Bristol City Council Clean Air Plan
Outline Business Case

Economic Case

OBC-05 | 3

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Bristol City Council

Economic Case

Contents

Acronyms and Abbreviations

ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
B&NES	Bath and North East Somerset
BCC	Bristol City Council
CAZ	Clean Air Zone
CSF	Critical Success Factor
Defra	Department for Environment, Food & Rural Affairs
DfT	Department for Transport
EFT	Emission Factor Toolkit
EU	European Union
EV	Electric Vehicle
FBC	Full Business Case
GBATS4M	Greater Bristol Area Transport Study v4M
GVA	Gross Value Added
HGV	Heavy Goods Vehicle
IMD	Indices of Multiple Deprivation
JAQU	Joint Air Quality Unit
JLTP	Joint Local Transport Plan
JTS	Joint Transport Study
JSP	Joint Spatial Plan
LEP	Local Enterprise Partnership
LGV	Light Goods Vehicle
NOx	Nitrogen Oxides
NO_2	Nitrogen Dioxide
NSC	North Somerset Council
OBC	Outline Business Case
PCM	Pollution Climate Mapping
PHV	Private Hire Vehicle
PM	Particulate Matter
SOC	Strategic Outline Case
SGC	South Gloucestershire Council
WECA	West of England Combined Authority

3. Introduction

3.1 Introduction

This chapter sets out the economic case and forms part of the BCC CAP Outline Business Case. This economic case has the following supporting documents:

- Appendix D Air Quality Assessment Reports
- Appendix E Transport Modelling Reports
- Appendix F Stated Preference Survey Report
- Appendix G Economics Methodology Report
- Appendix H Distributional and Equalities Impacts Report
- Appendix P Sensitivity Test Report
- Appendix T Environmental Assessment Report

A draft version of this report was published in January 2019. Since this report, further work has been undertaken to develop the scheme options, and this work is reported in the Option Assessment Report, appended to the OBC.

3.2 Options assessed

The Option Assessment Report (Appendix C to the OBC) sets out the option development work. The options considered are:

- Option 1:
  - Medium Area Class C (charging higher emissions buses, coaches, taxis, HGVs and LGVs);
  - Diesel car scrappage scheme;
  - HGV exclusion on links within the city centre with exceedances;
  - 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
  - 8-hour diesel car exclusion on Park Row/Upper Maudlin Street and Marlborough Street.
- **Medium CAZ D + plus Option 1:** As Option 1 but includes charging higher emission cars (this is defined at the New benchmark option which has been requested by JAQU to compare with the preferred option).
- **Option 2:** 8-hour small area diesel car exclusion (7am – 3pm)
- **Hybrid Option:** Option 1 + Option 2.

The initial assessment showed that the Hybrid Option and the Medium CAZ D + plus Option 1 (New Benchmark Option) are expected to achieve compliance by 2027. The Hybrid Option compliance date is driven by exceedances at only one location - Church Road [1]whereas the New Benchmark Option compliance date is driven by three locations, which include city centre locations. BCC's transport planners are of the view that interventions will much more successful and easier to implement at the Church Road location than the other three locations. This supports the hybrid option as being the option to be recommended to Cabinet for progression to Full Business Case stage.

This chapter reports the economic case for all four options, not just the preferred option. Option 1 and Option 2 were consulted on prior to the completion of the Option Assessment Report. Information is being provided for the Medium CAZ D + plus Option 1 as it is the New Benchmark Option.

[1] Subsequent to this work, further modelling was undertaken for Church Road, this is reported in Section 3.4.3

3.3 Transport Modelling Approach

3.3.1 Modelling methodology

This modelling methodology summarises the detailed methodology found in the Local Plan Transport Modelling Methodology Report (T3), and its appended technical notes, bringing together an overview of all the components of how the baseline and option testing has been carried out using the GBATS4M Transport Model.

3.3.2 Base and Baseline

3.3.2.1 Model Development

The Local Plan Transport Modelling Methodology Report (T3), chapters 3, 4 and 7, outlines the modelling methodology for the Base and Baseline models. It states that the GBATS4M variable demand model has been used to develop the 2021 baseline models, based on the inputs from the updated Uncertainty Log.

