the relationship between the average changes in $NO_2$ concentration brought by the CTAF scheme and areas with a low/high proportion of children.

### A3.8.1 Summary of the impacts on children across the Liverpool City Region

Figure A- 5. Boxplot of the change in $NO_2$ concentration within the children quintile groups across the Liverpool City Region

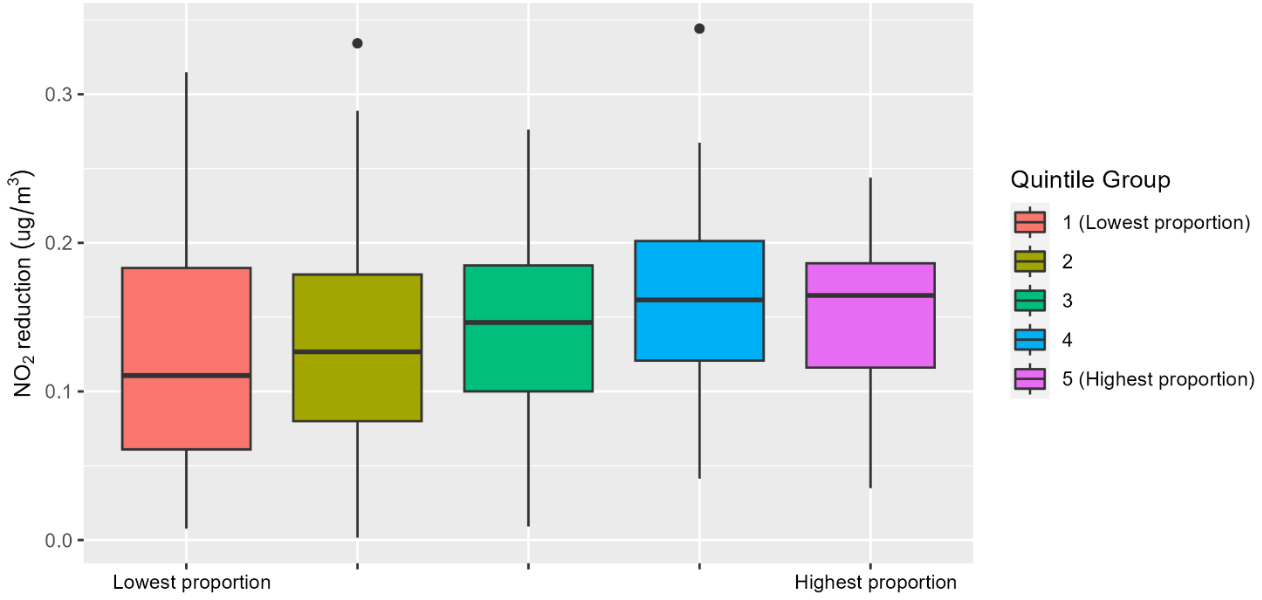


Table A- 6. Tabulated summary of the impacts within the children quintile groups across the Liverpool City Region

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.01 | 0.00 | 0.01 | 0.04 | 0.03 |
| 1st Quartile | 0.06 | 0.08 | 0.10 | 0.12 | 0.12 |
| Median | 0.11 | 0.13 | 0.15 | 0.16 | 0.16 |
| **Mean** | **0.13** | **0.13** | **0.15** | **0.16** | **0.15** |
| 3rd Quartile | 0.18 | 0.18 | 0.18 | 0.20 | 0.19 |
| Max | 0.31 | 0.33 | 0.28 | 0.34 | 0.24 |
| Total population | 357,983 | 338,930 | 331,997 | 319,606 | 268,459 |

The Spearman's Rank Correlation Coefficient was calculated as **0.20**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the children quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing LSOAs with the lowest proportion of children) and Quintile 5 (representing LSOAs with the highest proportion of children).

