Bristol City Council Clean Air Plan

Outline Business Case

Sensitivity Testing Report

OBC-39

October 2019

Bristol City Council

Bristol Clean Air Plan

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3	28.10.19	OBC draft	KT / KW	CB	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
HGV	Heavy Goods Vehicle
JAQU	Joint Air Quality Unit
LAQM	Local Air Quality Management
LGV	Light Goods Vehicle
HGV	Heavy Goods Vehicle
MSOA(s)	Middle Layer Super Output Area(s)
NRMM	Non-Road Mobile Machinery
NOx	Nitrous Oxides
NO_2	Nitrogen Dioxide
OBC	Outline Business Case
OGV	Other Goods Vehicle
OS	Ordnance Survey
PM	Particulate Matter
PSV	Public Service Vehicle
RSI	Roadside Interview
SP	Stated Preference
ULEV	Ultra Low Emissions Vehicle
(Web)TAG	Transport Analysis Guidance

1. Introduction

The UK has in place legislation transposing requirements in European Union law, to ensure that certain standards of air quality are met, by setting Limit Values on the concentrations of specific air pollutants. 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 published in 2017. The latter document provides the expected approach for local authorities when implementing and operating a Clean Air Zone (CAZ).

Due to forecast air quality exceedances, in 2017 Bristol City Council has been directed by the Minister Therese Coffey (Defra) and Minister Jesse Norman (DfT) to produce a Clean Air Plan to achieve air quality improvements in the shortest possible time. In line with Government guidance, as part of the Plan, Bristol City Council has considered a range of options for the implementation of a Clean Air Zone (CAZ), including both charging and non-charging measures, in order to achieve sufficient improvement in air quality and public health and in line with legal requirements as set out below. Bristol City Council (BCC) have produced an Outline Business Case (OBC) for the delivery of an option including a package of measures which will be most likely to bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in Bristol and reducing human exposure as quickly as possible.

Jacobs has been commissioned to support BCC to produce an Outline Business Case (OBC) for the delivery of the CAP; a package of measures which will bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in Bristol. The OBC assessed the shortlist of scenarios set out in the Strategic Outline Case, and proposes a preferred scenario including details of delivery. This document is written to support the OBC, and provides a summary of sensitivity tests undertaken for the transport and air quality analysis. This has been performed according to the guidance provided by JAQU in their 'supplementary note on sensitivity testing' issued in July 2018.

The sensitivity tests reported here relate to the final model results from the Hybrid scenario which includes an 8-hour diesel car ban within a medium sized CAZ C in 2027. This is referred to throughout this document as the 'core' or 'central' scenario.

Table 1-1 lists the sensitivity tests undertaken.

Table 1-1 List of Sensitivity Tests Performed for Transport and Air Quality

Traffic Modelling (Section 2)	Air Quality Modelling (Section 3)
• Fleet splits by fuel type: ANPR vs. NAEI(EFT) • HGV adjustment factors • Behavioural response to charging	• Euro 6 vehicles • Emissions at low speeds • Background concentrations • Model verification • Gradient • Primary NO_2 Fraction

A summary of all sensitivity tests and key findings in this report is provided in section 4.

1.1 Overview and Core Scenario

The core scenario combines Options 1 and 2 that working together create a Hybrid Option.

Option 1:

- Medium Area Class C (charging non-compliant buses, coaches, taxis, HGVs and LGVs);
- Diesel car scrappage scheme;
- HGV exclusion on links within the city centre with exceedances as follows:
  - Park Row/Upper Maudlin St/Marlborough St, Rupert Street, Lewins Mead, Baldwin Street;
- Close of Cumberland Road inbound to general traffic;
- M32 Park and Ride with bus lane inbound;
- Holding back traffic to the city centre through the use of existing signals; and

Option 2: 8-hour small area diesel car exclusion (7am – 3pm)

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

2. Traffic Modelling

2.1 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 OBC-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 2.2 considers uncertainties in the current and projected fleet composition with regards to HGV factors and fuel splits. Section 2.3 considers uncertainties in the predicted behavioural response to charging by developing and analysing the most likely 'pessimistic' and 'optimistic' alternative scenarios. 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 Core Scenario will achieve total compliance in 2027.

2.2 Fleet Composition

A vehicle's emissions depend on a variety of factors, such as its age and the type of fuel it consumes. Therefore, to accurately model the NO_2 pollution in Bristol, information was required regarding the composition of vehicles that enter Bristol City Centre. To accomplish this, permanent Automatic Number Plate Recognition (ANPR) camera data was obtained from BCC for a duration of six months in 2017 (February – July). In addition, a week survey was performed using ANPR cameras placed at key locations around and within the city centre to fill in the gaps, in July 2017. The captured number-plates were cross-referenced with data purchased from Carweb to gain information on the corresponding vehicle types, fuel types, and euro emissions standards. Details of the ANPR study can be found in OBC-24 ANPR Data Analysis and Application in Appendix E of the OBC. This ANPR data were used to estimate the fleet composition for the air quality verification year 2015 and the reference years 2021/31 for the Core Scenario. The fleet composition was projected into the future using tools provided by the JAQU. However, this methodology has several uncertainties associated with it. For example, number-plates are occasionally missed or misread using ANPR technology. Additionally, there is more than one method for predicting future fleet compositions. The sensitivity test, involving fuel splits initially obtained from the WebTAG Data Book[1], examined a more recent model of behaviour provided by the JAQU in version 9.1b of the Emission Factor Toolkit to test the differences this had on emissions and NO_2 concentrations for core scenario.

2.2.1 HGV adjustment factors

Light and heavy goods vehicles were not originally validated using short screenlines and grouped counts in 2013, therefore an additional technical note has been produced to report this. For full details refer to OBC-25 LGV/HGV Validation Technical Note. The key conclusions from this report are as follows:

- LGVs are generally well calibrated/validated on both the short screenline level and an individual link level screenlines and cordons;
- HGVs do not pass the WebTAG guidance for GEH statistics, but are close for the link flow difference criteria for the short screenlines and pass when each link is looked at individually;
- For both light and heavy goods vehicles, where WebTAG guidance is not met, the modelled flows are under assigned in some locations, over assigned in others; and
- The middle cordon relates closely to the medium CAZ boundary and the inner cordon relates closely to the small CAZ boundary. The calibration/validation of HGVs for the inner cordon is deemed more important than the middle cordon due the location of the compliance exceedances within Bristol. The HGV fit along the inner cordon is better than the middle cordon.

It was agreed with JAQU that HGV flow adjustments would be made on links with significant differences in modelled flows compared to observed counts. These adjustments would be carried through to future years for both the baseline and options.

The T-IRP panel has commented on this approach as follows in their feedback:

'It has been acknowledged in the report that there is an issue with the validation for HGVs specifically. This issue has been dealt with through the application of fixed factors (which will also be applied in scenario modelling). If HGVs are affected by proposed measures, doing something more complex than applying fixed factors should be considered, as these will add a lot of uncertainty into the modelling. If fixed factors are applied in the scenario modelling and HGV are targeted with measures, then at the least the implications of this assumption should be tracked through sensitivity testing and discussed in the AAS. RAG rating would be A/G if no measures affecting HGVs are being assessed.'

This test therefore involved the removal of the HGV adjustment factors applied. It should be noted that no HGV adjustment factors were applied to locations identified as critical in the air quality modelling hence there is very little effect on the results.

