Bristol City Council Clean Air Plan

Analytical Assurance Statement

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Contents

1. Overview

Poor air quality is the largest known environmental risk to public health in the UK[1]. Investing in cleaner air and doing more to tackle air pollution are priorities for the EU and UK governments, as well as for Bristol City Council (BCC). The Mayor of Bristol has often cited Bristol's 'moral and legal duty' to improve air quality in the city and the administration recognises that achieving improved air quality is not solely a transport issue. Notwithstanding the Council's work on a Clean Air Zone, efforts have been made to make citizens more aware of – and take personal responsibility for – various sources of air pollution, from traffic fumes to solid fuel burning. The Mayor has articulated a 'call to action' for local people, businesses and organisations to consider how small changes can make a significant difference in cutting toxic fumes across the city. BCC has monitored and endeavoured to address air quality in Bristol for decades and declared its first Air Quality Management Area in 2001. Despite this, Bristol has ongoing exceedances of the legal limits for Nitrogen Dioxide (NO_2) and these are predicted to continue until around 2027 without intervention.

The added context is that of the COVID-19 pandemic. Recent research suggests that poor air quality may be correlated with higher death / infection rates from COVID-19. This is further compounded by growing evidence that suggests that those from black, Asian and minority ethnic communities are more at risk of catching and dying from the virus and the fact that individuals from these communities are more likely to live in areas where air quality is poor. The challenge of maintaining public health and supporting economic recovery while also achieving legal air quality levels after lockdown restrictions are lifted will remain live and intersecting issues for the foreseeable future.

The UK Government continue to transpose European Union law into its Environment Bill[2], to ensure that certain standards of air quality continue to be met, by setting air quality assessment levels (AQALs) on the concentrations of specific air pollutants. It's very unlikely that these AQALs will differ to EU Limit Values prescribed by the European Union's Air Quality Directive and transcribed in the UK's Air Quality Standards Regulation 2010. Therefore, these Limit Values will remain in enforcement post-Brexit. In common with many EU member states, the EU Limit Value for annual mean nitrogen dioxide (NO_2) is breached in the UK and there are on-going breaches of the NO_2 limit value in Bristol. The UK government is taking steps to remedy this breach in as short a time as possible, with the aim of reducing the harmful impacts on public health. Within this objective, the Government has published a UK Air Quality Plan and a Clean Air Zone Framework, both originally published in 2017 (noting there have been subsequent revisions). The latter document provides the expected approach for local authorities when implementing and operating a Clean Air Zone (CAZ). The following business cases have been submitted to JAQU for the Clean Air Plan; Strategic Outline Case (April 2018), and an Outline Business Case (November 2019 and updated between April and June 2020).

Following the submission of the BCC CAZ Revised OBC, further work was undertaken to develop the Full Business Case (FBC) and develop a new option, the Small Area CAZ D option. This work, and the option development work undertaken as part of the FBC is presented in an updated Option Assessment Report (Appendix C FBC-16).

Jacobs supported BCC produce a Full Business Case for the delivery of the Clean Air Plan (CAP). The FBC provides an assessment of the Small Area CAZ D Option, which includes the following measures:

- Small Area Class D (charging non-compliant cars, buses, coaches, taxis, HGVs and LGVs);
- Fast Track Measures:
  - Closure of Cumberland Road inbound to general traffic; and
  - Holding back traffic to the city centre through the use of existing signals.

[1] Public Health England (2014) Estimating local mortality burdens associated with particular air pollution. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution
[2] Environment Bill 2019-21 https://services.parliament.uk/bills/2019-21/environment.html

The option modelling reflects the new baseline (with inclusion of Street Space schemes) as well as the Small CAZ D Option.

This Analytical Assurance Statement has been prepared in accordance with the requirements set out in the Joint Air Quality Units (JAQU) Evidence package of guidance. It considers the development of the base and baseline models, and the assessment of the shortlisted options. This version of the Analytical Assurance Statement is written to address issues raised by JAQU as part of their FBC review.

2. Limitations of the Analysis

2.1 Has the analysis been constrained by time or cost, meaning further proportionate analysis has not been undertaken? Could this further analysis lead to a substantive change in the conclusions?

Timescales for the project have been minimised as much as possible in order to comply with the Ministerial Directives, however this has not been at the expense of the quality of the traffic and air quality modelling. All modelling produced complies with JAQU guidance. In addition, the air quality modelling is compliant with Technical Guidance TG16, and the traffic modelling is largely compliant with TAG.

The air quality modelling has a greater level of detail in central Bristol where there are exceedances of the objective and at locations where there is the greatest traffic impact of the scheme. Outside of this area the model has a lower level of detail to reduce model run times to a manageable level. It is not anticipated that this assumption would substantially alter the outcome of the analysis.

The transport models used to assess the schemes were developed prior to the option development work, and in fact years before the study itself. If a modelling suite were developed for the sole purpose of assessing the options in the OBC and FBC, the models could have been structured to better reflect vehicle fuel types and CAZ vehicle compliance. However, using data collected during the study it has been possible to disaggregate the model in order to reflect vehicle fuel types and CAZ compliance in such a way that model validation has not been materially affected.

It is not anticipated that the assumptions outlined above regarding the modelling methodology will substantially alter the outcome of the analysis.

2.2 Does the analysis rely on appropriate sources of evidence and underpinning assumptions?

The project has made best use of data sources available at the time of assessment. The key data sources are discussed below, and a rating is provided to indicate the quality of the data source.

Since March 2020, there has been a reduction in traffic levels due to the COVID-19 lockdown restrictions. There are associated uncertainties about the impact of this on air quality in the future; for example, in terms of fleet renewal, levels of home working, use of public transport, etc. During the assessment more indications of the impacts of COVID-19 were available, but the full impact is unclear as the pandemic continues to influence transport, society and the economy. The impacts of COVID-19 have been considered in the following narrative about the evidence and assumptions.

2.2.1 ANPR surveys

The local fleet has been established from ANPR surveys, undertaken from 18th to 24th July 2017 . The survey covered all major routes into the city and captured traffic movements both into and out of 3 different cordons. Unfortunately, due to programme pressures at the time it was not possible to undertake the surveys during a neutral period. However, Bristol City Council has a number of permanent cameras located across the city. Data from the same period as the additional ANPR survey (July) and from a neutral period (June) has been analysed and found that the differences in fleet mix between the neutral and unneutral periods are minimal. As such, the ANPR survey data is considered to be reliable evidence of the fleet composition within Bristol. The ANPR data collected in 2017 is still considered a reasonable representation of the travel patterns at the time.

Rating: HIGH reliability rating

2.2.2 Age of the transport base model

The original 2013 base year traffic model was developed with, and validated against, a comprehensive set of traffic surveys conducted in 2013 in accordance with TAG criteria. This model has been used, combined with the development and highway changes, to develop a 2015 model for use in this study. The modelling work for the

OBC commenced in 2018, and during scheme development the model has become more dated. Due to the age of the model, checks were undertaken on traffic flows and speeds at locations where air quality was considered to be poor based on local monitoring data (i.e. critical locations). This is considered to be good modelling practice. Because of the discrepancies identified, adjustment factors were applied to the 2021 transport model outputs, and to subsequent modelled years, i.e. 2023 and 2031. This is considered to make best use of the modelling tools available. Traffic models in general have inherent inaccuracies but application of specific correction factors is considered to improve the accuracy of the results. This work is documented in the FBC-23, the transport modelling methodology report (T3). A check of model fit against traffic data was also undertaken for Church Road since this was identified as a critical location outside the scheme area. It has not been possible to take into account the correction factors at other locations on the network. However, it is noted that since the factors had the effect of bringing forward the compliance year then if corresponding adjustments were made elsewhere they would not be expected to give rise to a worsening of predicted concentration levels and therefore would not be expected to affect the conclusions of the study. Whilst it is recognised that the model is over 6 years old, the additional adjustments applied are considered to be reliable evidence for use in the study.
Rating: MODERATE reliability rating (when localised adjustments have been applied).

2.2.3 Transport model forecast assumptions

The transport model forecasts use information from the Emissions Factor Toolkit (which is discussed below) and local/regional growth assumptions. All sources of information that were used to prepare the forecast models (2021, 2023 etc) were done so without the inclusion of the impacts of COVID-19.

Bristol City Council have collated traffic and air quality data to consider the impact of the COVID-19 pandemic. This work is detailed in the Clean Air Zone Board Report – Traffic Behaviour 2019-2020 (Appendix S of the Option Assessment Report). Combining the evidence base available for both traffic volumes and air quality before, during and post lockdowns, the work concluded that the evidence shows a decline in traffic volumes and improvements to air quality during the first lockdown in particular. The second lockdown however, was less restrictive than the first and as such didn't lead to such a steep decline in traffic volumes. Following lockdown 2 and a subsequent transition between tiers 2 and 3, traffic numbers appeared to have returned to that of a similar pattern to pre-lockdown and a worsening of air quality in some parts of the city.

For comparative purposes, data from October 2019 and October 2020 was considered, as October 2020 was the key period when traffic had most chance to return to normal levels; before the lockdown 2 and Christmas period changed things again. This showed that traffic in the critical locations during October 2020 was 82% of that same time the previous year.

Taking everything into consideration, it was concluded that with some areas of the city back to near normal traffic levels (although not all), that compliance will not be achieved at a small number of key sites by non-charging measures alone and therefore this means that annual compliance will not be met.

In addition to the matters set out above, the forecasting work assumes that the scheme will be implemented in October 2021. It is likely that this will move to summer 2022 resulting in the exemptions being in operation in the first part of 2023. Mitigation measures will be offered in advance of the go live date, reducing the likelihood of compliance being impacted.

Rating: LOW reliability rating

2.2.4 Fleet projections (fuel split and Euro standard split)

The best available evidence has been used, as specified by JAQU. Both the traffic model/emissions and air quality model meet the quality criteria provided by JAQU. Local fleet composition data were derived from an analysis of ANPR data across the study area.