The Uncertainty Log was originally developed in 2015 therefore details for an up-to-date Uncertainty Log have been collated. This covers both development and scheme assumptions. The baseline model (2021) has the most recent scheme assumptions for the assessment year modelled within it based on the Near Certain and More than Likely entries in the Uncertainty Log, in accordance with WebTAG.

A growth model has been developed within the Demand Model which creates highway and public transport future year demand matrices using the production and attraction trip end totals for the new development, a gravity model to distribute these new developments using base year travel costs and then converting to origin and destination format. These new trips are then added to the base year matrices. Three-dimensional matrix balancing to build full reference case matrices is undertaken, retaining the base year trip length distribution and control to the National Trip End model (NTEM, Tempro V7.2) growth for West of England and external zones.

These matrices are then run through the variable demand model until convergence is achieved within the limits specified by the DfT.

Light and heavy goods vehicle growth is based on forecasts produced by the National Transport Model (NTM) as advised by WebTAG. Goods vehicles are not subject to change via the demand model.

Joint Spatial Plan growth has not been included in the development of the 2021 and 2031 baseline models as it is not sufficiently certain, in terms of the WebTAG criteria, to be included.

The 2021 Baseline highway model developed has been adapted to be able to model the implementation of a charging CAZ. The matrices have been split by compliance for each user class using the surveyed Automatic Number Plate Recognition (ANPR) data. A further adaption of the model has been undertaken with car matrices split by fuel type in order to assess a diesel car ban scheme.

3.3.2.2 ANPR Data

The 2017 Automatic Number Plate Recognition (ANPR) surveys were undertaken in July and the analysis (including tabulated data) and use is discussed fully in the ANPR Data Analysis and Application technical note which is appended to T3. A summary is provided here.

The ANPR data has been used to determine the compliance splits of the current fleet when compared to the CAZ framework criteria relating to Euro Standards. The registration data from the ANPR surveys have been cross referenced with data purchased from Carweb to gain information on vehicle type, fuel type and Euro standard. The ANPR data has also been used to split the taxi fleet from the car matrices and the coaches from the HGV matrices, by applying global factors, by time period.

The base year compliance splits by vehicle type (Car, Taxi, LGVs, Coaches and HGVs) have been determined from the 2017 ANPR data worked back to 2015 using the Emission Factor Toolkit national euro standard splits. The baseline has been adjusted to 2021 using the fleet projection tool within the Emission Factor Toolkit.

3.3.2.3 Matrix Compliance Splits

The base year highway model has 6 user classes: Car Non-business (Low Income), Car Non-business (Medium Income), Car Non-business (High Income), Car Business, LGV and HGV. These have been split into 16 user classes using the following methodology:

- Split the Car user classes into Car and Taxi user classes;
- Split the HGV user class into HGV and Coach user classes;
- Split Taxi, LGV, HGV and Coach matrices into compliant and non-compliant using the time period splits; and
- Further split the car user classes in two different ways, to test a charging CAZ scheme and a diesel car ban scheme respectively, as follows:
  - split into compliant / non-compliant cars
  - split into non-diesel / diesel cars.

3.3.2.4 Post-Processing

The ANPR data collected has also been used to determine the HGV rigid/artic split by compliance and fuel type splits for cars and LGVs. This has been used to add more detail to the modelled outputs via post processing, to produce inputs into the EFT.

First Bus provided information regarding the 2021 fleet composition by service. Non-First bus compliance splits have been derived from ANPR data adjusted to 2021 using the EFT tool. The bus fleet composition has been handled outside the transport model, before input to the EFT. This has enabled vehicle details for particular routes to be accounted for in both the current and future fleet.

3.3.2.5 Euro Standard Splits

The EFT has national Euro Standard splits within it. These have been overwritten with splits calculated from the 2017 ANPR data, projected forward to 2021 using the EFT.

3.3.2.6 2015 Base Compliance Splits

The base year compliance splits have been determined from the 2017 ANPR data worked back to 2015 using the EFT national euro standard splits. The ANPR Data Analysis and Application technical note (appended to T3), Chapter 3, details this process and the outputs. Table 3.1 shows the projected 2015 compliance data by time period – AM peak, IP (Interpeak) and PM peak.