### A.3.8.2 Summary of the impacts on children quintile groups across Greater Manchester

Figure A- 6. Boxplot of the change in $NO_2$ concentration within the children quintile groups across Greater Manchester

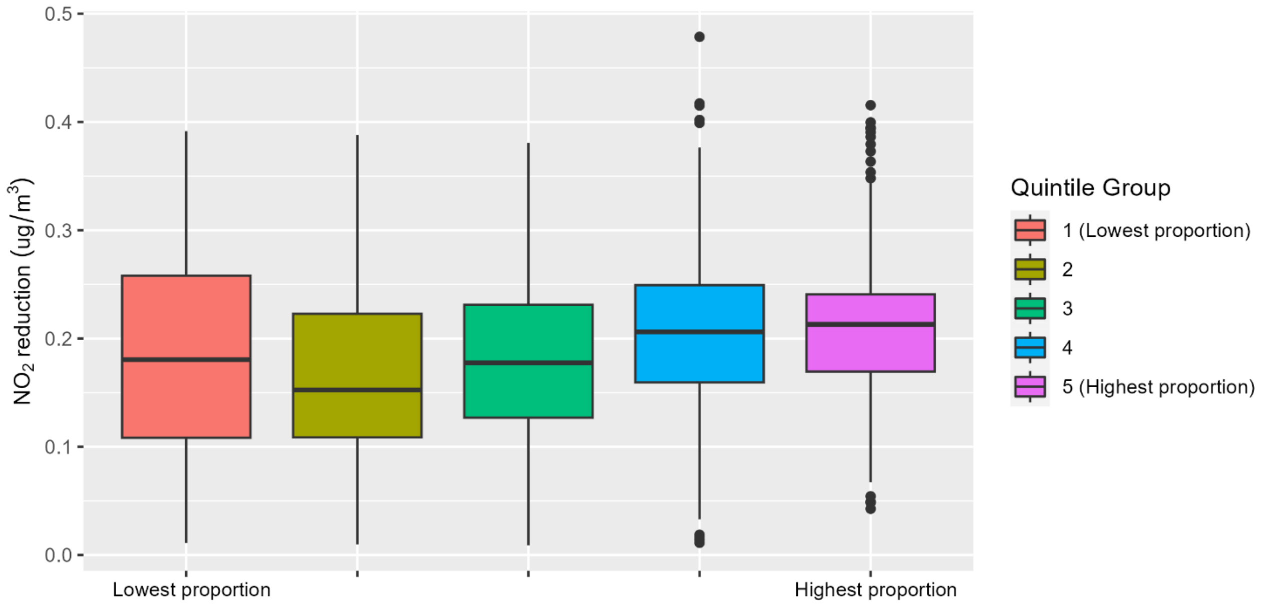


Table A- 7. Tabulated summary of the impacts within the children quintile groups across Greater Manchester

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.01 | 0.01 | 0.01 | 0.01 | 0.04 |
| 1st Quartile | 0.11 | 0.11 | 0.13 | 0.16 | 0.17 |
| Median | 0.18 | 0.15 | 0.18 | 0.21 | 0.21 |
| **Mean** | **0.19** | **0.16** | **0.18** | **0.21** | **0.21** |
| 3rd Quartile | 0.26 | 0.22 | 0.23 | 0.25 | 0.24 |
| Max | 0.39 | 0.39 | 0.38 | 0.48 | 0.42 |
| Total population | 390,402 | 475,347 | 557,578 | 583,203 | 925,724 |

The Spearman's Rank Correlation Coefficient was calculated as **0.18.**

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the children quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing LSOAs with the lowest proportion of children) and Quintile 5 (representing LSOAs with the highest proportion of children),

### A3.8.3 Summary of the impacts on children quintile groups across the West Midlands

Figure A- 7. Boxplot of the change in $NO_2$ concentration within children quintile groups across the West Midlands