Table 2-1 provides a summary of statistics (as recommended in JAQU's 'Supplementary Note on Sensitivity Testing') and Table 2-2 presents the compliance status for this sensitivity test as well as the 'Central' (Core scenario) modelling. Figure 2-1 shows the distribution of the resulting NO_2 concentrations. 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 narrowed slightly.

Table 2-1. Simple Summary Statistics for HGV adjustment factors(µg/m^3)

Statistic	2027 Core Scenario	
	Central	HGV Removal
Mean	20.6	20.6
Median	20.0	20.0
Maximum	39.5	39.6
Minimum	11.2	11.2
Upper Quartile	23.6	23.6
Lower Quartile	17.5	17.5
Standard Deviation	5.1	5.2
Range	28.3	28.4

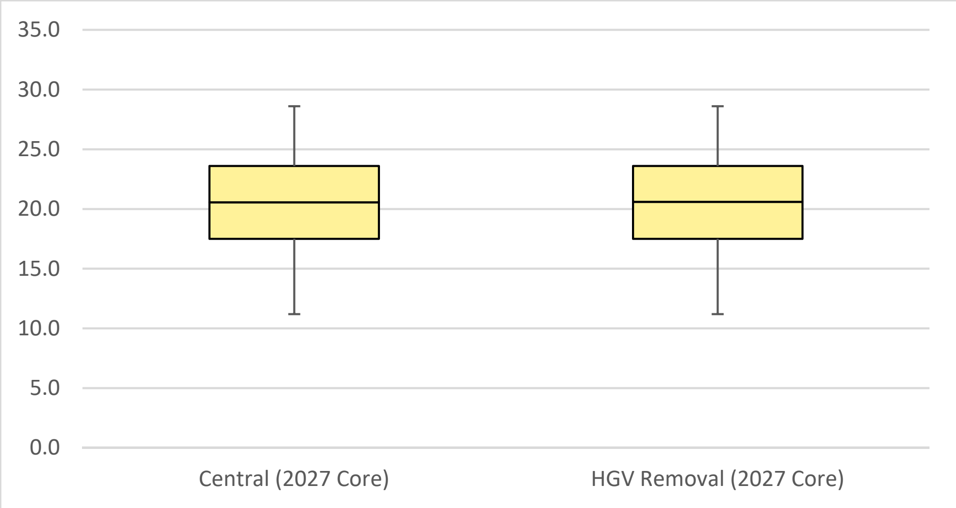

Figure 2-1 Distribution of NO_2 Concentrations for Compliance Splits by HGV factor adjustment

Table 2-2 Summary of Compliance Status for Compliance Splits by HGV factor adjustment

Statistic	2021 Core Scenario	
	Central	Fuel Splits
No. of Non-Compliance PCM Receptors	0	0
Compliance Status of Road Link with Highest NO2 Value	Compliant	Compliant
Maximum NO2 Percentage Gap from Compliance	-1.3	-1.0

2.2.2 Splits by Fuel Type: Comparison of NAEI (EFT) fleet projections

Vehicle emissions depend on the type of fuel it consumes. Petrol vehicles emit carbon dioxide (CO_2) and some nitrous oxides (NOx), while diesel vehicles emit significantly less CO_2 but significantly more NOx than petrol. In the air quality model, a diesel vehicle will cause higher NO_2 concentrations than its petrol equivalent. Therefore, the air quality model required the proportion of each vehicle type that was petrol, diesel, or electric. These splits can be obtained at a national level using the WebTAG Data Book[1] or similarly models published in the National Atmospheric Emissions Inventory (NAEI)[2] and transcribed for the Emission Factor Toolkit[3]. For the Bristol Study ANPR data were processed and aligned to the vehicle emission fleet categories issued in the EFT. This provided a 2018 fleet which could then be projected backwards or forwards using a tool incorporated in the EFT. Whilst undertaking the study JAQU issued version 9.1b of the EFT which has updated fuel split information compared to version 8.0.1a which has been applied from the onset of the study.

The sensitivity test examines the differences in annual mean NO_2 concentrations between the Core Scenario modelled using fuel splits derived from the WebTAG Databook and the new information provided in the EFT v9.1b.

Table 2-3 provides a summary of statistics and Table 2-4 presents the compliance status for this sensitivity test as well as the 'Central' (Core scenario) modelling. Figure 2-2 shows the distribution of the resulting NO_2 concentrations. 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 WebTAG Data Book.

[1] https://www.gov.uk/government/publications/tag-data-book
[2] https://naei.beis.gov.uk/
[3] https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

Table 2-3 Simple Summary Statistics for Compliance Splits by Fuel Type (µg/m³)

Statistic	2027 Core Scenario	
	Central	Fuel Splits
Mean	20.6	20.2
Median	20.0	19.7
Maximum	39.5	38.0
Minimum	11.2	11.1
Upper Quartile	23.6	23.2
Lower Quartile	17.5	17.2
Standard Deviation	5.1	5.0
Range	28.3	26.9

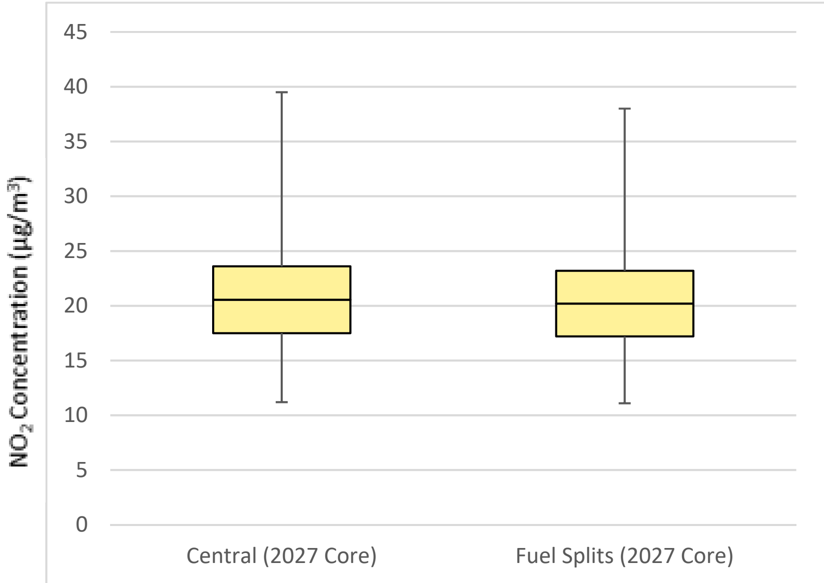

Figure 2-2 Distribution of NO_2 Concentrations for Compliance Splits by Fuel Type

Table 2-4 Summary of Compliance Status for Compliance Splits by Fuel Type

Statistic	2027 Core Scenario	
	Central	EFT Fuel Splits
No. of Non-Compliance PCM Receptors	0	0
Compliance Status of Road Link with Highest NO_2 Value	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	-1	-5

2.3 Behavioural Response to Charging

The success of the Clean Air Zone depends entirely on how it influences the behaviour of drivers in the region. The non-car drivers are expected to respond to the charging medium area CAZ C 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. Car drivers are expected to respond to the 8-hour small area car diesel ban either by avoiding the area, changing their travel mode, or changing to a petrol car, again all of which will help to improve NO_2 pollution in Bristol.

However, some car drivers will decide to change the time of day they travel and hence continue to use their diesel car.