One of the sensitivity tests undertaken integrated a one-year delay in the fleet improvement to simulate one possible post-COVID-19 / lockdown scenario whereby the vehicle fleet does not upgrade as quickly as anticipated. The results of this indicated that compliance would not be achieved in 2023 on Rupert Street or

Marlborough Street. It should be noted though, that this model scenario does not take potential decline in traffic volumes into account, which may offset the impact on air quality of the delay to fleet improvement to some extent.

Emerging national evidence suggests that the fleet turnover is slower than the 1 year delay sensitivity test, and thus:

Rating: LOW reliability rating

2.2.5 Traffic speeds

Speed data is taken from the traffic model. Alternative sources of speed data are available for the base year, for example Traffic Master or surveys, but such sources would not provide speed data for forecast years or for option assessments. Journey times within the traffic model have been validated, giving some confidence in the modelled speeds, however this validation necessarily covers a limited number of routes. A comparison between modelled speeds and TrafficMaster data was undertaken as described in the section relating to the "Age of the model" Rating: MODERATE reliability rating.

2.2.6 Stated Preference Surveys

A local Stated Preference survey was undertaken to establish the response rates of Cars and partially inform the response rates of other vehicle classes. The survey was undertaken by an online market research panel and targeted at a demographically representative sample of panel members in Bristol and the surrounding area. 1160 questionnaires were completed, and the data provided good coverage in terms of ages, trip travel purposes and origins. Stated Preference surveys do have limitations in that they rely on participants to make predictions about their future behavioural responses and there is often some difference in these predictions and how people actually respond. However, without these surveys, the analysis would have relied on stated preference work undertaken for London which has a number of differences to Bristol in terms of demographics, travel patterns and travel options. Therefore, the use of locally collected data is considered more appropriate.

For HGVs, local information regarding responses to a charging CAZ was not available hence the analysis used responses identified in the JAQU Evidence Package. This introduces some uncertainty regarding how well the JAQU data relates to local responses for Bristol. However, it can be seen that there is reasonable agreement between the evidence package responses and the Stated Preference results for cars and LGVs, providing increased assurance of the applicability of the JAQU data for HGVs.

The Stated Preference survey results do not differentiate between responses for LGV respondents who own the vehicle verses LGV respondents who operate the vehicles on behalf of large companies.

The Stated Preference surveys were conducted before the COVID-19 pandemic and therefore do not reflect the changes in attitude towards financial ability to upgrade vehicles, public transport provision, the perception of the safety of public transport and opportunities to work at home.

Rating: LOW reliability rating

2.2.7 Emissions Modelling

Emissions modelling was undertaken following guidance provided in the JAQU Evidence Package. The Emissions Factor Toolkit (EFT) used throughout the life of this project is version v8.0.1.a, which was the most up to date version when the modelling work started. Since then, versions 9 and 10 of the EFT have been released. The Air Quality Team applied the EFT to generate emissions rates using emission functions which have been consistent through subsequent versions of the tool. User defined fleets were compiled by the transport team using EFT version 9. These updated fleets were then pasted and applied to EFT v8.0.1.a. To summarise;

1. Traffic information was provided as compliant and non-compliant flows and fleet proportions based on EFT version 9.1b. The flows were AADT.

2. The data were pre-processed to the precise EFT format and then copied into the EFT (both flows and euro proportions)

3. EFTs were then run and then gradient factors applied to the compliant and non-compliant outputs.

4. The output NO_X emission rates from (3) were then post processed to derive NO_2 annual mean concentrations using the Jacobs bespoke rapid dispersion modelling technique

Rating: MODERATE reliability rating

2.2.8 Air Quality Model

The air quality modelling has been undertaken using ADMS Roads v4.1 and v4.2 (a precursor to v5). The ADMS Roads model is widely used for air quality modelling and assessment, particularly in relation to planning applications within the UK. Use of this model is in line with JAQU guidance.

The base year air quality models rely on Defra's EFT, and other Defra tools to provide background concentrations, convert NOx to NO_2, and incorporate location specific primary NO_2 fractions. As a result of the 2015 verification year, the tools used all had to be compatible with the 2015 background maps. These are industry standard tools, and usage of them follows best practice as well as recommendations within the JAQU guidance.

The model contains assumptions concerning the following:

- Canyon effects
- Air turbulence caused by vehicles
- Meteorological data

Modelling was undertaken at a number of receptors in a range of environments, reflecting the risk assessment of achieving compliance with the AAQD The approach utilised an ADMS output which produced a result for each source receptor combination. This facility was embedded into a new processing tool providing rapid NOx concentrations at each receptor based on the change in emission rates for any given scenario. The process was equally replicated for verification purposes to include dispersion model performance. Although the version of ADMS BCC used had the new canyon tool, BCC factored the canyon results into the processing tool to account for this change, so we're effectively still using ADMS Roads v4's canyon tool.

Rating: Overall MODERATE reliability rating

2.2.9 Use of 2015 air quality data

The base year air quality model also relies heavily on the 2015 air quality monitoring data which is used to verify the ADMS model. This data is collected across the city, in accordance with procedures outlined in LAQM TG16, with diffusion tubes bias adjusted in line with current guidance. The level of confidence in the verification process is necessarily enhanced when data from a number of automatic analysers have been used, as was the case in this assessment. It is therefore considered to be reliable evidence. Rating: HIGH reliability rating.

2.2.10 Summary

A comprehensive assessment of the evidence and underpinning assumptions has been undertaken by the project team in order to establish the quality of the base/baseline modelling and to consider the sensitivity tests which may be appropriate within the Full Business Case. The table below summarises the key assumptions which relate to the base and baseline modelling, along with a rating of reliability.

Assumption	Source	Reliability Rating
Base year fleet composition	ANPR data	High
Base year traffic flows	GBATs traffic model	Moderate (with localised adjustments)

Assumption	Source	Reliability Rating
Fleet projections (fuel split and Euro standard split)	EFT projections applied to ANPR data	Low/Moderate
Growth in traffic flows	TEMPRO v7.2 and other sources	Low/Moderate
Traffic speeds	GBATs traffic model	Moderate
Behavioural response to CAZ	SP and JAQU data sources	Low
Background concentrations	Defra maps (modelled) adjusted with local monitoring	Moderate
Measured concentrations	Diffusion tube and real-time monitoring sites	Moderate
Canyon effects	ADMS canyon definition (latest module)	Moderate/Low
Road widths	OS mapping	High
Gradients	Lidar	Moderate
Primary NO_2 Fraction	EFT	Moderate
Meteorological data (2015)	Meteorological office (via a supplier)	Moderate/Low

3. Risk of Error / Robustness of Analysis

3.1 Has there been sufficient time and space for proportionate levels of quality assurance to be undertaken? Have sufficient checks been made on the analysis to ensure absence of errors in calculations?

Quality Assurance (QA) plays an essential part in any analytical project and allowing sufficient time for appropriate quality assurance processes has been a priority within the project team. Effective QA ensures that decisions are made with an appropriate understanding of evidence and risks, and helps analysts ensure the integrity of the analytical output. Jacobs have a robust QA System certified under ISO9001.

Extensive QA has been undertaken on the traffic and air quality models by staff who are independent of the model development team. The models for this project are complex and include thousands of individual road-links. As such, there is a large amount of data and in order to check individual links a series of flags are incorporated into the process. These flags include predetermined thresholds. Whilst not full proof it does allow specific results to be highlighted for re-examination. In addition, checks have focused on methodologies, model set-up, model calculations, consistency of inputs using sample data at key locations, and sense checks of model outputs using sample data at key locations. Checking has covered all model inputs and outputs.

Wherever anomalies have been identified both from manual and automatic processes further checks have been undertaken to explore for errors in the data or calculations. The study team produced a series of technical notes required to ensure that the approach reflects guidance issued by JAQU.

This system is proportionate to the time and budget available, and the decisions been made based upon the model outputs. As such, the accuracy of the model results is expected to be reasonable and consistent. However, it is not an absolute guarantee that there are no errors within the model.

3.2 Have sufficiently skilled staff been responsible for producing the analysis?

All members of staff used in all aspects of the modelling are suitably qualified, the majority being senior consultants and above, reflecting the complexity of the modelling and the need for robustness of outcomes. The project has oversight from senior members of staff in all areas (traffic modelling, air quality modelling and economics) who are able to call on their extensive modelling and project experiences to guide the assessment process.

4. Uncertainty

4.1 Is the level of uncertainty proportionate to the decision being made at the time of the Full Business Case?

There are many components that contribute to the uncertainty of modelling predictions. The dispersion model used in this assessment is dependent upon the traffic data that have been used to calculate emission rates, which will have inherent uncertainties associated with them. There are then additional uncertainties, as models (both traffic and air quality) are required to simplify real-world conditions into a series of algorithms.

However, these uncertainties are not specific to this project, and are inherent in any traffic and/or air quality modelling project. The development of the base and baseline models has followed government guidance and best practice throughout in order to minimise the level of remaining uncertainty.

The base year modelling, both traffic and air quality, has been verified against recent and reliable observed/monitored data, providing reasonable confidence in the 2015 model. Predicting pollutant concentrations in a future year will always be subject to greater uncertainty. For obvious reasons, the model cannot be verified in the future, and it is necessary to rely on a series of projections provided by DfT and Defra as to what will happen to traffic volumes, background pollutant concentrations and vehicle emissions.

For air quality the dispersion modelling output in the base year 2015 was compared with 80 diffusion tube monitoring sites and 5 automatic monitoring sites. It is always useful to examine whether the dispersion model performs differently depending on spatial or physical attributes (e.g. certain road types or traffic situations). The preference is to apply a global adjustment so that the certainty in the performance of the model is not unduly biased geographically. In other words, there is a fair spatial distribution in over and underperforming receptors. The performance of the Bristol model was found to be reasonably good with global adjustment applied.