Table 3.1: 2015 Compliance Splits by Time Period, Medium Cordon

	Medium Cordon					
	AM		IP		PM	
Vehicle Category	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Non-compliant
Cars	36.1%	63.9%	34.7%	65.3%	35.3%	64.7%
LGV	0.2%	99.8%	0.2%	99.8%	0.2%	99.8%
HGV rigid	20.2%	79.8%	19.0%	81.0%	15.2%	84.8%
HGV artic	35.0%	65.0%	36.3%	63.7%	34.0%	66.0%
HGV	22.7%	77.3%	21.7%	78.3%	19.2%	80.8%
Taxi	11.5%	88.5%	9.1%	90.9%	10.7%	89.3%

Vehicle Category	Medium Cordon					
	AM		IP		PM	
	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Non-compliant
Bus	7.6%	92.4%	7.9%	92.1%	7.7%	92.3%
Coach	14.7%	85.3%	15.1%	84.9%	15.8%	84.2%
Total	28.4%	74.8%	27.1%	76.6%	30.0%	71.3%

3.3.2.7 2021 Baseline Compliance Splits

The fleet projection tool within the EFT version 8 has been used to project the euro standard splits from the 2017 ANPR data to the Baseline year of 2021. The ANPR Data Analysis and Application technical note (appended to T3), Chapter 4, details this process and the outputs. A summary of the projected 2021 compliance data by time period is provided in Table 3.2.

Table 3.2: 2021 Compliance Splits by Time Period

Vehicle Category	AM		IP		PM	
	Compliant	Non-compliant	Compliant	Non-compliant	Compliant	Non-compliant
Cars	74.0%	26.0%	72.8%	27.2%	73.4%	26.6%
LGV	58.0%	42.0%	63.1%	36.9%	58.2%	41.8%
HGV rigid	73.9%	26.1%	72.5%	27.5%	66.7%	33.3%
HGV artic	85.7%	14.3%	86.4%	13.6%	85.2%	14.8%
HGV	76.6%	23.4%	75.6%	24.4%	72.6%	27.4%
Taxi	39.7%	60.3%	33.7%	66.3%	37.7%	62.3%
Bus	65.2%	34.8%	66.3%	33.7%	65.7%	34.3%
Coach	68.8%	31.2%	69.6%	30.4%	70.6%	29.4%
Total	72.5%	30.8%	72.0%	31.7%	70.9%	30.3%

3.3.3 Clean Air Zone Option Testing

3.3.3.1 Primary Behavioural Responses

The primary responses have been modelled using the G-BATS4M highway model using the following methodology, as described in the Local Plan Transport Modelling Methodology Report (T3), Chapter 5:

- Pay Charge – no change to the highway model;
- Avoid Zone – a charge is applied to each inbound link to replicate the percentage change of non-compliant cars, LGVs and HGV's within the CAZ;
- Cancel journey / change mode – modelled by reducing the number of trips made by non-compliant vehicles to/from and within the CAZ area, to replicate the required percentage change from the baseline case; and
- Replace Vehicle – an adjustment to the link flows by extracting select cordon link flows for the non-compliant trips and switching the required proportion of replace vehicles from the non-compliant matrices to the compliant link flows.

3.3.3.2 Secondary Behavioural Responses

In addition to the primary behavioural responses, JAQU have set out some further assumptions on secondary responses for a charging CAZ for cars in paragraph 3.3 of the Evidence Package guidance. These have been used due to lack of any available local data.

These secondary responses have been applied during the calculation of the upgrade costs and post-processing of the extracted link-based flow data from the Transport Model for the 'replace vehicle' response.

3.3.3.3 Stated Preference Surveys

Stated preference survey of BCC / South Gloucestershire Council (SGC) / North Somerset Council (NSC)/ Bath and North East Somerset (B&NES) residents were undertaken in 2018. The work targeted owners of non-compliant cars / LGVs who drive in central Bristol, and 1100 online surveys completed Feb / March 2018.

The questionnaires asked how owners would respond to a small and medium size charging CAZ using structured 'multiple choice' exercises and then the results were analysed using logistical regression statistical techniques.

3.3.3.4 Upgrade Costs

In order to determine the primary response rates over a range of CAZ charges from the stated preference surveys, an upgrade cost is required for cars. The LGVs methodology for determining response rates also requires an estimation of an upgrade cost. The upgrade costs of other vehicle types (HGVs, Taxi, Bus and Coaches) were not used to calculate the primary response rates; rather, the primary response rates for these vehicle types were determined by other information collated.