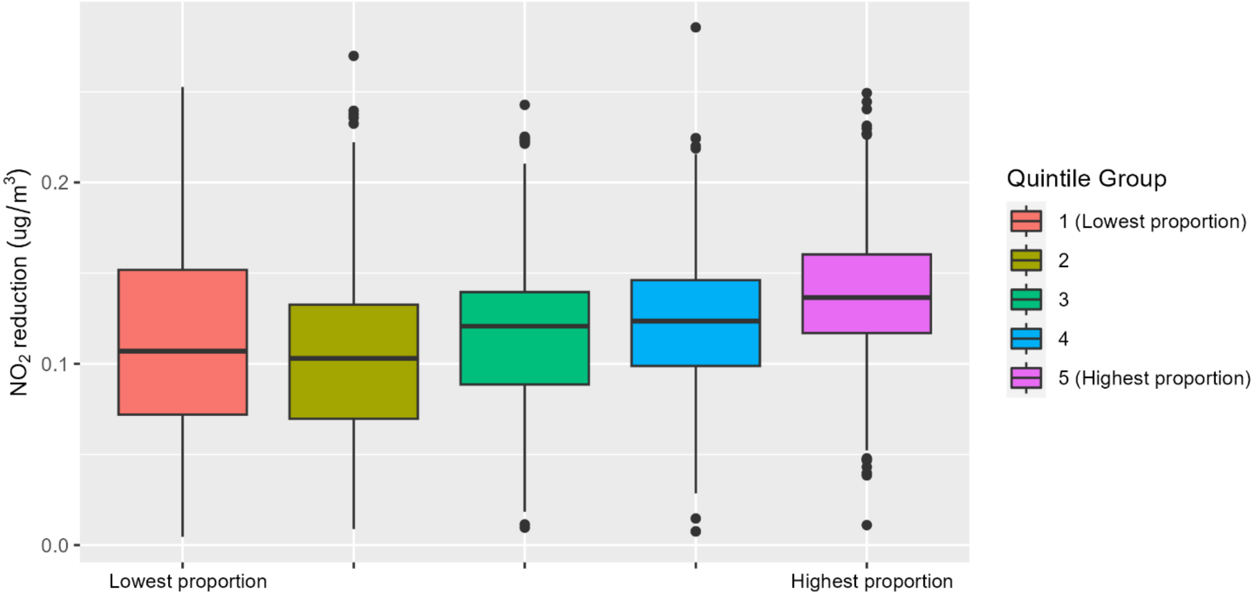


Table A- 8. Tabulated summary of the impacts within children quintile groups across the West Midlands

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1st Quartile | 0.07 | 0.07 | 0.09 | 0.10 | 0.12 |
| Median | 0.11 | 0.10 | 0.12 | 0.12 | 0.14 |
| **Mean** | **0.11** | **0.10** | **0.12** | **0.12** | **0.14** |
| 3rd Quartile | 0.15 | 0.13 | 0.14 | 0.15 | 0.16 |
| Max | 0.25 | 0.27 | 0.24 | 0.29 | 0.25 |
| Total population | 340,765 | 396,904 | 528,280 | 639,307 | 1,150,622 |

The Spearman’s Rank Correlation Coefficient was calculated as **0.28**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the children quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing LSOAs with the lowest proportion of children) and Quintile 5 (representing LSOAs with the highest proportion of children),

### A3.8.4 Summary of the impacts on children quintile groups across West Yorkshire

Figure A- 8. Boxplot of the change in $NO_2$ concentration within children quintile groups across West Yorkshire