The level of uncertainty within the base and baseline modelling has been minimised as far as possible and is suitable for decision making in the Bristol Clean Air Plan. However, it is recognised that COVID-19 results in some new uncertainty in the forecasted impacts.

To assess the uncertainty further, a series of sensitivity tests were undertaken on both the models of the baseline and preferred option as part of the Outline Business Case submitted to JAQU in October 2019 and May 2020, as reported below.

Full details of this assessment are provided in FBC-31 'Sensitivity Test report' appended to this report. A summary of the key results of the FBC sensitivity tests is provided below.

Test	Section Number	Summary	Key Results
October 2019 tests			
Uncertainties in the Traffic Modelling			
HGV adjustment factors	2.2.1	HGV flow adjustments were made on links with significant differences in modelled flows compared to observed counts. These adjustments were carried through to future years for both the baseline and Core scenario.	The statistics indicated that removing HGV adjustment factors had a negligible impact on NO_2 concentrations at reportable receptors. The maximum NO_2 concentration increased by one tenth of a microgram resulting in the gap between exceeding the Limit Value narrowing slightly.

Test	Section Number	Summary	Key Results
HGV adjustment factors	2.2.1	HGV flow adjustments were made on links with significant differences in modelled flows compared to observed counts. These adjustments were carried through to future years for both the baseline and Core scenario.	The statistics indicated that removing HGV adjustment factors had a negligible impact on NO_2 concentrations at reportable receptors. The maximum NO_2 concentration increased by one tenth of a microgram resulting in the gap between exceeding the Limit Value narrowing slightly.
Fleet Composition: Splits by Fuel Type	2.2.2	A test to examine the differences in annual mean NO_2 concentrations between the Core Scenario modelled using fuel splits derived from the TAG Databook and new information provided in the EFT v9.1b	If the EFT V9.1b fuel splits are used then the 2027 Core scheme would be compliant by a greater margin (-2 µg/m^3), with a maximum exceedance of 38.0 µg/m^3. The revised fuel splits are considered to be more robust than the TAG Data Book
Behavioural Reponses to Charging	2.3.1	Defined pessimistic and optimistic response rates based on confidence intervals of SP survey statistical modelling and adjusted assumptions for other vehicle types. Compared NO_2 concentrations to Core scenario.	The results for the high and low scenarios are very similar and overall, the 'Central' scenario is most representative. The conclusion of compliance is thus considered appropriate.
Uncertainties in the Air Quality Modelling			
Euro 6 Vehicles	3.1.1	The EFT is based on COPERT 5 which predicts different NOx emissions from Euro 6 diesel vehicles registered in different years (based on the expectation that Euro 6 emissions will reduce over time). Sensitivity test outlined in JAQU's 'Supplementary Note on Sensitivity Testing' has been run.	The results indicate that the central case assumption represents with reasonable certainty the range of expectant Euro 6 variance of NOx emissions from diesel light duty vehicles.
Emissions at Low Speeds	3.2.1	JAQU has set out a methodology to assess the uncertainty of emissions from vehicles travelling at low speeds in their 'Supplementary Note on Sensitivity Testing' which involves using a polynomial equation provided by JAQU which is based on using the COPERT emissions functions beyond their intended speed ranges.	There is little or no difference between the 'High' and 'Central' predictions, with a difference of -1.3% as a maximum percentage gap from compliance. The 'Low' scenario also predicts similar concentrations. In all three scenarios, the 2027 Core scenario is compliant.
Background Concentrations	3.3	To test the sensitivity of results to calibration adjustments made to the 2015 Defra modelled background concentrations (these being based on COPERT5 emission factors) compared with local NO_2 monitoring results.	Without a local calibration factor being applied to Defra's national pollution background maps, the predicted concentrations are generally lower than if backgrounds are calibrated, receptors remain compliant.
Model Verification	3.4	The model verification for road NOX and subsequent NO_2 on roads adjacent to monitoring sites was thoroughly tested and included comparing a zoned with a global approach. The verification factor applied to all receptors was 2.28 and was based on 85 sites. The zonal approach considered non-gradient roads, gradient roads and Rupert Street which has very specific air quality issues.	There was no justification for sensitivity testing the verification for any other parameters.

Test	Section Number	Summary	Key Results
Gradients	3.5.1	JAQU has set out a methodology to assess the uncertainty of vehicles travelling on gradients in their 'Supplementary Note on Sensitivity Testing' and suggest that LAs run a sensitivity test around gradient-based emission factors by removing the impact of modelling gradients if gradients were modelled in the 'central' scenario.	The results of the sensitivity tests for a 2027 Core scenario indicate that overall gradient has little impact on the results. Clearly, were specific links to be analysed where gradients are evident the results would show greater differences. There was a slight reduction in the mean and the maximum annual mean NO_2 concentrations, all receptors remained compliant
Primary NO_2 Fraction	3.6.1	There is emerging evidence that the average primary NO_2 fraction (f-NO_2) in exhaust emissions from road vehicles has begun to decrease in recent years. This is not taken into account within the EFT, as used for the air quality modelling. To account for this, JAQU suggest that a sensitivity test be carried out whereby the f-NO_2 values are reduced by 40% in the future projected year.	If the f-NO_2 values are reduced by 40% then the predicted concentrations are slightly lower, with the maximum predicted concentration being 4 $\mu g/m^3$ lower than the 'Central' scenario. This suggests that an earlier year to the predicted 2027 could be compliant if f-NO_2 values decrease in accordance with this assumption. On this basis, the 'Central' scenario with a 2027 compliant year is considered to be robust.
May 2020 tests			
Behavioural Reponses to Charging	4.2	Defined pessimistic response rates based on confidence intervals of SP survey statistical modelling and adjusted assumptions for other vehicle types. Compared NO_2 concentrations to Medium C + Small D scenario.	Air quality is likely to be adversely affected with the mean concentration increasing by 0.2$\mu g/m^3$ and the maximum by 0.5 $\mu g/m^3$. In terms of the compliance year, the 'pessimistic' scenario puts compliance back to 2024 from the 2023 Core estimate
P&R Decremental Test *	4.3	Removal of the M32 P&R but retained bus lane. Compared NO_2 concentrations to Medium C + Small D scenario.	Air quality would be adversely affected with the mean concentration increasing by 0.1$\mu g/m^3$ and the maximum by 0.4 $\mu g/m^3$. In terms of the compliance year, the 'decremental' scenario would put compliance back to 2024 from the 2023 Core estimate
Age of Transport Model	4.4	Traffic flow and speed adjustments were made on critical links in terms of Air Quality. Compared NO_2 concentrations to Medium C + Small D scenario.	Air quality is likely to improve slightly. However, across the study area these changes were marginal as shown by the mean remaining the same as the Core scenario. The maximum concentration is reduced by 1.4 $\mu g/m^3$. In terms of the compliance year, the 'speed and flow' scenario brought compliance forward to 2022 from the 2023 Core estimate.
Revised Boundary around St Philips Causeway *	4.5	Changes made to the Medium CAZ boundary to exclude St Philips Causeway. Compared NO_2 concentrations to Medium C + Small D scenario.	Air quality is likely to improve very slightly. The change in concentration across the range of statistics was approximately 0.1$\mu g/m^3$. In terms of the compliance year, the 'revised boundary' scenario had no effect on the compliance year.

Test	Section Number	Summary	Key Results
Diesel Car Ban Test	4.6	Defined adjusted response rates related to linked trip and time of day assumptions. Compared NO_2 concentrations to the Revised Hybrid	For this test, air quality improved very slightly. The change in the annual mean concentration across remained the same however the maximum concentration reduced by 0.7 µg/m³. In terms of the compliance year, the 'diesel ban sensitivity' scenario pushed the compliance back to 2024 from the Core scenario at Marlborough and Baldwin Street.
Uncertainties in the Air Quality Modelling			
Euro 6 Vehicles	3.1.1	The EFT is based on COPERT 5 which predicts different NOx emissions from Euro 6 diesel vehicles registered in different years (based on the expectation that Euro 6 emissions will reduce over time). Sensitivity test outlined in JAQU's 'Supplementary Note on Sensitivity Testing' has been run.	The optimistic Euro 6 scenario was predicted to reduce the maximum concentration by approximately 3 µg/m³, whereas the Euro 6 pessimistic scenario predicted a near 4 µg/m³ increase. In terms of the compliance year, the 'Euro 6 pessimistic' scenario pushed the compliance year back beyond 2025 at the Marlborough Street and Baldwin Street critical locations and forward to 2021 from 2023 at 5 critical locations...The results indicate that the central case results are sensitive to the optimistic and pessimistic assumptions made for changes to Euro NOx emissions standards expected from diesel light duty vehicles.