3.3.3.5 Proposed Charge Rates

Table 3.3 shows the proposed charges. These are selected as the minimum charges required to address the air quality exceedances within Bristol and are in line with charges being considered by other local authorities.

The methodology for determining the proposed charge rates for all vehicle type is discussed fully in OBC-26 Primary Behavioural Response Calculation Methodology in Appendix E of the OBC and Table 3 3 shows the final proposed charges. The charges were initially set for Cars, taxis and LGVs so that the responses of avoid zone, change mode / cancel journey and replace vehicle combined roughly equated to the combined JAQU CAZ responses. These charges were found to be insufficient to bring about compliance and so testing with higher charges was undertaken. Above a certain level there are diminished returns to further increases and so the final proposed charges arrived at were at this point.

Table 3.3: Bristol CAZ Proposed Charges

Charge Class	Daily Charge
Cars*	£9.00
Taxis	£9.00
LGVs	£9.00
HGVs	£100.00
Buses	£100.00
Coaches	£100.00

*CAZ D option only

3.3.4 Calculated Response Rates for Option 1

The methodology for calculating the primary response rates for Option 1 is discussed fully in OBC-26 Bristol Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix E of the OBC and is summarised as follows (with cars not being charged in this option, there is no response required):

- LGVs - The primary response rates are calculated from the stated preference survey responses which were identified as a 'van'. Again, the upgrade cost is used to determine a range of primary responses for different charge rates from the Medium zone area;
- HGVs - The primary behavioural response rates for HGVs were taken from 'Table 2 – Behavioural responses to charging Clean Air Zones' in the Evidence Package, provided by JAQU.;
- Taxis - The taxi response rate is based on Bristol enforcing compliance for taxis through their licensing agreements with taxi operators;
- Coaches - The initial response rates for coaches were taken from 'Table 2 – Behavioural responses to charging Clean Air Zones' in the Evidence Package, provided by JAQU; and
- Buses - The response rates for buses were determined through discussions between Bristol and bus operators.

Table 3.4 shows the final primary behavioural response rates by vehicle type produced using the methodology set out above and the charge rates in Table 3.3.

Table 3.4: Calculated Response Rates for Option 1

Response	Cars Low Income	Cars Medium Income	Cars High Income	Cars Employers Business	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	0.0%	0.0%	0.0%	0.0%	4.1%	15.9%	8.8%	0.0%	17.8%
Avoid Zone	0.0%	0.0%	0.0%	0.0%	0.0%	19.2%	4.3%	0.0%	0.0%
Cancel Journey / Change Mode	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	4.3%	6.4%	11.4%
Replace Vehicle	0.0%	0.0%	0.0%	0.0%	95.9%	62.2%	82.6%	93.6%	70.8%

3.3.5 Calculated Response Rates for Medium CAZ D + Option 1 (benchmark option)

The methodology for calculating the primary response rates for Medium CAZ D + Option 1 is discussed fully in OBC-26 Bristol Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix E of the OBC and is summarised as follows:

- Cars - The upgrade cost has been used to determine a range of primary responses for different charge rates using the stated preference survey responses for diesel cars from the Medium zone area;
- Other vehicle types are as per Option 1.

An adjustment for foreign vehicles has been applied to the response rates calculated from the methodology set out above, as foreign vehicles cannot be reliably charged (their details are not captured in the Driver and Vehicle Licensing Agency (DVLA) database in order to determine if the vehicle is compliant and so enforcement can only occur through a manual process with limited powers). The final response rates will assume a 'worst case', i.e. that these vehicles continue to drive within the zone but do not pay the charge. In reality it is unlikely that this will be the case for all foreign vehicles.

Table 3.5 shows the final primary behavioural response rates by vehicle type produced using the methodology set out above and the charge rates in Table 3.3.