For the Core scenario, the behavioural response to charging CAZ C 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 OBC-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 methodology for calculating the primary response rates for the small area diesel car exclusion is summarised as follows:

- Calculate 24-hour car diesel exclusion response rate for the small area - the pay charge response rate was set to zero, the avoid zone, cancel trip/change mode and replace vehicle rates have been determined by the stated preference surveys for diesel cars which have been proportioned so that the total response rate totals 100 per cent;
- Calculate 8-hour (7am-3pm) car diesel ban based on the assumptions outlined in Section 6.3 OBC-26 Primary Behavioural Response Calculation Methodology. This methodology takes into account the estimated proportions of trips to change time of day (TOD response) to avoid the exclusion period and the estimated extent to which trips are linked between different time periods by trip purpose. Since not all trip purposes are modelled separately in GBATS, the relevant purposes were then re-combined using weighted averages to yield responses for each modelled trip purpose.

The final Core scenario response rates are provided in Table 2-5 and 2-6 below. A detailed report on the methodology for calculating these response rates is available in OBC-26 Response Rates Technical Note Appendix E of the OBC.

Table 2-5 Core Scenario Primary Behavioural Response Rates – Medium CAZ C

Response	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	4.1%	15.9%	8.8%	0.0%	17.8%
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	95.9%	62.2%	82.6%	93.6%	70.8%

Table 2-6 Core Scenario Primary Behavioural Response Rates – Car Diesel Exclusion

Response Rate	Cars Low-High Inc			Cars Emp Bus		
	AM	IP	PM	AM	IP	PM
Pay Charge	NA	NA	NA	NA	NA	NA
Avoid Zone	15.44%	14.56%	0.00%	17.47%	14.56%	0.00%
Cancel Journey / Change Mode	21.03%	21.85%	15.74%	23.79%	23.52%	22.18%
Replace Vehicle	43.04%	19.45%	31.54%	58.74%	58.07%	54.75%
Time of Day Choice	20.49%	31.94%	0.00%	0.00%	0.00%	0.00%

2.3.1 Development of Pessimistic and Optimistic Scenarios

Medium CAZ C

To account for uncertainties in the Core scenario response rates, alternative scenarios were developed assuming pessimistic and optimistic 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 C 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 CAZ C, the replace vehicle response was decreased by 20% and the change in the replace vehicle response was compensated for by a change in the pay charge response. The pessimistic response rates for the Medium CAZ C are given in Table 2.7

Table 2-7 Pessimistic Scenario Primary Response Rates– Medium CAZ C

Response	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	23%	28%	25%	0.0%*	32%
Avoid Zone	0%	19%	4%	0.0%	0%
Cancel Journey / Change Mode	0%	3%	4%	6.4%	11%
Replace Vehicle	77%	50%	66%	93.6%	57%

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

The optimistic scenario accounts for the most-likely uncertainties that would lead to a higher behavioural response to CAZ charging. In this case, less drivers would pay the CAZ charge and the NO_2 pollution in the city centre would improve beyond that which was predicted in the core scenario. To develop an optimistic scenario for the charging CAZ C, the replace vehicle response was increased by 20% and the change in the replace vehicle response was compensated for by a change in the pay charge response. The optimistic response rates for the Medium CAZ C are given in Table 2.8.

Table 2-8 Optimistic Scenario Primary Response Rates– Medium CAZ C

Response	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	0.0%	3.5%	0.0%	0.0%	3.6%
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	100%	75%	91%	93.6%	85%

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

8-Hour Car Diesel Exclusion

For the 8-hour car diesel exclusion, the parameters of the SP survey statistical models were adjusted to the top or bottom end of their 95% confidence intervals so that more/less drivers would replace the vehicle over the other responses over a 24-hour time period. These responses were then run through the process for converting 24-hour car diesel exclusion to an 8-hour car diesel exclusion. The optimistic and pessimistic responses from SP survey were then reversed, as a higher replace vehicle under SP optimistic responses results in lower avoid zone, cancel trip and change mode responses and higher time of day choice, resulting in more diesels in the CAZ area compared to the core. While a lower replace vehicle under SP pessimistic responses results in higher avoid zone, cancel trip and change mode responses and higher time of day choice, resulting in fewer diesels in the CAZ area compared to the core. The pessimistic and optimistic response rates for the car diesel exclusion are given in Table 2.9 and 2-10 respectively.

Table 2-9: Pessimistic Scenario Primary Response Rates – Car Diesel Exclusion

Response Rate	Cars Low-High Inc			Cars Emp Bus		
	AM	IP	PM	AM	IP	PM
Pay Charge	NA	NA	NA	NA	NA	NA
Avoid Zone	15.53%	10.87%	0.00%	13.04%	10.87%	0.00%
Cancel Journey / Change Mode	18.59%	19.32%	13.92%	21.04%	20.80%	19.61%
Replace Vehicle	48.33%	21.95%	35.43%	65.92%	65.17%	61.45%
Time of Day Choice	21.55%	35.73%	0.00%	0.00%	0.00%	0.00%

Table 2-10: Optimistic Scenario Primary Response Rates – Car Diesel Exclusion

Response Rate	Cars Low-High Inc			Cars Emp Bus		
	AM	IP	PM	AM	IP	PM
Pay Charge	NA	NA	NA	NA	NA	NA
Avoid Zone	25.34%	23.89%	0.00%	28.67%	23.89%	0.00%
Cancel Journey / Change Mode	29.31%	30.46%	21.94%	33.16%	32.79%	30.91%
Replace Vehicle	28.01%	12.83%	20.54%	38.17%	37.73%	35.58%
Time of Day Choice	17.34%	20.58%	0.00%	0.00%	0.00%	0.00%

2.3.2 Results from Air Quality Testing

Table 2-6 provides a summary of statistics and Table 2-7 presents the compliance status for each of these scenarios as well as the 'Central' model results. Figure 2-3 shows the distribution of the resulting NO_2 concentrations. The 2027 Core scenario is compliant in both the 'Low' (Optimistic) and 'Central' (Core) and 'High' (Pessimistic) scenario, with a percentage gap of up to -1.3% (0.5 μg/m^3). It should be noted, that the results for the high and low scenarios are very similar and overall, the 'Central' scenario is most representative, and the conclusion of compliance is thus considered appropriate.

Table 2-6 Simple Summary Statistics for Response Rates (μg/m^3)

Statistic	2027 Core Scenario		
	Low Optimistic	Central	High Pessimistic
Mean	20.4	20.6	20.7
Median	20.0	20.0	20.0
Maximum	39.6	39.5	39.8
Minimum	11.2	11.2	11.3
Upper Quartile	23.4	23.6	24.0
Lower Quartile	17.5	17.5	17.6
Standard Deviation	5.0	5.1	5.2
Range (Max - Min)	28.4	28.3	28.5

Table 2-7 Summary of Compliance Status for Response Rates

Statistic	2027 Core Scenario		
	Low	Central	High
No. of Non-Compliance PCM Receptors	0	0	0
Compliance Status of Road Link with Highest NO_2 Value	Compliant	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	-1.0	-1.3	-0.5