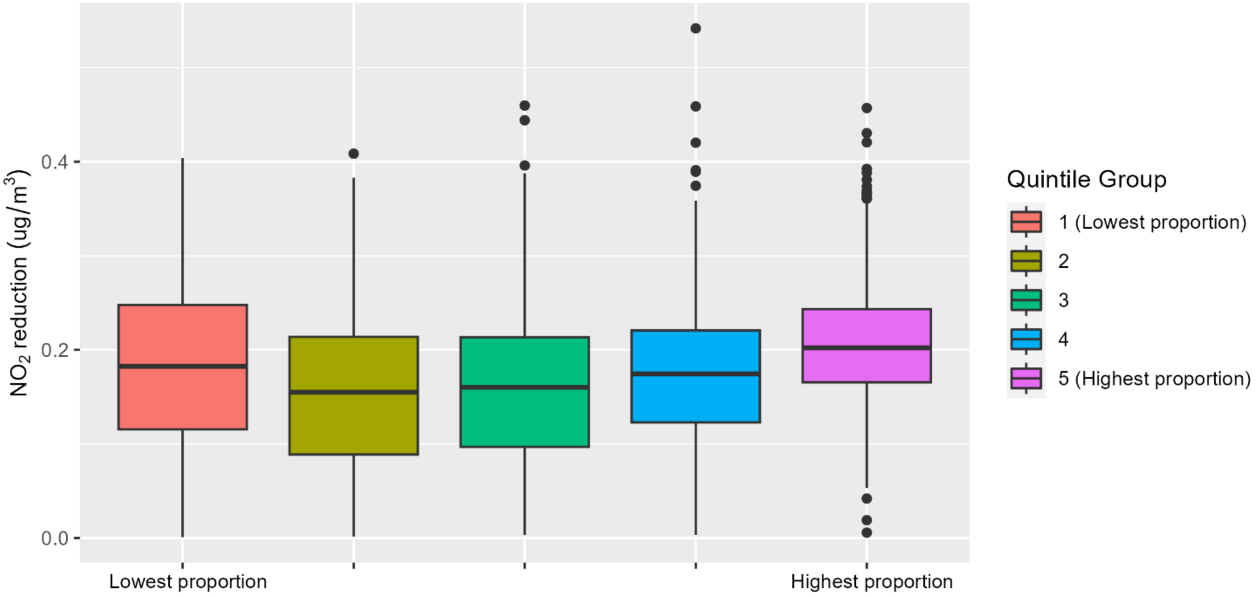


Table A- 9. Tabulated summary of the impacts within children quintile groups across West Yorkshire

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 1st Quartile | 0.12 | 0.09 | 0.10 | 0.12 | 0.17 |
| Median | 0.18 | 0.15 | 0.16 | 0.17 | 0.20 |
| **Mean** | **0.18** | **0.16** | **0.16** | **0.18** | **0.21** |
| 3rd Quartile | 0.25 | 0.21 | 0.21 | 0.22 | 0.24 |
| Max | 0.40 | 0.41 | 0.46 | 0.54 | 0.46 |
| Total population | 330,404 | 438,757 | 462,585 | 452,964 | 737,386 |

The Spearman's Rank Correlation Coefficient was calculated as **0.18**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the children quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ experienced by those living in Quintile 1 (representing LSOAs with the lowest proportion of children) and Quintile 5 (representing LSOAs with the highest proportion of children).

## A3.9 IMPACTS OF THE PROPOSED POLICY ON CONCENTRATION OF $NO_2$ IN AREAS WITH A LOW/HIGH PROPORTION OF ELDERLY CITIZENS

This section details the results from the analysis undertaken to understand the relationship between the changes in $NO_2$ concentration brought by the CTAF scheme and areas of low/high levels elderly citizens.

### A3.9.1 Summary of the impacts on elderly quintile groups across the Liverpool City Region

Figure A- 9. Boxplot of the change in $NO_2$ concentration within elderly quintile groups across the Liverpool City Region

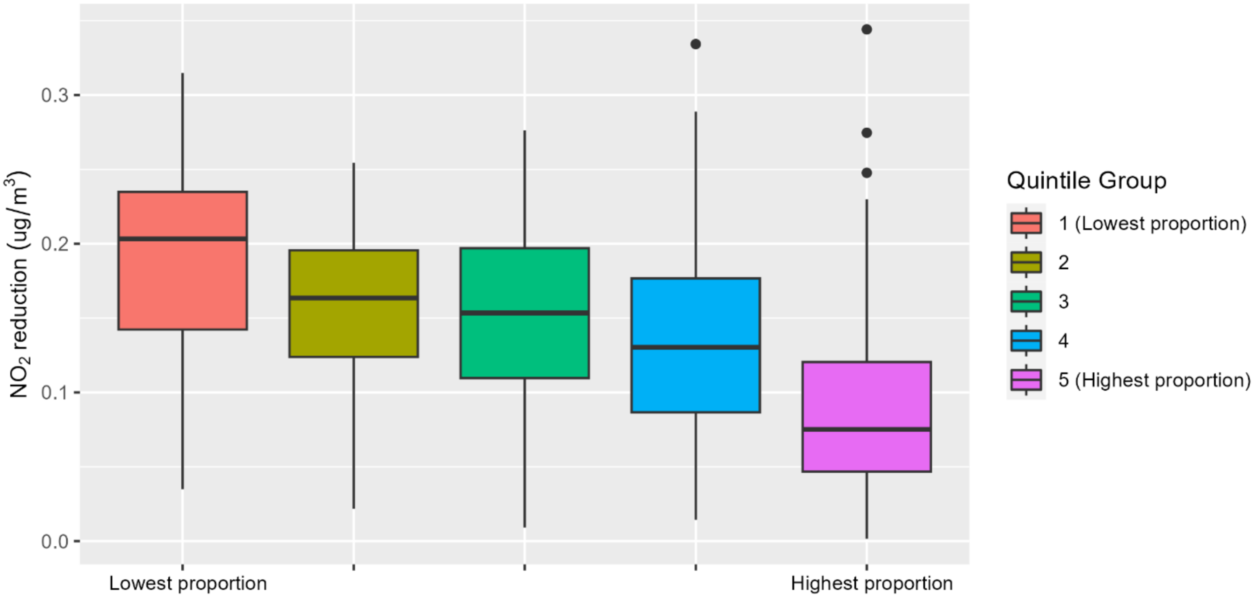


Table A- 10. Tabulated summary of the impacts on elderly quintile groups across the Liverpool City Region