Table 3.5: Final Primary Behavioural Response Rates for Medium CAZ D + Option 1 (benchmark option)

Response	Cars Low Income	Cars Medium Income	Cars High Income	Cars Employers Business	Taxis	LGVs	HGVs	Buses	Coaches
Pay Charge	4.4%	7.3%	5.2%	9.4%	4.1%	15.9%	8.8%	0.0%	17.8%
Avoid Zone	10.8%	14.1%	16.1%	18.0%	0.0%	19.2%	4.3%	0.0%	0.0%
Cancel Journey / Change Mode	39.9%	22.1%	14.2%	14.5%	0.0%	2.6%	4.3%	6.4%	11.4%
Replace Vehicle	44.9%	56.5%	64.5%	58.1%	95.9%	62.2%	82.6%	93.6%	70.8%

3.3.6 Calculated Response Rates for Option 2

The methodology for calculating the primary response rates for Option 2 is discussed fully in OBC-26 Bristol Clean Air Plan: Primary Behavioural Response Calculation Methodology in Appendix E of the OBC and is summarised as follows:

- Calculate 24-hour diesel car exclusion response rates 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 which have been normalised so that the total response rate sum to 100 per cent, as shown in Table 3.6;

Table 3.6: 24-hour Primary Behavioural Response Rates for Diesel Cars

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) diesel car ban based on the assumptions outlined in Table 3.6 to yield final response rates shown in Table 3.7.

Table 3.7: 8-hour (7am-3pm) Diesel Car 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 3.8: Final 8-hour (7am-3pm) Diesel Car 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%

3.3.7 Calculated Response Rates for Hybrid Option

The primary response rates for the Hybrid Option are as follows:

- Cars – as per Option 2, as shown in Table 3.6; and
- All other vehicle types – as per Option 1, as shown in Table 3.4.

3.4 Air Quality Modelling Approach

3.4.1 Overview of approach

Dispersion modelling has been undertaken using ADMS-Roads version 4.1 and 4.1. ADMS v4.1 is one of the "standard" models recommended in JAQU's 'Transport and Air Quality' guidance. ADMS-Roads v4.2 is a new version and contains a feature which allows a concentration output to be reported from every emissions source (i.e. road section) to every receptor. The model is approved by Defra and used extensively in the United Kingdom.

The model base year is 2015, with monitoring data for this year used to verify and adjust the modelled concentrations. Option 1, Option 2, Medium CAZ D + Option 1, and the hybrid of Option 1 and Option 2 have been modelled for the future years 2021 and 2031, together with the future baseline (with the aforementioned measures) for the same years.

Both options showed exceedances of the NO_2 limit in Bristol city centre in 2021 and no exceedances in 2031. So, in order to compare the two options in terms of reaching compliance in the shortest time possible and estimate in which year compliance would be reached, modelling results have been interpolated between 2021 and 2031.

The model domain includes all roads that are listed within the national Pollution Climate Mapping (PCM) model for the study area, as exceeding the annual mean Limit Value in 2021 for NO_2 (as published by Defra), as well as roads where annual mean NO_2 concentrations are known to exceed the national air quality objective, based on the most recent review and assessment report published by BCC.

The domain also includes all potential displacement routes which may be affected by the measures, identified from the traffic model.

As part of the assurance process Air Quality Consultants (AQC) reviewed the modelling of the hybrid option. Following this review, further work was undertaken to refine the modelling at Church Road, and to create forecast models closer to the compliance year. The results of this work are reported in section 3.4.3.

3.4.2 Summary of results

A detailed assessment of the impacts of Option 1, Option 2, the hybrid option and the benchmark option (Medium CAZ D+ Option 1) the options on air quality has been undertaken for the OBC using traffic and air quality models. The number of Non-Compliant Receptors Per Year, Per Scenario summarised in Table 3.9.

Table 3.9: Number of Non-Compliant Receptors Per Year, Per Scenario

Road Name	Number of Non-Compliant Receptors in Each Scenario (2021)				
	Final Reference	Option 1	Option 2	Medium CAZ D +	Hybrid
2021	138	65	104	57	62
2022	97	47	72	45	37
2023	64	40	46	37	25
2024	48	32	37	22	18
2025	33	23	21	14	7
2026	26	14	14	12	3[2]
2027	10	4	4	0	0
2028	6	4	0	0	0

[2] Exceedances in 2026 and 2027 are on Church Road.

Road Name	Number of Non-Compliant Receptors in Each Scenario (2021)				
	Final Reference	Option 1	Option 2	Medium CAZ D +	Hybrid
2029	5	0	0	0	0
2030	0	0	0	0	0

Following the work reported above, further assessment work was undertaken to confirm the compliance year. This work is reported in the following section.