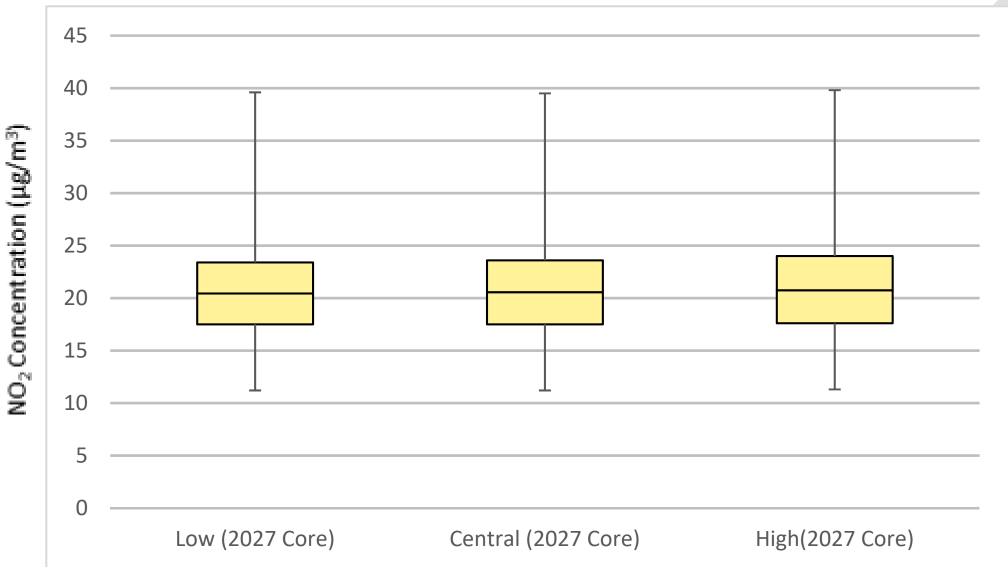

Figure 2-3 Distribution of NO_2 Concentrations for Response Rates

2.4 Diesel Car Ban Eight-hour Timing Review

In addition to the sensitivity testing set out in this chapter, work has been undertake to review the timing of the diesel ban, this work is reported in Appendix A. the report was written to review the effectiveness of an 8-hour diesel car exclusion during the 7am to 3pm time period compared to other times of day. The analysis shows that it is expected that a 'split' 8-hour car diesel ban would not be more effective than a 'contiguous' 8-hour car diesel ban scheme.

3. Air Quality Modelling

There are many components that contribute to the uncertainty of modelling air quality predictions. The road traffic emissions dispersion model used in this assessment is dependent upon the traffic data that have been input, which will have inherent uncertainties associated with them. There are then additional uncertainties, as models are required to simplify real-world conditions into a series of algorithms. The key uncertainties are explained below and where practical, sensitivity analyses have been carried out to determine the sensitivity of the model to each parameter.

The sensitivity of input parameters has been tested on the Core Hybrid scenario in year 2027.

3.1 Vehicle-Specific Emission Factors

3.1.1 Euro 6 Diesel Vehicles

The EFT includes NOx speed-emission coefficients taken from the European Environment Agency COPERT 5 emission calculation tool[4] 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 3-1 and Figure 3-1 provide the summary statistics requested in JAQU's 'Supplementary Note on Sensitivity Testing'. Table 3-2 then presents the compliance status 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 low, with the maximum predicted concentrations for the Core scenario ranging from 38.4 µg/m^3 to 41.8 µg/m^3. The maximum percentage gap from compliance ranges from -4.0% to 4.5% for the 'Low' and 'High' scenarios respectively. It is noted that the 'Central' scenario lies midway between the 'High' and Low' scenarios in terms of predicted concentrations. 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.

Table 3-1 Simple Summary Statistics for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions (µg/m^3)

Statistic	2027 Baseline	2027 Core		
		Low	Central	High
Mean	21.6	20.2	20.6	21.2
Median	20.6	19.7	20.0	20.6
Maximum	46.3	38.4	39.5	41.8
Minimum	11.5	11.1	11.2	11.6
Upper Quartile	25.2	23.3	23.6	24.5

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

Statistic	2027 Baseline	2027 Core		
		Low	Central	High
Lower Quartile	17.8	17.3	17.5	17.9
Standard Deviation	6.1	4.9	5.1	5.5
Range	34.8	27.3	28.3	30.2

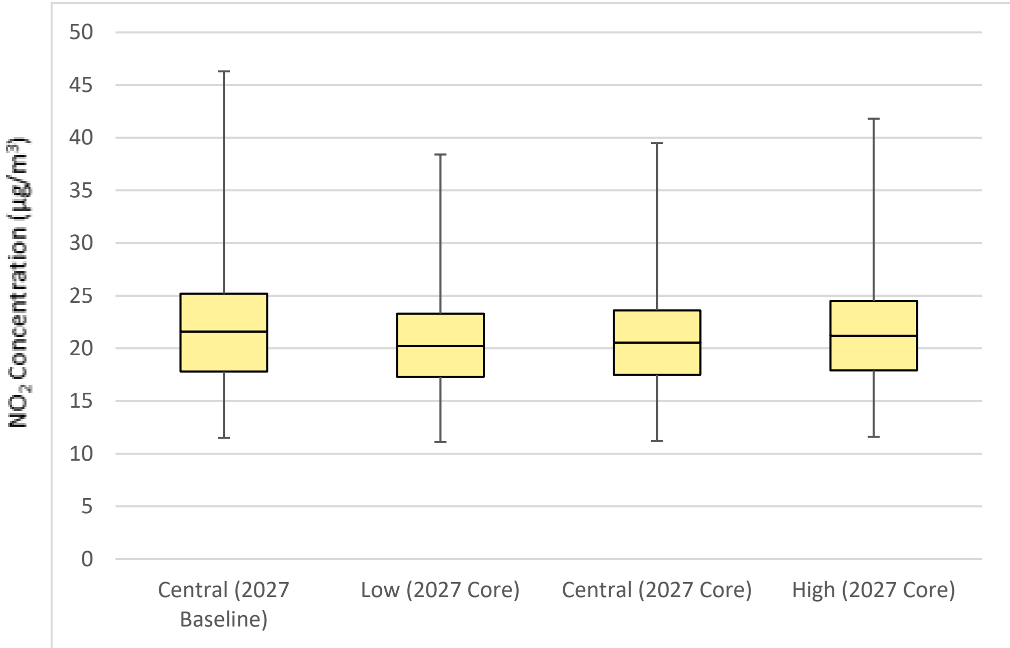

Figure 3-1 Distribution of NO_2 Concentrations for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions

Table 3-2 Summary of Compliance Status for Sensitivity Testing of Euro 6 Diesel Vehicle Emissions

Statistic	2027 Baseline	2027 Core		
	Central	Low	Central	High
No. of Non-Compliance PCM Receptors	10	0	0	3
Compliance Status of Road Link with Highest NO_2 Value	Non-Compliant	Compliant	Compliant	Non-Compliant
Maximum NO_2 Percentage Gap from Compliance	15.8	-4.0	-1.3	4.5

3.2 Relationship between traffic speed and emissions

3.2.1 Emissions at low speeds

Roads with queuing traffic or lots of start/stop behaviour will in general have lower average vehicle speeds than other roads and so stop/start driving is accounted for by way of reduced average speeds in the EFT. Traffic speeds have been estimated from the SATURN (GBATS) model which was validated against journey time data. The speeds are based on the average speed along a road. In reality, the speed will very often be slower at the start and end of a road and faster in the middle. The air quality model includes an adjustment to reduce speeds at the starts and ends of roads and where congestion is most likely. The reduced speeds will lead to higher vehicle emissions and thus increased pollution. In addition, the average vehicle speed along a road will be lower than that which occurs along the middle section of the road. The model therefore assumes higher emissions along the entire road than may occur in reality. The exception to this is where significant idling occurs, so as to reduce the link-average speed (as an annual average) below the minimum of the speed range in the EFT emissions functions (i.e. <5km/h).