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 |
| 1st Quartile | 0.14 | 0.12 | 0.11 | 0.09 | 0.05 |
| Median | 0.20 | 0.16 | 0.15 | 0.13 | 0.08 |
| **Mean** | **0.19** | **0.16** | **0.15** | **0.13** | **0.09** |
| 3rd Quartile | 0.23 | 0.20 | 0.20 | 0.18 | 0.12 |
| Max | 0.31 | 0.25 | 0.28 | 0.33 | 0.34 |
| Total population | 244,135 | 424,919 | 347,061 | 323,356 | 277,504 |

The Spearman’s Rank Correlation Coefficient was calculated as **-0.45**.

The results show that:

- There is a statistically significant correlation between the level of $NO_2$ reduction and the elderly quintile groups.
- There is only a very small difference in terms of the absolute concentration change of $NO_2$ across the quintile (1 – 4) groups. The exception to this trend is shown in Quintile 5 (representing LSOAs with the highest proportion of elderly citizens) where the level of average $NO_2$ reduction is under half the value shown for Quintile 1 (representing LSOAs with the lowest proportion of elderly citizens).

### A3.9.2 Summary of the impacts on elderly quintile groups across Greater Manchester

Figure A- 10. Boxplot of the change in $NO_2$ concentration within elderly quintile groups across Greater Manchester

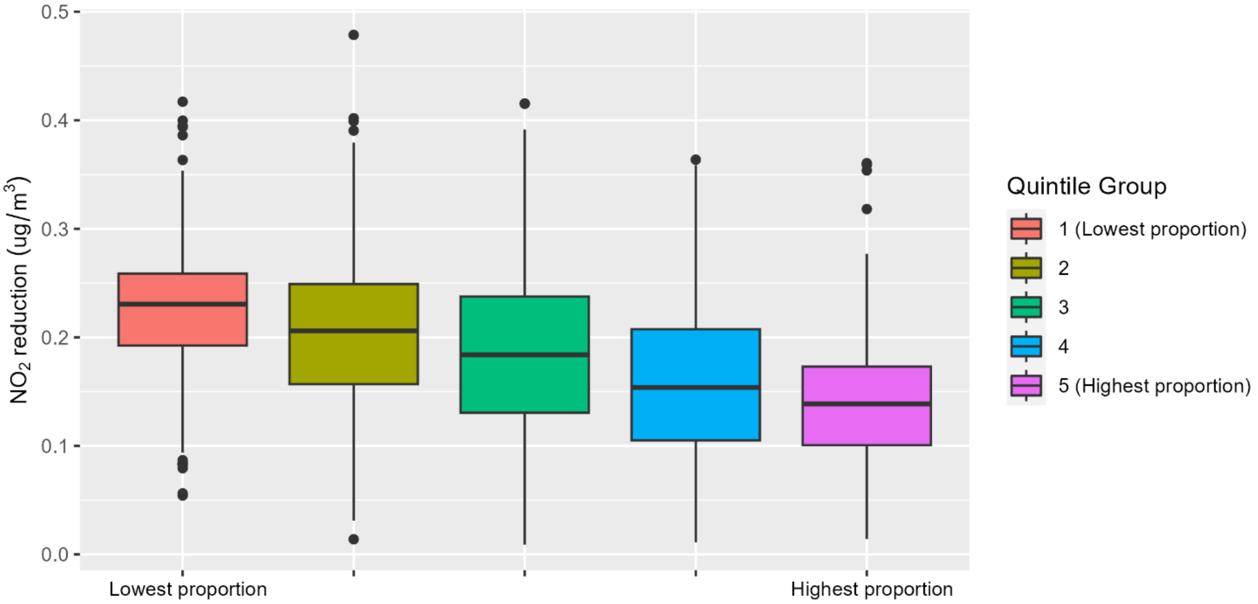


Table A- 11. Tabulated summary of the impacts within elderly quintile groups across Greater Manchester