Further detail is provided on the options assessment and their compliance years in the following section, Table 3.10 and Figures 3.1-3.4.

3.4.2.1 Option 1

The implementation of Option 1 has a significant impact in 2021, as the 65 anticipated non-compliances are less than half of the number modelled in the Final Reference case. The Option 1 compliance year is anticipated to be 2029. It achieves compliance on Marlborough Street and Church Road (the two most significant locations in this assessment) by 2027, but is held back by non-compliance at 4 receptors on Park Street. All other locations are anticipated to be compliant prior to 2027.

Park Street's high annual mean NO2 concentrations in the 2021 Final Reference scenario are predominantly caused by high proportions of diesel cars, LGVs and HGVs, as well as the presence of a gradient, which exacerbates pollutant emissions from HGVs in particular. Unfortunately, the Upper Maudlin Street / Park Row diesel ban was predicted to cause a percentage of non-compliant vehicles to reroute onto Park Street increasing annual mean NO2 concentrations at reportable receptors. This is one of the reasons that Option 1 by itself was not taken forwards.

3.4.2.2 Option 2

As Option 1 was still being considered, other options were being developed to see if a compliance year of 2029 could be bettered. Option 2 comprises a diesel car ban within a specific boundary (i.e. smaller than the medium area in Option 1) in central Bristol operating between 7am and 3pm, 7 days a week. This is a simpler but more stringent solution as it focuses directly on the highest polluting vehicles.

Option 2 did not appear to have an immediate significant impact on compliance across the network when compared with Option 1. It reduced the number of non-compliances by 34 to a total of 104 in 2021, which is attributable to the fact that it covers a much smaller area than the measures in Option 1.

However, Option 2 achieves a compliance year of 2028, which is one year earlier than Option 1. The additional number of non-compliances in the 2021 Option 2 scenario are locations outside of the diesel ban zone, with less significant exceedances of the EU Limit Value. Locations with smaller exceedances of the EU Limit Value are more likely to be brought to compliance naturally (i.e. owing to improvements in vehicle emissions technology), without specific intervention. The diesel ban targets the areas with the largest modelled annual mean NO2 concentrations where diesel emissions have been shown to significantly contribute to the non-compliance.

Table 6-1 indicates that there are 4 non-compliant, reportable receptors in 2027 with Option 2 implemented. One of these is located on Marlborough Street, with the remaining three located along Church Road. The Marlborough Street exceedance is considered to be caused by a combination of high levels of diesel cars and LGVs, which is exacerbated by the presence of tall 'canyons' which prevent pollutant dispersion. Pollutant concentrations in canyons are often much worse than those outside of canyons with similar traffic.

Table 3.10: Details of the non-compliant sites

	Rupert Street	Marlborough Street	Upper Maudlin Street	Park Row	Park Street	Queen's Road	College Green	Ward Bdy (Chelt' Road)	New'land Way	Church Road
2021 Results (ug/m3)										
Background NO2	19.0	19.2	19.4	18.9	18.0	17.8	18.3	17.6	17.6	15.7
Baseline	50.0	59.4	46.9	47.5	49.1	41.9	49.2	40.5	50.6	53.3
Option 1	45.4	47.6	39.2	36.8	48.0	40.2	43.6	39.0	44.2	50.3
Option 2	46.2	51.1	41.9	40.3	47.1	38.9	46.3	39.7	45.8	53.9
Medium CAZ D+	43.5	44.5	36.7	34.0	44.4	38.5	42.1	36.9	41.3	48.5
Hybrid	41.7	44.2	36.7	35.6	41.4	35.0	39.8	38.3	39.3	50.8
2031 Results (ug/m3)										
Background NO2	14.9	14.9	15.1	14.5	13.8	13.6	14.2	13.5	13.6	12.1
Baseline	32.9	37.6	29.6	30.2	31.9	27.0	29.8	27.4	31.9	32.1
Option 1	33.0	34.2	27.8	27.1	37.0	30.2	30.5	28.9	31.6	32.6
Option 2	31.2	32.5	26.9	26.7	29.5	25.3	28.2	26.5	29.2	31.9
Medium CAZ D+	32.5	36.8	27.4	27.0	36.7	29.6	30.1	28.4	31.1	32.2
Hybrid	30.0	30.4	25.6	25.2	29.3	25.0	27.3	27.3	27.9	31.7
Compliance Year										
Baseline	2027	2030	2025	2026	2027	2023	2026	2022	2027	2028
Option 1	2026	2027	2021	2021	2029	2022	2024	2021	2025	2027
Option 2	2026	2028	2023	2022	2026	2021	2025	2021	2025	2028
Medium CAZ D+	2025	2027	2021	2020	2027	2021	2023	2021	2023	2027
Hybrid	2023	2025	2021	2020	2023	2021	2021	2021	2021	2027