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' and state that this methodology should be followed. This involves using a polynomial equation provided by JAQU which is based on using the COPERT emissions functions beyond their intended speed ranges. Details are provided in JAQU's 'Supplementary Note on Sensitivity Testing'. This methodology has been followed to calculate NOx emissions, and the resulting predicted NO_2 concentrations from the air quality model. This results in a 'Low' emissions scenario which uses the speed thresholds from COPERT V4 and a 'High' emissions scenario extends the speed thresholds down to 5 km/h. The 'Low' and 'High' NO_2 concentrations have then been compared to the 'Central' NO_2 concentrations (i.e. without applying the polynomial equation).

Table 3-3 and Figure 3-2 provide a summary of statistics as requested in JAQU's 'Supplementary Note on Sensitivity Testing'. Table 3-4 then presents the compliance status for each of these scenarios as well as the 'Central' modelling. 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.

Table 3-3 Simple Summary Statistics for Sensitivity Testing of Low Speeds (µg/m^3)

Statistic	2027 Baseline	2027 Core		
		Low	Central	High
Mean	21.6	20.5	20.6	20.6
Median	20.6	20.0	20.0	20.0
Maximum	46.3	39.5	39.5	39.5
Minimum	11.5	11.2	11.2	11.2
Upper Quartile	25.2	23.6	23.6	23.6
Lower Quartile	17.8	17.5	17.5	17.5
Standard Deviation	6.1	5.1	5.1	5.1
Range	34.8	28.3	28.3	28.3

Table 3-4 Summary of Compliance Status for Sensitivity Testing of Low Speeds

Statistic	2027 Baseline	2027 Core		
	Central	Low	Central	High
No. of Non-Compliance PCM Receptors	10	0	0	0
Compliance Status of Road Link with Highest NO_2 Value	Non-Compliant	Compliant	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	15.8	-1.3	-1.3	-1.3

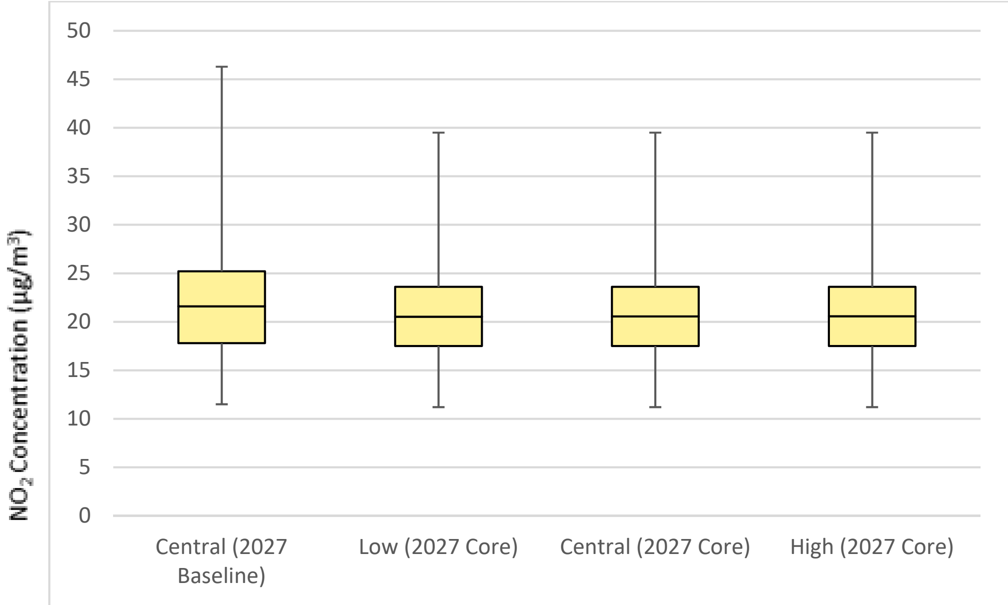

Figure 3-2 Distribution of NO_2 Concentrations for Sensitivity Testing of Low Speeds

3.3 Background Concentrations

Background NO_x, and NO_2 concentrations, for the 2015 base year, were derived from Defra's background mapped data[5] based on COPERT 5.0 emission factors. An interpolation process of background concentrations was undertaken, and results extracted to all modelled receptors. A calibration between the extracted, interpolated results with the 2015 urban background diffusion tube air quality monitoring stations was undertaken. The measured nitrogen dioxide concentration within the modelling domain was compared to the mapped background. It was found that mapped background nitrogen dioxide concentrations were lower than monitored values, and therefore all mapped background nitrogen dioxide concentrations have been calibrated by applying a factor of 3.37%.

To test the sensitivity of the results to this issue, NO_2 concentrations have been predicted for 2027 for both the baseline and Core scenario, with and without the local calibration applied to the background concentrations. In order to accurately take account of different background concentrations model verification should be re-calculated with the uncalibrated backgrounds. This is because background concentrations affect the derived 'measured' local road contributions and hence the calibration factor for the modelled local road contributions. For this test this aspect was not considered.

Table 3-5 and Figure 3-3 provide a summary of statistics as requested in JAQU's 'Supplementary Note on Sensitivity Testing'. Table 3-6 then presents the compliance status for each of these scenarios. 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.

[5] https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2015

Table 3-5 Simple Summary Statistics for Sensitivity Testing of Background Concentrations (µg/m^3)

Statistic	2027 Baseline	2027 Core	
		Without Calibration	With Calibration
Mean	21.6	20.1	20.6
Median	20.6	19.4	20.0
Maximum	46.3	39.1	39.5
Minimum	11.5	10.9	11.2
Upper Quartile	25.2	23.1	23.6
Lower Quartile	17.8	17.0	17.5
Standard Deviation	6.1	5.0	5.1
Range	34.8	28.2	28.3

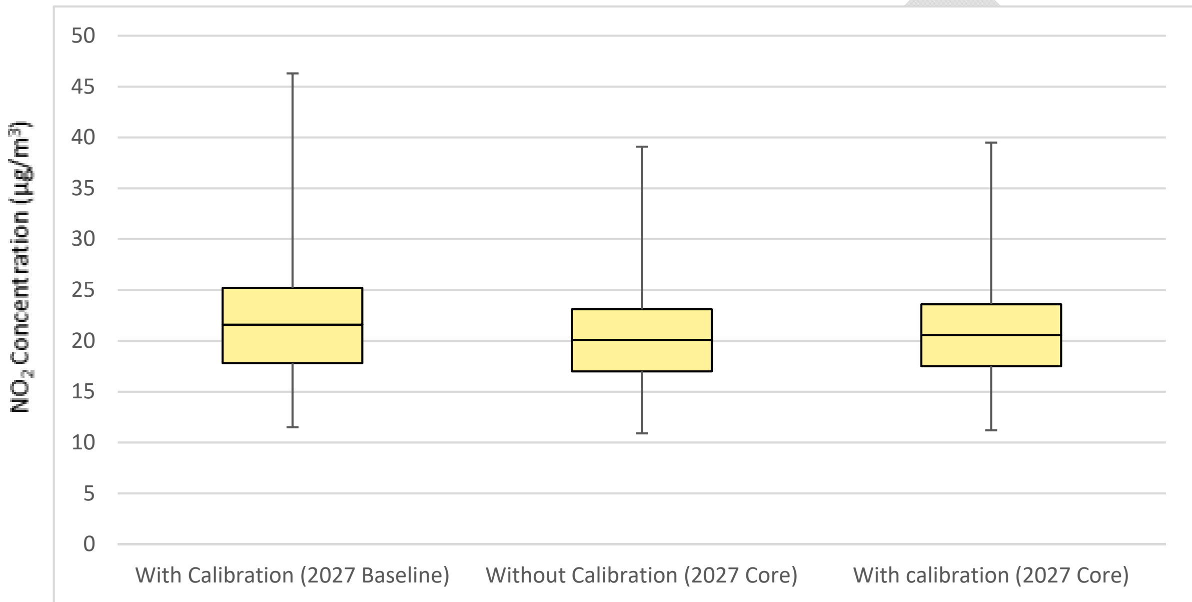

Figure 3-3 Distribution of NO_2 Concentrations for Sensitivity Testing of Background Concentrations

Table 3-6 Summary of Compliance Status for Sensitivity Testing of Background Concentrations

Statistic	2027 Baseline	2027 Core	
	With Calibration	Without Calibration	With Calibration
No. of Non-Compliance PCM Receptors	10	0	0
Compliance Status of Road Link with Highest NO_2 Value	Non-Compliant	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	15.8	-2.3	-1.3

3.4 Model Verification

The model verification for road NO_X 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.