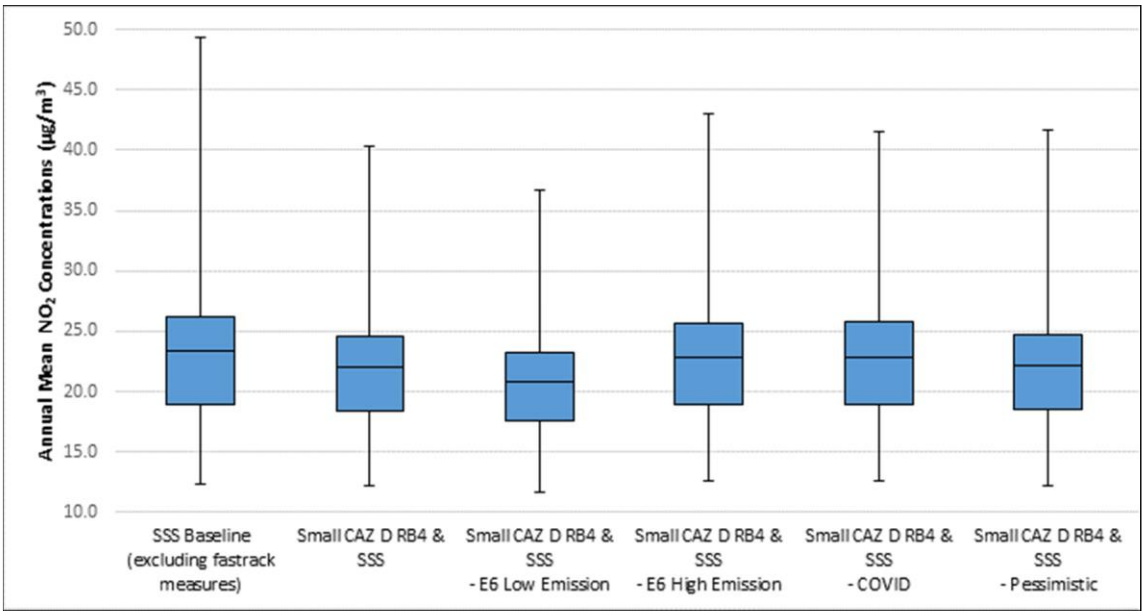
*These tests are not applicable to the Small CAZ D option

In summary, a wide range of sensitivity testing were undertaken which showed both compliance and non-compliance with the Ambient Air Quality Directive limit value. Whilst this demonstrates that there was some variability within the results (as would be expected in any modelling process), the likelihood of compliance and non-compliance occurring was fairly similar, even when taking into account cumulative aspects. There was emerging evidence that the average primary nitrogen dioxide fraction (f-NO_2) in exhaust emissions from road vehicles has begun to decrease in recent years, and the sensitivity testing has demonstrated that this may result in lower concentrations in some locations; this assumption was a noticeable uncertainty associated with the modelling.

Following the submission of the BCC CAZ Revised OBC in April/June 2020, further work was undertaken to develop the scheme, and this work resulted in the development of a new option, the Small area CAZ D option. This work, and the option development work undertaken as part of the FBC is presented in an updated Option Assessment Report (Appendix C FBC-16). The results of sensitivity testing work supporting this new option is summarised below.

Test	Section Number	Summary	Key Results
Behavioural Reponses to Charging	4.2	Defined pessimistic response rates based on confidence intervals of SP survey statistical modelling and adjusted assumptions for other vehicle types. Compared NO_2 concentrations to Small D scenario.	Air quality is likely to be adversely affected with the mean concentration increasing by 0.1 µg/m^3 and the maximum by 1.3 µg/m^3. The compliance year is pushed back beyond 2023. This test illustrates the "breaking point" of the scheme as it shows that adjusting the response rates based on the Stated Preference survey confidence limits will delay the scheme compliance beyond 2023.
One Year Fleet Delay Test	4.3	One-year fleet renewal delay undertaken as a sensitivity test due to the potential effects of COVID-19 on the natural fleet turnover through time.	Air quality is likely to be adversely affected across the whole model domain, with the mean concentration increasing by 0.8 µg/m^3 and the maximum by 1.2 µg/m^3. The compliance year is pushed back beyond 2023.
Uncertainties in the Air Quality Modelling			
Euro 6 Vehicles	3.1.1	The EFT is based on COPERT 5 which predicts different NOx emissions from Euro 6 diesel vehicles registered in different years (based on the expectation that Euro 6 emissions will reduce over time). Sensitivity test outlined in JAQU's 'Supplementary Note on Sensitivity Testing' has been run.	The Low Emission Euro 6 scenario was predicted to reduce the maximum concentration by 3.6 µg/m^3, whereas the Euro 6 High Emission scenario predicted a 2.7 µg/m^3 increase. In terms of the compliance year, the High Emission scenario pushed the compliance year back beyond 2023 at the Marlborough Street critical location. The Low Emission scenario may have brought the compliance year forward from 2023, although without other modelled years for this scenario, it is not possible to tell. The results indicate that the central case results are sensitive to changes in Euro 6, 6c and 6d proportions and the associated NOx emissions standards expected from diesel light duty vehicles.

Further to the information presented in the sensitivity test report, the figure below provides an overview of performance resulting from each of the sensitivity tests considered. Results should be compared against the box plot second from the left. Box plots are a simple way of representing several statistical parameters simultaneously (i.e. minimum, maximum, average/median, first quartile, and third quartile.). The number of observations upon which these statistics are based equal 1399 receptors. The plots indicate range of concentrations, the average represented by the horizontal line in the blue box and the difference between the average, Q1 and Q3 is represented by the extents of blue box. The number of observations within quartiles are the same across all scenarios because the receptors remain the same. The statists indicate that the high Euro 6 and COVID response increases the overall annual mean NO_2 concentration (i.e. max and minimum). The mean minus Q1 and Q3 are largely unaffected. In general, the statistics assured that the range of likely behaviour response to affect the compliance year compared to the core scenario are likely.


Annual Mean NO_2 Concentrations (µg/m³)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
SSS Baseline (excluding fastrack measures)
Small CAZ D RB4 & SSS
Small CAZ D RB4 & SSS - E6 Low Emission
Small CAZ D RB4 & SSS - E6 High Emission
Small CAZ D RB4 & SSS - COVID
Small CAZ D RB4 & SSS - Pessimistic

5. Use of Analysis

5.1 Does the evidence provided support the business case? Is there evidence the agreed target will be achieved?

5.1.1 'Bristol CAZ Air Quality Modelling Review' undertaken for the OBC by AQC

Air Quality Consultants Ltd (AQC) were commissioned to undertake a high-level review of air quality modelling for the Bristol CAZ. The review considered:

- Modelling methodology and Quality Assurance procedures (with specific reference to the appropriateness of the dispersion modelling methodology);
- Model setup, focusing on areas driving compliance, the factors behind this and whether factors are specific to Bristol or caused by model setup or assumptions; and
- Provide general comments on air quality aspect of the work undertaken.

In its review of the verification process, AQC noted that there is no evidence that an overall bias exists in the modelling setup that results in over- or under-predicting of impacts, notwithstanding that the model uses a single adjustment factor derived from all the monitoring sites together to control its base concentrations. Model simplifications do cause the model to over- and under-predict in some locations, but there is no systematic bias either way. Advice for future modelling is to ensure that model parameters such as specific details of receptors and locations (e.g. canyon dimensions), are correct.

Some of the key links that had either monitored or modelled high concentrations of NO_2 were subject to specific consideration and review of how monitoring and modelling results relate to each other and are subject to uncertainty feeding through to assessments. This is summarised below.

Location	AQC comments	AQC recommendations
A420 Church Road in St George	2015 modelled concentrations worse than measured, and considered over-estimates – in general, measured concentrations are compliant Set up of canyons potentially important Modelled traffic more than published counts (though counts not considered definitive)	No specific changes recommended, but consider canyon impacts Diffusion-tube monitoring of A420 to check measured concentrations Run a sensitivity test with different traffic figures, potentially changing canyon parameters at the same time
Marlborough Road (past Bristol Royal Infirmary and Children's Hospital)	Both monitoring and modelling show exceedances No particular concerns about modelling as this is a location where high concentrations would be expected	No modelling issues Marlborough Road is a particular issue that will need resolving
Park Street	No monitoring nearby to compare with modelling, but results seem higher than might be expected Traffic speeds were considered too slow and canyon effects are particularly important in driving results (as canyons may be too high)	No immediate recommendations, but canyon heights should be reviewed and a sensitivity test with lower heights considered
A38 Parson Street	Modelling is under-predicting compared to monitoring at two diffusion tubes However, nothing was identified that would cause this differential (traffic data, gradients and speeds are reasonable, though canyons would be more accurately represented)	No specific recommendations for modelling improvements, other than potentially to review canyon details Investigate impacts of the scheme at monitored locations which modelling under-predicts, to see whether reductions predicted by the model would bring monitored concentrations into compliance And careful consideration of future monitoring data also suggested

Location	AQC comments	AQC recommendations
Lower Ashley Road	Location where monitors are measuring exceedance and modelling under-predicts No obvious modelling causes for this identified, though canyons could be considered in more detail	No particular action, but careful consideration of future monitoring data suggested

The review also identified some receptors that were modelled to have large changes in concentrations between 2015 and 2021 baselines, which were not necessarily expected. Most of these resulted from either mis-matches of link IDs between the traffic and air quality models or changes in road layout (in turn affecting link IDs). Large changes in traffic volume were also causes of commensurately large changes in concentrations; notable locations were on the A4174 and Park Street (though at the latter no conclusive reasons were identified as to why this resulted in a disproportionate increase in concentrations). No locations were deemed critical to the outcomes of testing, so no actions are recommended, but changes could be made if the model is improved in future. Park Street is an exception in that it is a notable location for comparison between monitoring and modelling, and hence also discussed in the table above.

The interpolation process (between 2021 and 2031 model years) was queried, as linear interpolation has been employed to date. The review concluded that a non-linear approach could suggest an earlier compliance year. This was not considered to necessarily change the definitive assessment of compliance year, but moreover to steer the modelling team to an interim modelled year of 2025.

In summary, AQC's overall conclusions were that:

- Assessment of the compliance year for Bristol CAZ could be conservative (based on specific locations and interpolation as noted above);
- There is no overall bias in modelling (to over- or under-predict concentrations), though some specific locations will need particular reference and comparison between modelled and monitored results, and care should be taken in using this information for identifying location-specific measures accordingly (further modelling and/or monitoring is recommended at Church Road, Park Street and Parson Street);
- An interim model year of 2025 (between 2021 and 2031) should be employed to assess compliance (largely as a result of conservative linear interpolation previously being employed); and
- Also noted that Defra uses 40.4 $\mu g/m^3$ as compliant with the Limit Value when reporting to the European Commission, and that this could be used (instead of the 39.9 $\mu g/m^3$ limit currently used).

5.1.2 Air Quality Modelling Results for the Small CAZ option

The aim of the Bristol Clean Air Plan is to achieve compliance with the annual mean NO_2 EU Limit Value in the shortest possible timeframe, which is in line with Guidance provided by the JAQU. To this aim, the Small Area CAZ D (and fast track measures) scenario reported in this assessment is evidence based and has evolved over time with a focus on where improvements were needed most.