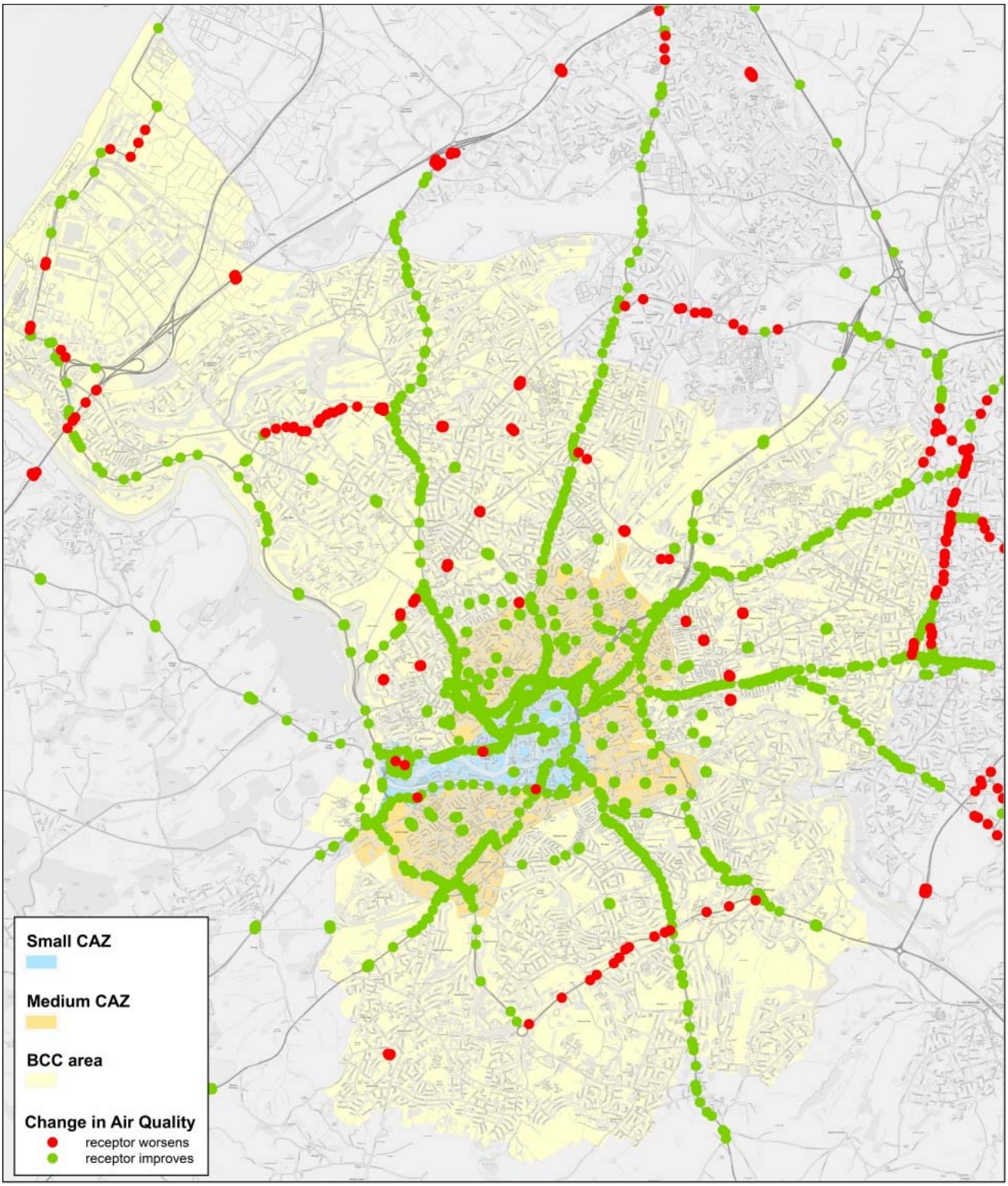

Figure 3.1:NO_2 impacts of Option 1