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1st Quartile | 0.19 | 0.16 | 0.13 | 0.11 | 0.10 |
| Median | 0.23 | 0.21 | 0.18 | 0.15 | 0.14 |
| **Mean** | **0.23** | **0.21** | **0.18** | **0.16** | **0.14** |
| 3rd Quartile | 0.26 | 0.25 | 0.24 | 0.21 | 0.17 |
| Max | 0.42 | 0.48 | 0.42 | 0.36 | 0.36 |
| Total population | 893,655 | 730,309 | 609,679 | 445,885 | 252,726 |

The Spearman's Rank Correlation Coefficient was calculated as **-0.40**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the elderly quintile groups.
- There is only a very small difference in terms of the average absolute concentration change of $NO_2$ experienced by those living in Quintile 1 LSOAs (representing LSOAs with the lowest proportion of elderly citizens) and Quintile 5 LSOAs (representing LSOA's with the highest proportion of elderly citizens).

### A3.9.3 Summary of the impacts on elderly quintile groups across the West Midlands

Figure A- 11. Boxplot of the change in $NO_2$ concentration within elderly quintile groups across the West Midlands

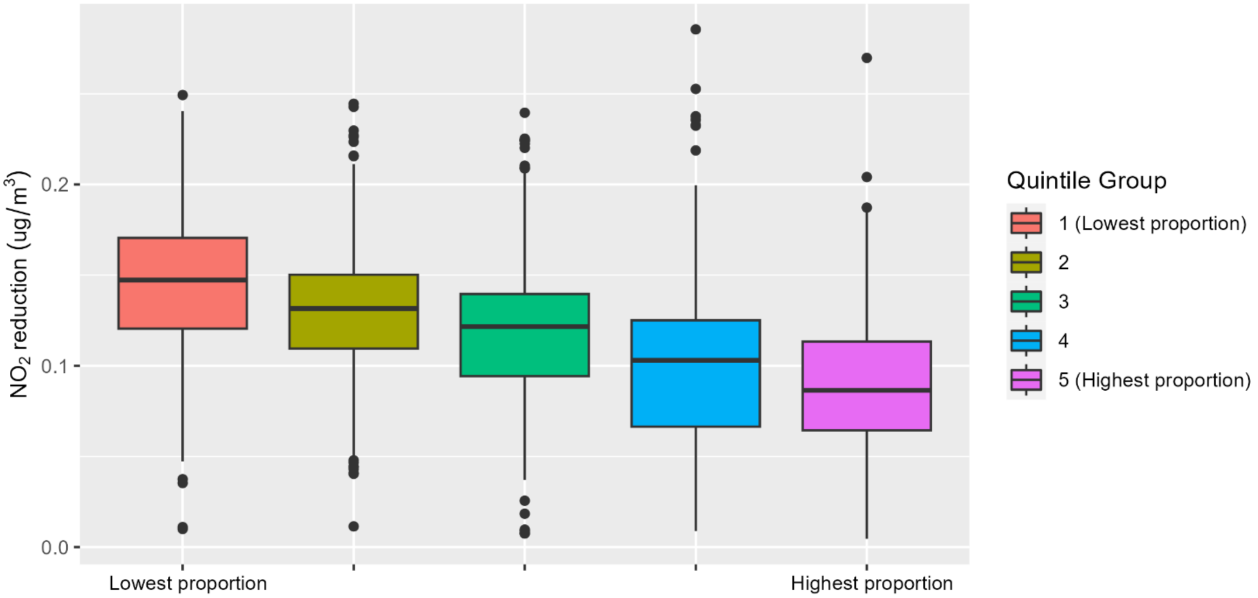


Table A- 12. Tabulated summary of the impacts within elderly quintile groups across the West Midlands

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| 1st Quartile | 0.12 | 0.11 | 0.09 | 0.07 | 0.06 |
| Median | 0.15 | 0.13 | 0.12 | 0.10 | 0.09 |
| **Mean** | **0.15** | **0.13** | **0.12** | **0.10** | **0.09** |
| 3rd Quartile | 0.17 | 0.15 | 0.14 | 0.13 | 0.11 |
| Max | 0.25 | 0.24 | 0.24 | 0.29 | 0.27 |
| Total population | 1,035,726 | 712,865 | 624,085 | 408,626 | 274,576 |

The Spearman’s Rank Correlation Coefficient was calculated as **-0.43**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the elderly quintile groups.
- There is only a very small difference in terms of the average absolute concentration change of $NO_2$ experienced by those living in Quintile 1 LSOAs (representing LSOAs with the lowest proportion of elderly citizens) and Quintile 5 LSOAs (representing LSOA’s with the highest proportion of elderly citizens).