The main focus areas preventing earlier compliance were Marlborough Street, Upper Maudlin Street and Baldwin Street. The Small Area CAZ D achieves compliance on Marlborough Street in 2023. Compliance on Upper Maudlin Street is estimated to be 2021. Street space schemes in place on Baldwin street alone achieve compliance at this location by 2021. Overall, this scenario achieves compliance by 2023 across the whole of BCC.

With regards to individual receptors, the Small Area CAZ D improves annual mean NO_2 concentrations at 1,153 and 1,059 of the reportable receptors within Bristol in 2021 and 2023 respectively, whilst increasing concentrations at 9 and 7 receptors respectively in these years. The number of receptors that modelled improvements vastly outweighs the number that modelled disbenefits and the disbenefits to not push back the compliance year. By 2031, there are a larger number of disbenefits (76) predicted, which is attributable to the net disbenefit of the fast track measures and other non-charging measures over a largely redundant Small CAZ D by this year. However, these are not anticipated to result in non-compliance with the EU Limit Value. Uncertainty in the modelling was approximately 7 μg/m^3 and hence caution is recommended in terms of the anticipated outcomes of this study.

Overall, the Small Area CAZ D scenario is the most successful scenario assessed to date and aims to achieve compliance across BCC by 2023.

6. Summary

This Analytical Assurance Statement for the Bristol Clean Air Plan outlines the main limitations, risks, uncertainties within the assessments undertaken, and the suitability for use. All questions set out by JAQU in the Evidence Package of guidance have been answered comprehensively within this document.

The assessments for the Clean Air Plan have been undertaken with appropriate sources of data, and any limitations and risks with the data sources or methodologies have been identified. A full range of sensitivity testing was completed for the Full Business Case to assess the impact of altering key assumptions on the outcomes of the modelling.

The Small CAZ D modelling and sensitivity work shows:

- The scheme has a modelled compliance year of 2023;
- If the behavioural response to charging is not as great as anticipated, compliance is less likely to be achieved in 2023;
- If there is a one-year delay in fleet improvement, compliance is less likely to be achieved in 2023; and
- The modelling is sensitive to changes in Euro 6 / 6c / 6d proportions and associated emissions. Should the emissions be higher than anticipated, compliance is less likely to be achieved by 2023. On the other hand, if the emissions are lower than anticipated, compliance by 2023 would be more likely, or even brought forward to earlier 2023.

The COVID-19 pandemic has affected the reliability of a number of the sources of information that were used in the transport forecasting work. The validity of the Stated Preference surveys will be affected by the transport and socio- economic changes associated with the pandemic. Furthermore the EFT forecasts of fleet changes will also be impacted by the pandemic. Both underpin the analysis and the uncertainty is likely to affect the compliance year of the Small CAZ D option.

Appendix A - FBC-31 'Sensitivity Test report'

Bristol City Council Clean Air Plan Final Business Case

Sensitivity Testing Report

FBC 39

February 2021

Bristol City Council

Bristol City Council Clean Air Plan Final Business Case

Project No:	673846.ER.20
Document Title:	Sensitivity Testing Report
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Date:	February 2021
Client Name:	Bristol City Council
Project Manager:	HO
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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
1	11.10.2019	Initial OBC draft for comment	KT / KW	CB	HO	HO
2	27.10.19	OBC draft	KT / KW	CB	HO	HO
3	28.10.19	OBC draft	KT / KW	CB	HO	HO
4	18.05.20	FBC draft	KT / KW	CB	HO	HO
5	19.05.20	FBC draft	KT / KW	CB	HO	HO
6	11.2.21	FBC Draft	DW / KW	CB/KT	HO	HO
7	17.2.21	FBC Draft	DW / KW	CB/KT	HO	HO

Contents

Acronyms and Abbreviations

ANPR	Automatic Number Plate Recognition
BCC	Bristol City Council
CAZ(s)	Clean Air Zone(s)
CAP	Clean Air Plan
CO_2	Carbon Dioxide
Defra	Department for Environment Food & Rural Affairs
DfT	Department for Transport
EFT	Emissions Factors Toolkit
Euro	European
FBC	Full Business Case
HGV	Heavy Goods Vehicle
JAQU	Joint Air Quality Unit
LAQM	Local Air Quality Management
LGV	Light Goods Vehicle
HGV	Heavy Goods Vehicle
NOx	Nitrous Oxides
NO_2	Nitrogen Dioxide
OBC	Outline Business Case
OS	Ordnance Survey
PM	Particulate Matter
RSI	Roadside Interview
SP	Stated Preference
(Web)TAG	Transport Analysis Guidance

1. Introduction

1.1 Context

Poor air quality is the largest known environmental risk to public health in the UK[1]. Investing in cleaner air and doing more to tackle air pollution are priorities for the EU and UK governments, as well as for Bristol City Council (BCC). The Mayor of Bristol has often cited Bristol's 'moral and legal duty' to improve air quality in the city and the administration recognises that achieving improved air quality is not solely a transport issue. Notwithstanding the Council's work on a Clean Air Zone, efforts have been made to make citizens more aware of – and take personal responsibility for – various sources of air pollution, from traffic fumes to solid fuel burning. The Mayor has articulated a 'call to action' for local people, businesses and organisations to consider how small changes can make a significant difference in cutting toxic fumes across the city. BCC has monitored and endeavoured to address air quality in Bristol for decades and declared its first Air Quality Management Area in 2001. Despite this, Bristol has ongoing exceedances of the legal limits for Nitrogen Dioxide (NO_2) and these are predicted to continue until around 2027 without intervention.

The added context is that of the COVID-19 pandemic. Recent research suggests that poor air quality may be correlated with higher death / infection rates from COVID-19. This is further compounded by growing evidence that suggests that those from black, Asian and minority ethnic communities are more at risk of catching and dying from the virus and the fact that individuals from these communities are more likely to live in areas where air quality is poor. The challenge of maintaining public health and supporting economic recovery while also achieving legal air quality levels after lockdown restrictions are lifted will remain live and intersecting issues for the foreseeable future.

The UK Government continue to transpose European Union law into its Environment Bill[2] , to ensure that certain standards of air quality continue to be met, by setting air quality assessment levels (AQALs) on the concentrations of specific air pollutants. It's very unlikely that these AQALs will differ to EU Limit Values prescribed by the European Union's Air Quality Directive and transcribed in the UK's Air Quality Standards Regulation 2010. Therefore, these Limit Values will remain in enforcement post-Brexit. In common with many EU member states, the EU Limit Value for annual mean nitrogen dioxide (NO_2) is breached in the UK and there are on-going breaches of the NO_2 limit value in Bristol. The UK government is taking steps to remedy this breach in as short a time as possible, with the aim of reducing the harmful impacts on public health. Within this objective, the Government has published a UK Air Quality Plan and a Clean Air Zone Framework, both originally published in 2017 (noting there have been subsequent revisions). The latter document provides the expected approach for local authorities when implementing and operating a Clean Air Zone (CAZ). The following business cases have been submitted to JAQU for the Clean Air Plan; Strategic Outline Case (April 2018), and an Outline Business Case (November 2019 and updated between April and June 2020).

Following the submission of the OBC, further work was undertaken to develop the scheme, which resulted in the development of a new option - the Small area CAZ D. This work, and the option development work undertaken as part of the OBC, is presented in an updated Option Assessment Report (Appendix C FBC-16). The OBC version of this report is appended to the updated Option Assessment Report.

This report provides details of the following sensitivity tests on the Small CAZ D scenario:

- Behavioural response to charging;
- Fleet renewal delay by one year; and
- Euro 6 Vehicles (Low and High Emission scenarios).

[1] Public Health England (2014) Estimating local mortality burdens associated with particular air pollution. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution
[2] Environment Bill 2019-21 https://services.parliament.uk/bills/2019-21/environment.html

A summary of all sensitivity tests and key findings in this report is provided in section 6.

1.2 Scheme description

The Small CAZ D scheme includes the following components:

- Small Area Class D – (charging non-compliant cars, buses, coaches, taxis, HGVs and LGVs);
- Closure of Cumberland Road inbound to general traffic; and
- Holding back traffic to the city centre through the use of existing signals.

Full details of the modelling methodology for this scheme can be found in FBC-23 Local Plan Transport Modelling Methodology Report (T3) and transport model results can be found in FBC-27 Local Plan Transport Model Forecasting Report (T4).

2. Previous Sensitivity Testing

Sensitivity testing has been carried out on previous scenarios, the Hybrid Option and the Medium area CAZ C/Small area CAZ D option in October 2019 and May 2020 respectively. The outcomes of these various sensitivity tests carried out on the options are shown in FBC-39 Sensitivity Testing Report submitted in May 2020.

3. Consideration of tests to be undertaken at the FBC stage

Following the submission of the BCC CAZ OBC, further work was undertaken to develop the scheme, and this work resulted in the development of a new option, Small CAZ D option. This work, and the option development work undertaken as part of the FBC is presented in an updated Option Assessment Report (Appendix C FBC-16). Further to this, JAQU have provided feedback on the OBC from the T-IRP.

Consideration has been given to the choice of sensitivity tests to support the FBC. A list of the sensitivity tests undertaken for the FBC are set out in Table 3.1.

Table 3-1: Sensitivity tests supporting this FBC

Source	Description	Recommended to be undertaken for the FBC
OBC sensitivity test	Behavioural response to charging	Yes – previous pessimistic test showed slightly higher mean NO_2 when compared to the previous core scenario (Medium CAZ C/Small CAZ D) – so redo this test
OBC sensitivity test	Euro 6 vehicles	Yes – previous high emissions test showed slightly higher mean NO_2 when compared to the previous central case – so redo this test
JAQU	One-year fleet renewal delay	Yes – as COVID-19 may have an impact of the natural uptake of newer/cleaner vehicles.