The analysis of Gradient Emissions reported in AQ3 and issued as Appendix D of the OBC, showed the only parameter that was found to have a systematic effect on the verification was the combined percentage of light goods vehicles and heavy-duty vehicles on hilly roads adjacent to monitoring sites. Since no other correlations were found, there was no justification for sensitivity testing the verification for any other parameters.

3.5 Dispersion Uncertainties

3.5.1 Gradients

Vehicle emissions on roads with gradients have been uplifted (as explained in the Air Quality Modelling Methodology Report (AQ2) and the decision of whether an individual road should have this adjustment applied is important. The approach taken has been to apply this uplift to all roads where the gradient is greater than 2.5%, which has been based on Environment Agency in England Lidar data. The roads have been broken into sections based on observations of gradient changes. There should, therefore, be no significant changes in gradient along any individual link; but this is based on subjective, and thus uncertain, observations. The Lidar data will also have inherent uncertainties associated with it. The data are provided at a 1 x 1 m resolution and it is possible that the camber of roads and the choice of road length may have affected the heights used to determine the gradient. It is thus possible that the gradient of some roads may have been underestimated slightly and others overestimated slightly. This would result in emissions potentially not uplifted enough or uplifted too much.

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. Bristol is quite hilly and hence this test is applicable.

A test was undertaken to assess the sensitivity of the Core results to this uncertainty. The results have then been compared to the 'Central' scenario.

Table 3-7 and Figure 3-4 provide a summary of statistics as requested in JAQU's 'Supplementary Note on Sensitivity Testing'. Table 3-8 then presents the compliance status for each of these scenarios as well as the 'Central' modelling. 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.

Table 3-7 Simple Summary Statistics for Sensitivity Testing of Gradients ($\mu g/m^3$)

Statistic	2027 Baseline	2027 Core	
	With Gradients	Without Gradients	With Gradients
Mean	21.6	20.5	20.6
Median	20.6	20.0	20.0
Maximum	46.3	39.4	39.5
Minimum	11.5	11.2	11.2
Upper Quartile	25.2	23.6	23.6
Lower Quartile	17.8	17.5	17.5
Standard Deviation	6.1	5.1	5.1
Range	34.8	28.2	28.3

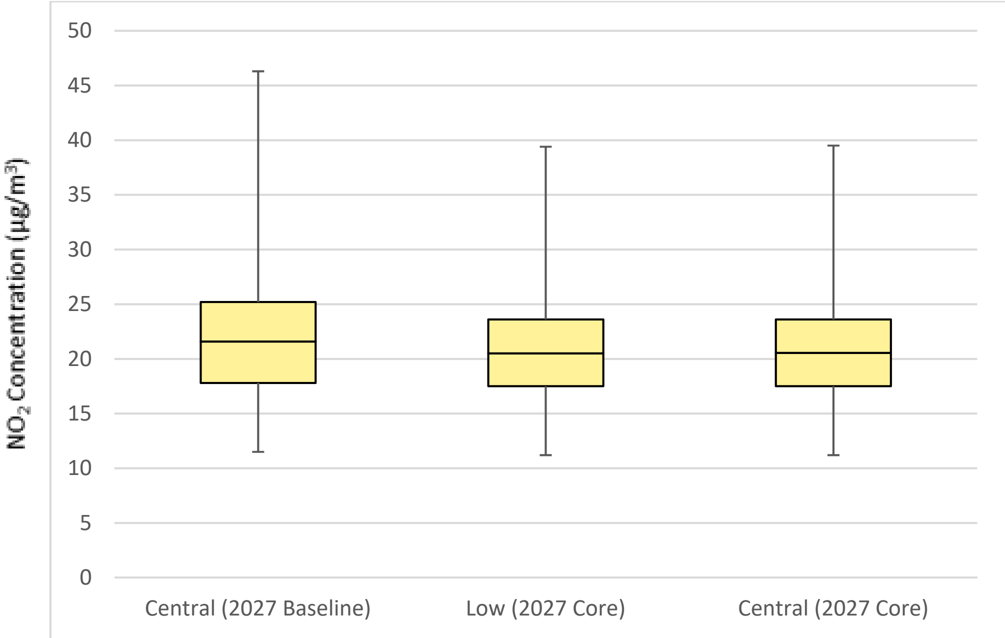

Figure 3-4 Distribution of NO_2 Concentrations for Sensitivity Testing of Gradients

Table 3-8 Summary of Compliance Status for Sensitivity Testing of Gradients

Statistic	2027 Baseline	2027 Core	
	With Gradients	Without Gradients	With Gradients
No. of Non-Compliance PCM Receptors	10	0	0
Compliance Status of Road Link with Highest NO_2 Value	Non-Compliant	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	15.8	-1.5	-1.3

3.6 Relationship of NOx and NO_2

3.6.1 Primary NO_2 Fraction

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[6]. 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. Following the JAQU guidance, the f-NO_2 values have been reduced by this percentage and the NO_2 concentrations re-calculated (in Defra's NOx to NO_2 Calculator) using these reduced f-NO_2 values. The results from this 'Low' scenario have then been compared to the NO_2 concentrations without applying this reduction ('Central' scenario).

Table 3-9 provides a summary of statistics (as requested in JAQU's 'Supplementary Note on Sensitivity Testing') and Table 3-10 presents the compliance status for each of these scenarios as well as the 'Central' modelling. Figure 3-5 shows the distribution of the resulting NO_2 concentrations. If the f-NO_2 values are reduced by 40% then the predicted concentrations are slightly lower, with the maximum predicted concentration being 4

[6] Grange S. et al., (2017) Lower vehicular primary emissions of NO_2 in Europe than assumed in policy projections, Nature Geoscience, pp 914-920, ISSN 1752-0908, https://doi.org/10.1038/s41561-017-0009-0

µg/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. It should be noted, that this is based on the assumption that current f-NO_2 values are correct. Using the f-NO_2 values from the EFT is JAQU's recommended approach.