### A3.9.4 Summary of the impacts on elderly quintile groups across West Yorkshire

Figure A- 12. Boxplot of the change in $NO_2$ concentration within elderly quintile groups across West Yorkshire

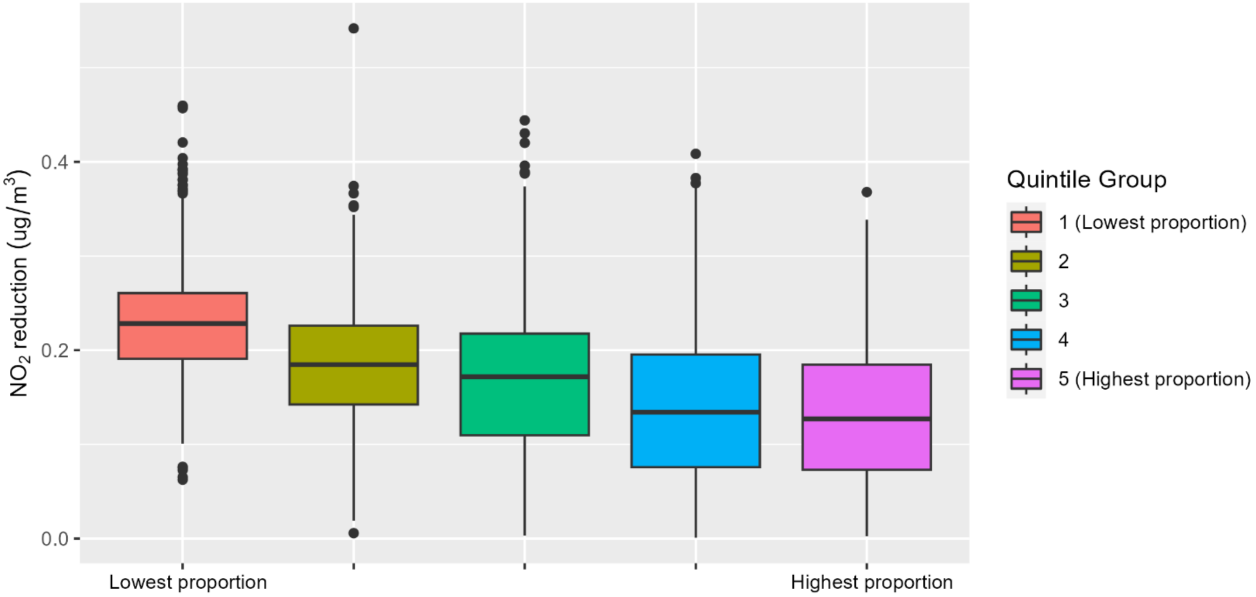


Table A- 13. Tabulated summary of the impacts within elderly quintiles across West Yorkshire

| | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 |
|---|---|---|---|---|---|
| Min. | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1st Quartile | 0.19 | 0.14 | 0.11 | 0.08 | 0.07 |
| Median | 0.23 | 0.18 | 0.17 | 0.13 | 0.13 |
| **Mean** | **0.23** | **0.19** | **0.17** | **0.14** | **0.14** |
| 3rd Quartile | 0.26 | 0.23 | 0.22 | 0.20 | 0.18 |
| Max | 0.46 | 0.54 | 0.44 | 0.41 | 0.37 |
| Total population | 640,965 | 553,595 | 477,740 | 498,298 | 251,498 |

The Spearman's Rank Correlation Coefficient was calculated as **-0.43**.

The results show that:

- There is a statistically significant correlation between the mean level of $NO_2$ reduction and the elderly quintile groups.
- There is only a very small difference in terms of the average absolute concentration change of $NO_2$ experienced by those living in Quintile 1 LSOAs (representing LSOAs with the lowest proportion of elderly citizens) and Quintile 5 LSOAs (representing LSOA's with the highest proportion of elderly citizens).

T: +44 (0) 1235 75 3000
E: enquiry-ee@ricardo.com
W: www.ricardo.com