In deriving the list above, consideration was given to other potential sensitivity tests, the rationale for not undertaking these tests is set out in Table 3-2.

Table 3-2: Justification for not undertaking further sensitivity tests in this FBC

Description	Justification for not undertaking the sensitivity test in the FBC
Age of transport model	Adjustments made to the model to account for the age of the model have been included in the core scenario.
Fleet splits by fuel type: ANPR vs.NAEI (EFT)	Latest Core Scenario uses EFT splits
HGV adjustment factors	Previous test showed slightly lower mean NO_2 when compared to a previous core scenario (the hybrid)
Emissions at low speeds	Previous high emissions test shows no difference in the mean NO_2 compared to the previous central case
Background concentrations	Assessment showed that without a local calibration factor being applied to Defras national pollution background maps, the predicted concentrations are generally lower than if backgrounds are calibrated, receptors remain compliant.
Air Quality model verification	No evidence to justify test in the OBC
Gradient	Previous test without gradients test showed slightly lower mean NO_2 when compared to the previous with gradients test
Primary NO_2 factor	Previous low test showed lower mean NO_2 when compared to the previous central case

4. Traffic Modelling

4.1 Overview

In estimating the effects of the Core Scenario, the air quality predictions are dependent upon the traffic data used in the modelling. These data are a combination of national predictions, JAQU guidance, consultations with BCC, and local studies. The data sources used in the traffic modelling have been selected to give the best possible representation of the effects of the CAZ. Like all predictions, this methodology has several uncertainties associated with it. A detailed account of the forecasting methodology and core scenario assumptions can be found in FBC-27 Transport Model Forecasting Report (T4). In this section, a series of sensitivity tests have been developed based on known uncertainties in these assumptions.

Section 4.2 considers uncertainties in the predicted behavioural response to charging by developing and analysing the most likely 'pessimistic' alternative scenario. Section 4.4 considers a fleet renewal delay of one year. These four variations are modelled using the Small CAZ D option. When appropriate, air quality testing has been performed to estimate the emissions, NO_2 concentrations, and compliance of the test scenarios and compare the results to the core scenario. Air quality modelling indicates that the Small CAZ D will achieve total compliance in 2023.

4.2 Behavioural Response to Charging

The success of the Clean Air Zone depends largely on how it influences the behaviour of drivers in the region. The drivers of non-car vehicles are expected to respond to the charging Small area CAZ D by either avoiding the area, changing their travel mode, or changing to a compliant vehicle, all of which will help to improve NO_2 pollution in Bristol. However, some drivers will decide to pay the CAZ charge instead of changing their behaviour.

For the Core scenario, the behavioural response to charging CAZ D was predicted using a variety of sources. A stated preference (SP) survey was conducted on drivers in Bristol and the surrounding areas to determine how they would respond, and how likely they would be to upgrade their vehicle based on various CAZ charges and upgrade costs. The final response rates were based on statistical models from the SP survey and predicted costs for upgrading to a compliant vehicle. For non-compliant light goods vehicle, responses for 'vans' from the stated preference surveys were used. A full report of the SP survey and statistical modelling is provided in FBC-28 Stated Preference Surveys Report. For coaches and HGVs, the proportions from 'Table 2 – Behavioural responses to charging Clean Air Zones' within the JAQU Evidence package have been used. Bus and Taxi responses are based on talks with Bristol City Council and the service providers.

The final Core scenario response rates for the Small CAZ D option are provided in Table 4.1. A detailed report on the methodology for calculating these response rates is available in FBC-26 Response Rates Technical Note Appendix E of the FBC.

Table 4-1: Core Scenario Primary Behavioural Response Rates – Small CAZ D

Response	Cars Low Income	Cars Medium Income	Cars High Income	Cars Employers Business	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	4.3%	10.4%	5.4%	6.8%	4.1%	15.9%	8.8%	0.0%	17.8%
Avoid Zone	15.6%	19.0%	15.7%	7.7%	0.0%	19.2%	4.3%	0.0%	0.0%
Cancel Journey / Change Mode	39.8%	20.4%	14.2%	30.7%	0.0%	2.6%	4.3%	6.4%	11.4%
Replace Vehicle	40.4%	50.3%	64.6%	54.8%	95.9%	62.2%	82.6%	93.6%	70.8%

4.2.1 Development of Pessimistic Scenario

Non-Car Vehicle Types

To account for uncertainties in the Core scenario response rates, an alternative scenario was developed assuming pessimistic driver responses in terms of expected air quality impacts. The pessimistic scenario accounts for the most-likely uncertainties that would cause more drivers to pay the CAZ D charge than in the Core scenario. In this case, there would be a smaller behavioural response to charging and therefore a smaller improvement to the NO_2 pollution in Bristol city centre. To develop a pessimistic scenario for the charging non-car vehicle types, the replace vehicle response was decreased by 20% for taxis, HGVs and Coaches and the change in the replace vehicle response was compensated for by a change in the pay charge response.

For LGVs, the parameters of the SP survey statistical models were adjusted to the bottom end of their 95% confidence intervals so that more drivers would pay the charge over replacing their vehicles over a 24-hour time-period. The pessimistic response rates for the non-car vehicle types are given in Table 4-2.

Table 4-2: Pessimistic Scenario Primary Response Rates– Non-Car Vehicle Types

Response	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	23.3%	27.2%	25.3%	0.0% *	31.9%
Avoid Zone	0.0%	19.2%	4.3%	0.0%	0.0%
Cancel Journey / Change Mode	0.0%	2.6%	4.3%	6.4%	11.4%
Replace Vehicle	76.7%	51.0%	66.1%	93.6%	56.7%

** This value was 0.0% in core scenario, so a percent change cannot be calculated.*

Cars

For the Small CAZ D, where cars are also charged over the Small CAZ area, the parameters of the Stated Preference survey statistical models were adjusted to the top or bottom end of their 95% confidence intervals so that more drivers would pay the charge over the replace their vehicles over a 24-hour time-period. The pessimistic response rates for the Small CAZ D are given in Table 4-3.

Table 4-3: Pessimistic Scenario Primary Response Rates – Small CAZ D

Response	Cars Low Income	Cars Medium Income	Cars High Income	Cars Employers Business
Pay Charge	10.0%	19.8%	13.6%	8.8%
Avoid Zone	15.6%	19.0%	15.7%	7.7%
Cancel Journey / Change Mode	39.8%	20.4%	14.2%	30.7%
Replace Vehicle	35%	41%	56%	53%

4.2.2 Results from Air Quality Testing

The air quality summary statistics for the 'pessimistic' scenario are presented in Table 4-4 and as distributional box plots in Figure 4-1. In each case, results are presented for the 2023 reference case, central case for the Core scenario (i.e. Small Area CAZ D) and the sensitivity test. Generally, as expected air quality was adversely affected with the mean NO_2 concentration increasing by 0.1 $\mu g/m^3$ and the maximum by 1.3 $\mu g/m^3$.

The maximum modelled annual mean NO_2 concentration was 41.6 $\mu g/m^3$, indicating that a compliance year of 2023 would not be achieved in this scenario. However, as 2023 was the only modelled year for this scenario, it is not possible to discern the anticipated compliance year. The model results at critical locations are presented in Table 4-5.

Table 4-4 Simple Summary Statistics for Sensitivity Testing of the pessimistic scenario (µg/m³) – 2023 Annual mean NO_2 concentrations

Statistic	Reference Case	Central Case	Pessimistic scenario
Mean	23.3	22.0	22.1
Median	22.1	21.2	21.3
Maximum	49.4	40.3	41.6
Minimum	12.3	12.2	12.2
Upper Quartile	26.2	24.6	24.7
Lower Quartile	18.9	18.4	18.5
Standard Deviation	6.2	5.2	5.3
Range	37.1	28.1	29.4

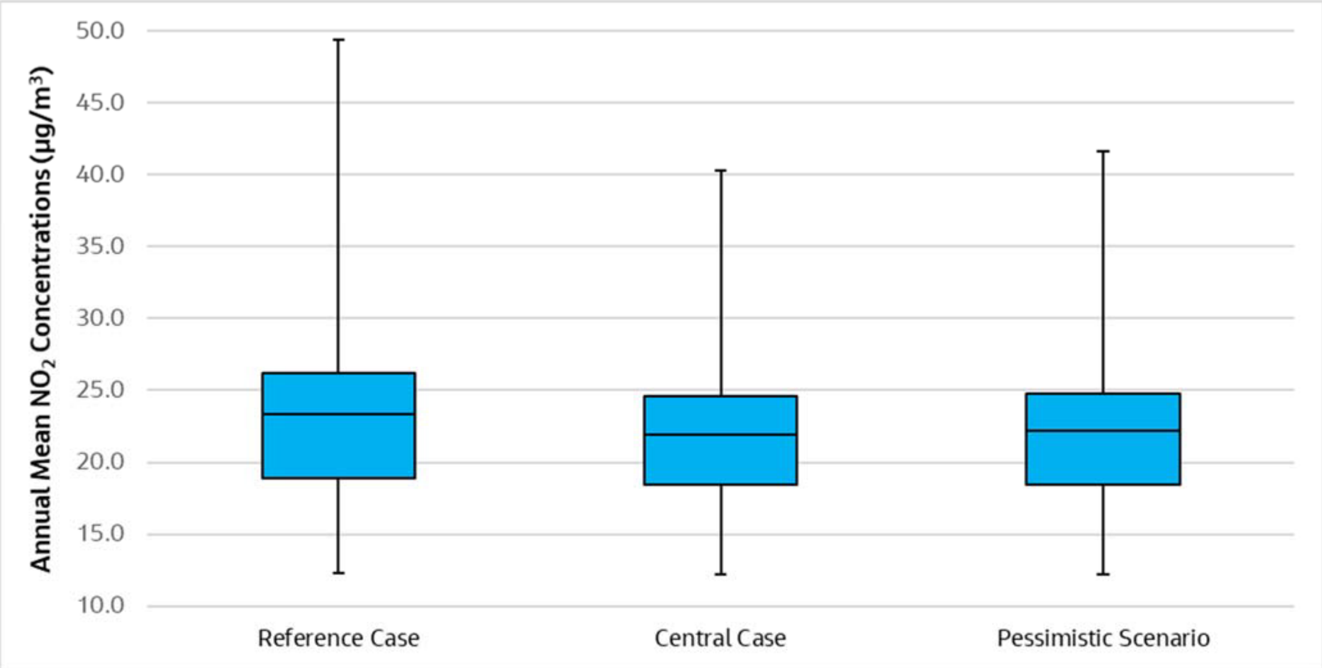

Figure 4-1 Distribution of 2023 Annual Mean NO_2 Concentrations for Sensitivity Testing of the pessimistic scenario