Table 3-9 Simple Summary Statistics for Sensitivity Testing of f-NO_2 (µg/m^3)

Statistic	2027 Baseline	2027 Core	
		Low	Central
Mean	21.6	19.8	20.6
Median	20.6	19.4	20.0
Maximum	46.3	35.4	39.5
Minimum	11.5	11.1	11.2
Upper Quartile	25.2	22.7	23.6
Lower Quartile	17.8	17.1	17.5
Standard Deviation	6.1	4.6	5.1
Range	34.8	24.3	28.3

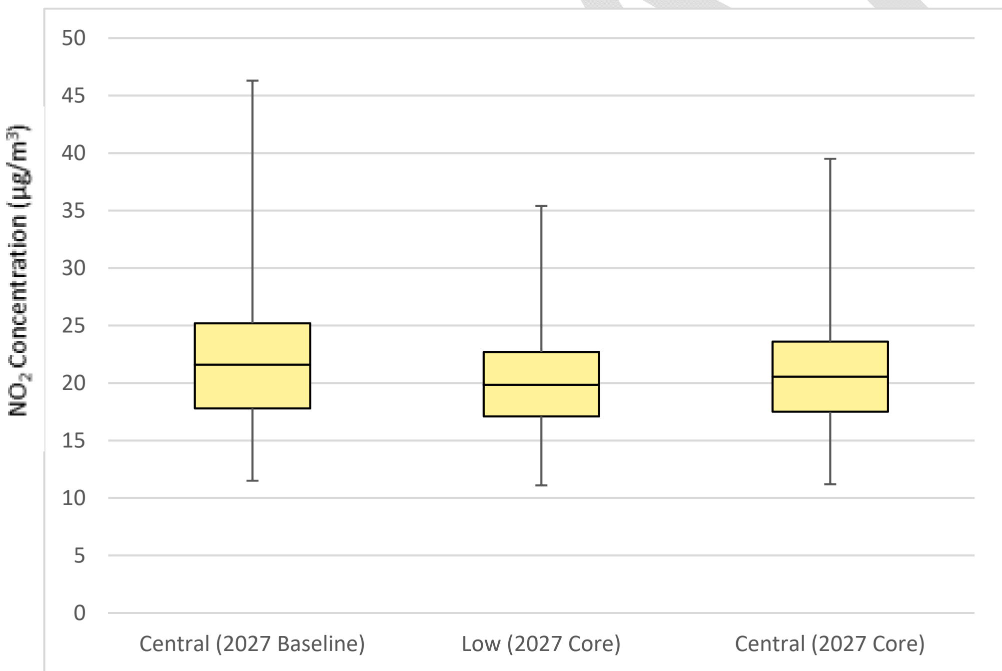

Figure 3-5 Distribution of NO_2 Concentrations for Sensitivity Testing of f-NO_2

Table 3-10 Summary of Compliance Status for Sensitivity Testing of f-NO_2

Statistic	2027 Baseline	2027 Core	
	Central	Low	Central
No. of Non-Compliance PCM Receptors	10	0	0
Compliance Status of Road Link with Highest NO_2 Value	Non-Compliant	Compliant	Compliant
Maximum NO_2 Percentage Gap from Compliance	15.8	-11.5	-1.3

3.6.2 Regional Ozone

Defra's NOx to NO_2 Calculator[7] calculates NO_2 concentrations from NOx concentrations, based on the reactions of mixing of nitric oxide, nitrogen dioxide and ozone. This relies on tabulated concentrations of ozone above the surface layer for each local authority, which have been modelled for each year between 2015, 2021 and 2031. There is an uncertainty in these predictions. Other NOx to NO_2 approaches are available, but none are clearly more appropriate and the use of Defra's NOx to NO_2 Calculator, which is the recommended method in the JAQU guidance. This issue will contribute to the overall uncertainty in the conclusions of the assessment.

[7] Defra (2018) Local Air Quality Management (LAQM) Support Website. Retrieved from http://laqm.defra.gov.uk/

4. Results Summary Table

For all sensitivity tests, a summary and key results is provided in Table 4-1 below:

Table 4-1 Summary of sensitivity analysis

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 WebTAG 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 WebTAG 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.

Test	Section Number	Summary	Key Results
Model Verification	3.4	The model verification for road NOX and subsequent NO2 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.
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 µg/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.

Appendix A Diesel Car Ban Eight-hour Timing Review

Bristol City Council Clean Air Plan

Outline Business Case

Diesel Car Ban Eight-hour Timing Review

OBC-39 – Appendix A

October 2019

JACOBS

Bristol Clean Air Plan

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Document history and status

Revision	Date	Description	By	Review	Approved
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2	24/10/2019	Draft 2	KW	CB	HO

Contents

1. Introduction

Jacobs has been commissioned to support BCC to produce an Outline Business Case (OBC) for the delivery of the CAP; a package of measures which will bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in central Bristol. The OBC assesses the shortlist of options set out in the Strategic Outline Case[1], and proposes a preferred option including details of delivery. The OBC forms a bid to central government for funding to implement the CAP. This report provides information about the diesel car ban timing which is appended to the sensitivity test report that supports the OBC.

1.1 Purpose of this Report

This report is written to review the effectiveness of an 8-hour diesel car exclusion during the 7am to 3pm time period compared to other times of day.

[1] Bristol City Council Clean Air Plan: Strategic Outline Case, April 2018 (https://www.cleanairforbristol.org/wp-content/uploads/2018/05/Strategic-Outline-Case_BCC_Final_05.04.18.pdf)

2. Behavioural Response Methodology

2.1 Calculated Response Rates for Diesel Car Exclusion 7am-3pm (Option 2)

Full details of the calculation of the behavioural responses is provided in the OBC-23 Bristol Clean Air Plan: Transport Modelling Methodology Report and the OBC-26 Bristol Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix E of the OBC.

The methodology for calculating the primary response rates for the small area diesel car exclusion (7am-3pm) is summarised as follows:

- Calculate 24-hour car diesel exclusion response rate for the small area - the pay charge response rate was set to zero, the avoid zone, cancel trip/change mode and replace vehicle rates have been determined by the stated preference survey diesel car responses which have been normalised so that the total response rate totals 100 per cent, as shown in Table 2-1;

Table 2-1: 24-hour Primary Behavioural Response Rates for Diesel Car Exclusion

Response	Cars Low Income	Cars Medium Income	Cars High Income	Cars Employers Business
Pay Charge	0.0%	0.0%	0.0%	0.0%
Avoid Zone	17.5%	17.5%	17.5%	17.5%
Cancel Journey / Change Mode	23.8%	23.8%	23.8%	23.8%
Replace Vehicle	58.7%	58.7%	58.7%	58.7%

- Calculate 8-hour (7am-3pm) car diesel ban responses based on the assumptions outlined in Table 2-2, with final response rates shown in Table 2-3. This methodology takes into account the estimated proportions of trips to change time of day (TOD response) to avoid the exclusion period and the estimated extent to which trips are linked between different time periods by trip purpose.