Table 4-5 2023 Modelled Annual Mean NO_2 Results for Sensitivity Testing of the Pessimistic Scenario

	Rupert Street	Marlborough Street	Upper Maudlin Street	Park Row	Park Street	Queen's Road	College Green	Cheltenham Road	Newfoundland Way	Church Road	Baldwin Street
Receptor ID (Reference Case Max)	15160	12649	12636	12014	6925	7098	11949	12708	13742	24587	11589
2023 Modelled Annual Mean NO_2 Results ($\mu g/m^3$)											
Reference Case (Baseline)	46.0	49.4	42.1	38.9	32.4	30.1	35.2	37.0	43.9	37.9	23.7
Central Case (Small Area CAZ D)	39.8	40.3	34.6	32.7	26.5	25.8	29.7	35.5	36.3	36.5	22.2
Pessimistic scenario	40.6	41.6	35.4	33.5	27.3	26.2	30.5	35.7	37.1	36.7	22.3
Difference (Sens Test – Central Case)	0.8	1.3	0.8	0.8	0.8	0.4	0.8	0.2	0.8	0.2	0.1

4.3 One-Year Fleet Delay

JAQU requested that a one-year fleet renewal delay be undertaken as a sensitivity test. The test was assumed to represent the potential effect of COVID-19 on the natural fleet turnover. Therefore, the 2023 vehicle compliance splits and fuel type splits have been replaced with 2022 values.

The fleet projection tool within the EFT v9.1b was used to project the euro standard splits from the 2017 ANPR data to the Baseline compliance splits. The forecast compliance splits by vehicle type for 2022 are summarised in Table 4-6. These were used for the one-year fleet delay sensitivity test from which the Small CAZ D core response rates were applied. The core response rates are shown in Table 4-1.

Table 4-6: 2022 Compliance Splits by Time Period

Vehicle Category	AM		IP		PM	
	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Non-compliant
Cars	78.5%	21.5%	77.4%	22.6%	78.0%	22.0%
LGV	66.4%	33.6%	71.0%	29.0%	66.5%	33.5%
HGV rigid	79.9%	20.1%	78.7%	21.3%	73.9%	26.1%
HGV artic	89.4%	10.6%	90.0%	10.0%	89.0%	11.0%
HGV	82.2%	17.8%	81.4%	18.6%	78.9%	21.1%
Taxi	68.8%	31.2%	68.8%	31.2%	68.8%	31.2%
Bus	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%
Coach	75.9%	24.1%	76.5%	23.5%	77.4%	22.6%
Total	76.7%	23.3%	76.8%	23.2%	76.9%	23.1%

The EFT v9.1b has been used for the fuel splits for 2022. An additional adjustment has been made to car fuel splits due to identification by BCC of an increase in petrol taxis replacing diesel. These were applied to the traffic link data extracted from the model runs via post-processing before input to the EFT. Table 4-7 shows the fuel type splits from the 2022 and 2031 EFT v9.1b with taxi adjustment.

Table 4-7: Fuel Type Splits (2022)

Vehicle Category	2022		
	Petrol	Diesel	Electric
Cars	61.02%	37.98%	1.00%
LGVs	0.46%	99.32%	0.22%

4.3.1 Results from Air Quality Testing

The air quality summary statistics for the One-Year Fleet Delay for the Core scenario are presented in Table 4-8 and as distributional box plots in Figure 4-2. In each case results are presented for the 2023 reference case, central case for the Core scenario and the sensitivity test. For this test, air quality is likely to worsen to a greater extent than the Pessimistic scenario, as indicated by the increase in the mean of modelled values of 0.8 μg/m^3. This is because the Pessimistic scenario focusses predominantly on trips associated with the CAZ area and immediate surroundings, whereas assumptions in the One-Year Fleet Delay scenario affect the whole model domain. The maximum value increased by 1.2 μg/m^3, which is actually slightly less than the Pessimistic scenario.

As with the Pessimistic scenario, the compliance year is likely to be after 2023, but it is not possible to calculate when it is likely to occur.

Table 4-8 Simple Summary Statistics for Sensitivity Testing of the One-Year Fleet Delay scenario (μg/m^3) – 2023 Annual mean NO_2 concentrations.

Statistic	Reference Case	Central Case	One-Year Fleet Delay scenario
Mean	23.3	22.0	22.8
Median	22.1	21.2	21.9
Maximum	49.4	40.3	41.5
Minimum	12.3	12.2	12.6
Upper Quartile	26.2	24.6	25.8
Lower Quartile	18.9	18.4	19.0
Standard Deviation	6.2	5.2	5.6
Range	37.1	28.1	28.9

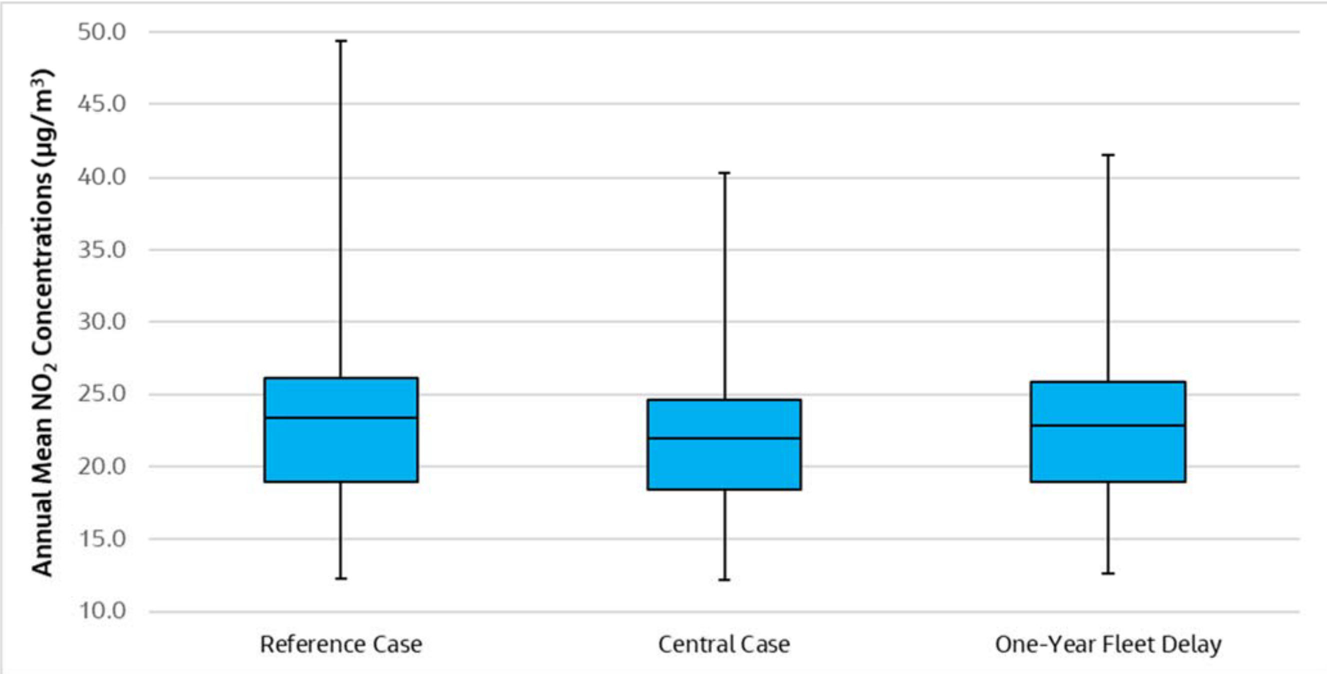

Figure 4-2 Distribution of NO_2 Concentrations for Sensitivity Testing of Speed and Flow adjusted

Table 4-9 2023 Modelled Annual Mean NO_2 Results for Sensitivity Testing of the One-Year Fleet Delay Scenario

	Rupert Street	Marlborough Street	Upper Maudlin Street	Park Row	Park Street	Queen's Road	College Green	Cheltenham Road	Newfoundland Way	Church Road	Baldwin Street
Receptor ID (Reference Case Max)	15160	12649	12636	12014	6925	7098	11949	12708	13742	24587	11589
2023 Modelled Annual Mean NO_2 Results ($\mu g/m^3$)											
Reference Case (Baseline)	46.0	49.4	42.1	38.9	32.4	30.1	35.2	37.0	43.9	37.9	23.7
Central Case (Small Area CAZ D)	39.8	40.3	34.6	32.7	26.5	25.8	29.7	35.5	36.3	36.5	22.2
One-Year Fleet Delay scenario	41.4	41.5	36.1	34.0	27.4	26.6	30.9	37.0	38.1	39.0	22.6
Difference (Sens Test – Central Case)	1.6	1.2	1.5	1.3	0.9	0.8	1.2	1.5	1.8	2.5	0.4

5. Air Quality Sensitivity Test Results

5.1 Vehicle-Specific Emission Factors – Euro 6 Diesel Vehicles

The EFT includes NOx speed-emission coefficients taken from the European Environment Agency COPERT 5 emission calculation tool[3], and fleet and fuel compositions in line with Department for Transport projections. COPERT 5 predicts different NOx emissions from Euro 6 diesel vehicles registered in different years. This is based on a general expectation that emissions from these vehicles will reduce over time. Over a similar timeframe, new aspects of the Euro 6 emissions standards will come into force, but it is important to recognize that the Euro 6 emissions reductions assumed within COPERT 5 do not, and were not intended to, coincide precisely with specific iterations of the Euro 6 emissions standards themselves. Thus, for example, COPERT 5 does not contain emissions factors specific to Euro 6d-temp vehicles.

The JAQU suggest that local authorities run a 'low emissions' and 'high emissions' scenario for the future emissions standards in their projected reference year and 'with measures' model runs. The JAQU suggest that an appropriate 'low emissions' scenario would be to assume that Euro 6c diesel cars and LGVs achieve the same emissions level as Euro 6d vehicles. This can simply be achieved by moving the proportion of diesel cars and LGVs in the Euro 6c category of the EFT into the Euro 6d category.

For the 'high emissions' scenario the JAQU recommended that Euro 6c cars and LGVs achieve emissions halfway between Euro 6 and Euro 6c and that Euro 6d cars and LGVs achieve emissions halfway between Euro 6c and Euro 6d. This can be achieved by moving 50% of the cars and LGVs in the Euro 6c category of the EFT into the Euro 6 (non-RDE) category and moving 50% of the cars and LGVs in the Euro 6d category of the EFT into the Euro 6c category.

Table 5-1 and Figure 5-1 provide the summary statistics requested in JAQU's 'Supplementary Note on Sensitivity Testing'. Table 5-1 then presents the modelled annual mean NO_2 concentrations at the critical locations for each of these scenarios, as well as the 'Central' case. These sensitivity tests demonstrate that the potential effect of the assumed uncertainty in future Euro 6 diesel vehicles is relatively high. The Low Emission Euro 6 scenario was predicted to reduce the maximum concentration by 3.6 $\mu g/m^3$, whereas the High Emission Euro 6 scenario predicted a 2.7 $\mu g/m^3$ increase. The mean concentration changed by approximately -0.8 and +1.2 $\mu g/m^3$ for the Low Emission and High Emission scenarios respectively.

The results indicate that the central case is particularly sensitive to the assumptions around the categorisation of Euro 6 light duty vehicles.

With just the 2023 results, it is not possible to calculate specific compliance years for these sensitivity tests, although it is clear that the High Emission scenario does not achieve compliance in 2023. Given the large decrease in maximum modelled values in the Low Emission scenario, it is possible to speculate that this scenario may bring overall compliance forward to an earlier year than 2023. The modelled results at the critical locations are presented in Table 5-2.

Table 5-1 Simple Summary Statistics for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions ($\mu g/m^3$) – Annual mean NO_2 concentration.

Statistic	Reference Case	Euro 6 – High Emission	Central Case	Euro 6 – Low Emission
Mean	23.3	22.8	22.0	20.8
Median	22.1	21.9	21.2	20.1
Maximum	49.4	43.0	40.3	36.7
Minimum	12.3	12.6	12.2	11.7
Upper Quartile	26.2	25.7	24.6	23.2
Lower Quartile	18.9	18.9	18.4	17.6
Standard Deviation	6.2	5.6	5.2	4.6
Range	37.1	30.4	28.1	25.0

[3] http://copert.emisia.com

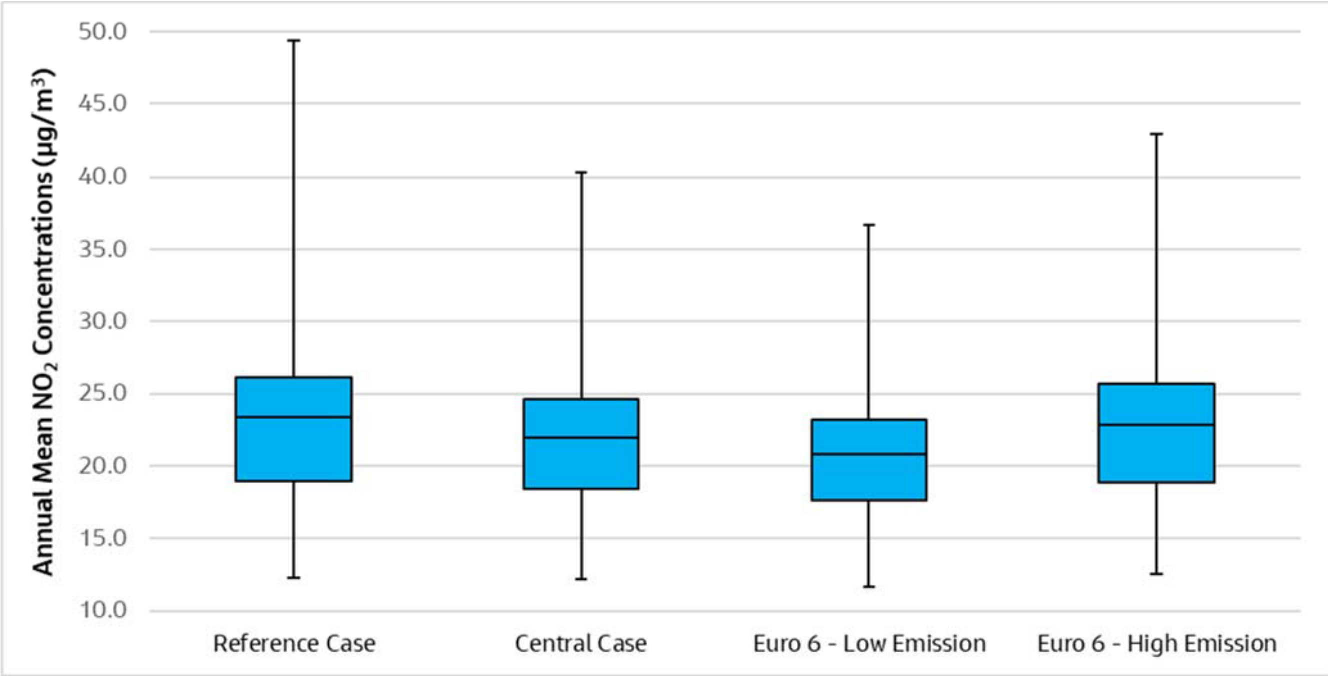

Figure 5-1 Distribution of NO_2 Concentrations for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions

Table 5-2 2023 Modelled Annual Mean NO_2 Results for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions

	Rupert Street	Marlborough Street	Upper Maudlin Street	Park Row	Park Street	Queen's Road	College Green	Cheltenham Road	Newfoundland Way	Church Road	Baldwin Street
Receptor ID (Reference Case Max)	15160	12649	12636	12014	6925	7098	11949	12708	13742	24587	11589
2023 Modelled Annual Mean NO_2 Results (µg/m^3)											
Reference Case (Baseline)	46.0	49.4	42.1	38.9	32.4	30.1	35.2	37.0	43.9	37.9	23.7
Central Case (Small Area CAZ D)	39.8	40.3	34.6	32.7	26.5	25.8	29.7	35.5	36.3	36.5	22.2
Euro6 – High Emission scenario	42.2	43.0	37.1	35.1	27.7	27.1	31.4	37.1	39.2	38.6	22.7
Difference (High Em. Scenario – Central Case)	2.4	2.7	2.5	2.4	1.2	1.3	1.7	1.6	2.9	2.1	0.5
Euro6 – Low Emission scenario	36.6	36.7	31.3	29.6	24.8	24.0	27.5	33.4	32.5	33.7	21.4
Difference (Low Em. Scenario – Central Case)	-3.2	-3.6	-3.3	-3.1	-1.7	-1.8	-2.2	-2.1	-3.8	-2.8	-0.8

6. Results Summary Table

For all sensitivity tests, a summary and key results is provided in Table 6-1 below:

Table 6-1 Summary of sensitivity analysis

Test	Section Number	Summary	Key Results
Transport Modelling Based Sensitivity Tests			
Behavioural Reponses to Charging	4.2	Defined pessimistic response rates based on confidence intervals of SP survey statistical modelling and adjusted assumptions for other vehicle types. Compared NO_2 concentrations to Small D scenario.	Air quality is likely to be adversely affected with the mean concentration increasing by 0.1 μg/m³ and the maximum by 1.3 μg/m³. The compliance year is pushed back beyond 2023. This test illustrates the "breaking point" of the scheme as it shows that adjusting the response rates based on the Stated Preference survey confidence limits will delay the scheme compliance beyond 2023.
One Year Fleet Delay Test	4.3	One-year fleet renewal delay undertaken as a sensitivity test due to the potential effects of COVID-19 on the natural fleet turnover through time.	Air quality is likely to be adversely affected across the whole model domain, with the mean concentration increasing by 0.8 μg/m³ and the maximum by 1.2 μg/m³. The compliance year is pushed back beyond 2023.
Air Quality Modelling Based Sensitivity Tests			
Euro 6 Vehicles (Low and High Emission scenarios)	5.1	The EFT is based on COPERT 5 which predicts different NOx emissions from Euro 6 diesel vehicles registered in different years (based on the expectation that Euro 6 emissions will reduce over time). Sensitivity test outlined in JAQU's 'Supplementary Note on Sensitivity Testing' has been run.	The Low Emission Euro 6 scenario was predicted to reduce the maximum concentration by 3.6 μg/m³, whereas the Euro 6 High Emission scenario predicted a 2.7 μg/m³ increase. In terms of the compliance year, the High Emission scenario pushed the compliance year back beyond 2023 at the Marlborough Street critical location. The Low Emission scenario may have brought the compliance year forward from 2023, although without other modelled years for this scenario, it is not possible to tell. The results indicate that the central case results are sensitive to changes in Euro 6, 6c and 6d proportions and the associated NOx emissions standards expected from diesel light duty vehicles.