Table 2-2: 8-hour (7am-3pm) Car Diesel Exclusion Methodology

Time Period	Commute	Education	Other	Business
AM (7-10)	TOD - shift to pre 7am, based on calcluated % that travel in 30 mins post 7am compared to 7am-10am CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - shift to post 3pm (as per SP RV) CTCM - from SP AZ - from SP RV - 0% SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%
IP (10-3)	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - shift to post 3pm (as per SP RV) CTCM - from SP AZ - from SP RV - 0% SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%
PM (3-7)	TOD - 0% CTCM - some linked to earlier trips - PA/OD factors used from RSI surveys AZ - 0% RV/SV - some linked to earlier trips - PA/OD factors used from RSI surveys	TOD - 0% CTCM - some linked to earlier trips - PA/OD factors used from RSI surveys AZ - 0% RV/SV - some linked to earlier trips - PA/OD factors used from RSI surveys	TOD - shift from pre 3pm CTCM - some linked to earlier trips - PA/OD factors used from RSI surveys AZ - 0% RV - 0% SV - some linked to earlier trips - PA/OD factors used from RSI surveys	TOD - 0% CTCM - some linked to earlier trips - PA/OD factors used from RSI surveys AZ - 0% RV - some linked to earlier trips - PA/OD factors used from RSI surveys

Key:
SP – Stated Preference Surveys
TOD – Time of Day Choice
CTCM – Cancel Trip / Change Mode
AZ – Avoid Zone
RV – Replace Vehicle
SV – Switch Vehicle

Table 2-3: Final 8-hour (7am-3pm) Car Diesel Exclusion Primary Response Rates

Response Rate	Cars Low-High Inc			Cars Emp Bus		
	AM	IP	PM	AM	IP	PM
Pay Charge	NA	NA	NA	NA	NA	NA
Avoid Zone	15.44%	14.56%	0.00%	17.47%	14.56%	0.00%
Cancel Journey / Change Mode	21.03%	21.85%	15.74%	23.79%	23.52%	22.18%
Replace Vehicle	43.04%	19.45%	31.54%	58.74%	58.07%	54.75%
Time of Day Choice	20.49%	31.94%	0.00%	0.00%	0.00%	0.00%

2.2 Calculated Response Rates for Diesel Car Exclusion (7am-10am and 2pm-7pm)

An alternative timing for the 8-hour exclusion was identified based on a review of hourly traffic count data for the central Bristol area. This identified that a 'split' time period of 7am-10am and 2pm-7pm would cover the highest traffic flows.

The methodology for calculating the primary response rates for the small area 8-hour split diesel car exclusion (7am-10am and 2pm-7pm) is summarised as follows:

- Use the 24-hour car diesel exclusion response rate for the small area, as shown previously in Table 2-1;
- Calculate the split 8-hour diesel car ban responses based on the assumptions outlined in Table 2-4, with final response rates shown in Table 2-5. Again, this methodology takes into account the estimated proportions of trips to change time of day (TOD response) to avoid the exclusion period and the estimated extent to which trips are linked between different time periods by trip purpose.

Table 2-4: Split 8-hour Car Diesel Exclusion Methodology

Time Period	Commute	Education	Other	Business
AM (7-10)	TOD - shift to pre 7am, based on calcluated % that travel in 30 mins post 7am compared to 7am-10am CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - shift to post 10am (as per SP RV) CTCM - from SP AZ - from SP RV - 0% SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%
IP (10-2)	TOD - shift from after 2pm CTCM - some linked to earlier/later trips - PA/OD factors used from RSI surveys AZ - 0% RV/SV - some linked to earlier/later trips - PA/OD factors used from RSI surveys	TOD - 0% CTCM - some linked to earlier trips - PA/OD factors used from RSI surveys AZ - 0% RV/SV - some linked to earlier trips - PA/OD factors used from RSI surveys	TOD - shift from before 10am/after 2pm CTCM - some linked to earlier/later trips - PA/OD factors used from RSI surveys AZ - 0% RV - 0% SV - some linked to earlier/later trips - PA/OD factors used from RSI surveys	TOD - 0% CTCM - some linked to earlier/later trips - PA/OD factors used from RSI surveys AZ - 0% RV - some linked to earlier/later trips - PA/OD factors used from RSI surveys
IP (2-4)	TOD - shift to pre 2pm, based on calcluated % that travel in 30 mins post 2pm compared to 2pm-4pm CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - shift to pre 2pm (as per SP RV) CTCM - from SP AZ - from SP RV - 0% SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%
PM (4-7)	TOD - shift to post 7pm, based on calcluated % that travel in 30 mins pre 7pm compared to 4pm-7pm CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%	TOD - shift to pre 2pm (as per SP RV) CTCM - from SP AZ - from SP RV - 0% SV - from SP Percentages above proportioned so total equal 100%	TOD - 0% CTCM - from SP AZ - from SP RV - from SP SV - from SP Percentages above proportioned so total equal 100%

Key:
SP – Stated Preference Surveys
TOD – Time of Day Choice
CTCM – Cancel Trip / Change Mode
AZ – Avoid Zone
RV – Replace Vehicle
SV – Switch Vehicle

Table 2-5: Final Split 8-hour Car Diesel Exclusion Primary Response Rates

Response Rate	Cars Low-High Inc			Cars Emp Bus		
	AM	IP	PM	AM	IP	PM
Pay Charge	NA	NA	NA	NA	NA	NA
Avoid Zone	15.44%	5.44%	15.55%	17.47%	5.82%	17.47%
Cancel Journey / Change Mode	21.03%	13.04%	21.18%	23.79%	15.59%	23.79%
Replace Vehicle	43.04%	10.87%	34.05%	58.74%	38.49%	58.74%
Time of Day Choice	20.49%	14.96%	29.22%	0.00%	0.00%	0.00%

3. Results and Conclusion

3.1 Results

The response rates calculated above for each 8-hour diesel car exclusion scenario have been applied to Baseline car diesel trips within the Small CAZ area for each time period. This gives an indication of how many diesel car trips will be 'removed' from the CAZ over a 12-hour time period for each scenario i.e. either avoid the zone, cancel trip / change mode or be replaced with a non-diesel vehicle. Tables 3-6 and 3-7 show the results for both scenarios for 2021 and 2031 respectively.

Table 3-6: 2021 Diesel Cars Removed from Zone

Diesel cars	Cars Low-High Inc			Cars Emp Bus			Total
	AM (7-10)	IP (10-4)	PM (5-7)	AM (7-10)	IP (10-4)	PM (5-7)	
Baseline	356,073	581,942	406,315	36,489	102,758	22,674	1,506,250
Removed 7am-3pm:	283,106	325,084	192,122	36,489	98,807	17,443	953,051
Removed 7am-10am and 2pm-7pm:	283,106	170,781	287,573	36,489	61,552	22,674	862,174

Table 3-7: 2031 Diesel Cars Removed from Zone

Diesel cars	Cars Low-High Inc			Cars Emp Bus			Total
	AM (7-10)	IP (10-4)	PM (5-7)	AM (7-10)	IP (10-4)	PM (5-7)	
Baseline	332,159	571,461	384,347	34,537	100,686	21,682	1,444,872
Removed 7am-3pm:	264,093	319,229	181,735	34,537	96,815	16,680	913,088
Removed 7am-10am and 2pm-7pm:	264,093	167,705	272,025	34,537	60,311	21,682	820,353

The results indicate that the 'contiguous' 7am-3pm 8-hour diesel car exclusion would remove more diesel cars from the exclusion zone on a daily basis than the 'split' diesel car exclusion, by around 10%. This is intuitively explained by a number of factors, as follows:

- the split diesel car exclusion allows more opportunity for time of day choice, with less significant changes to travel times required, meaning it will be easier for some drivers to avoid the exclusion times;
- the inter-peak 10am-2pm time period where there is no exclusion offers a significant time frame for 'other' trips to access the Small CAZ with a diesel car;
- the 7am-3pm exclusion covers a significant proportion of the day capturing journeys from home, therefore trips during the 3pm-7pm time period are likely to include a high proportion of linked 'return journey' trips which would therefore also be impacted by the diesel car exclusion earlier in the day.

3.2 Conclusion

Based on the above preliminary analysis it is expected that a 'split' 8-hour car diesel ban would not be more effective than a 'contiguous' 8-hour car diesel ban scheme. Additional work is proposed to verify this conclusion, in particular, since the expected effectiveness of the exclusion scheme would be particularly sensitive to assumptions regarding the extent to which trips are linked between different times of day.