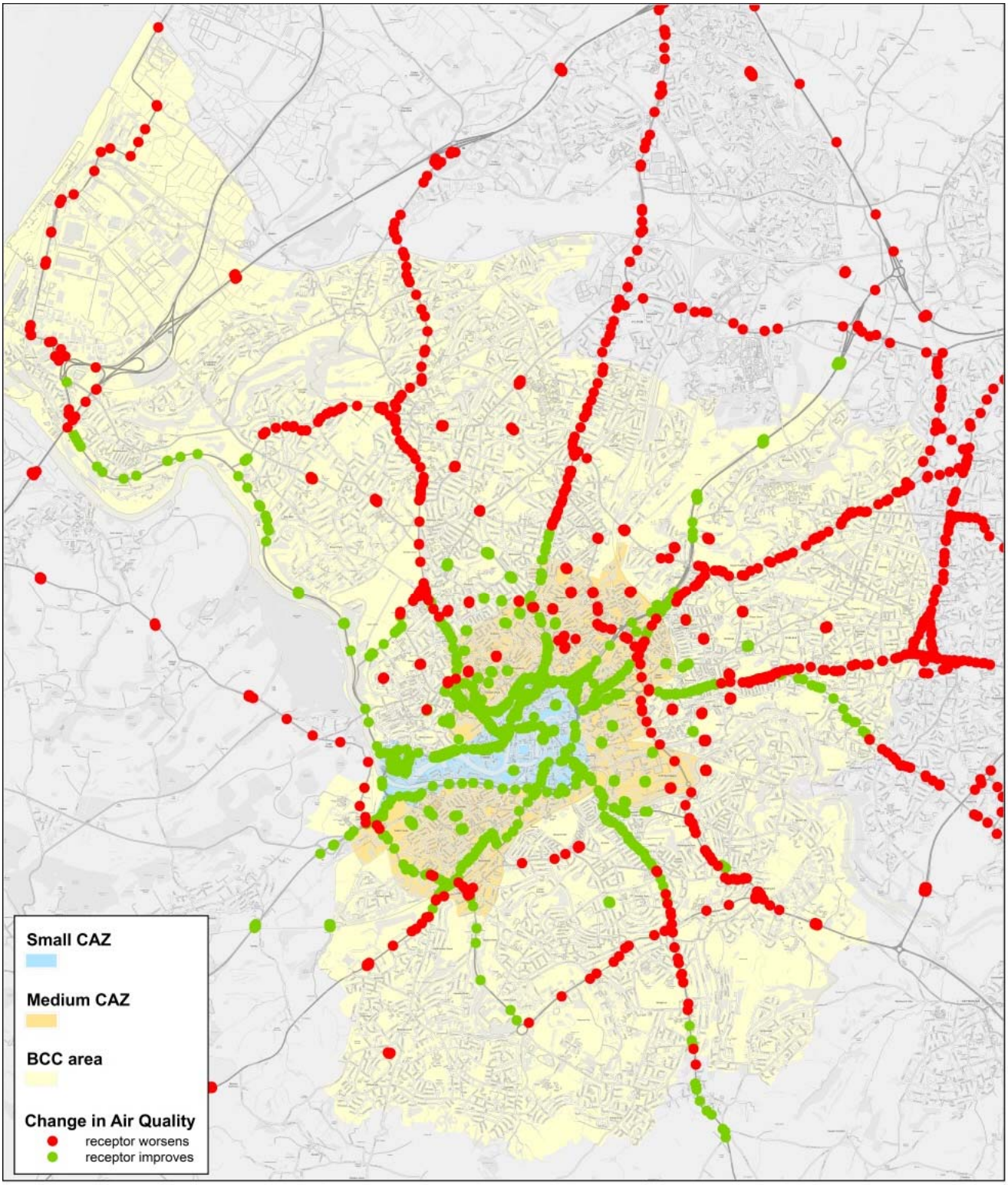

Figure 3.2: NO_2 impacts of Option 2

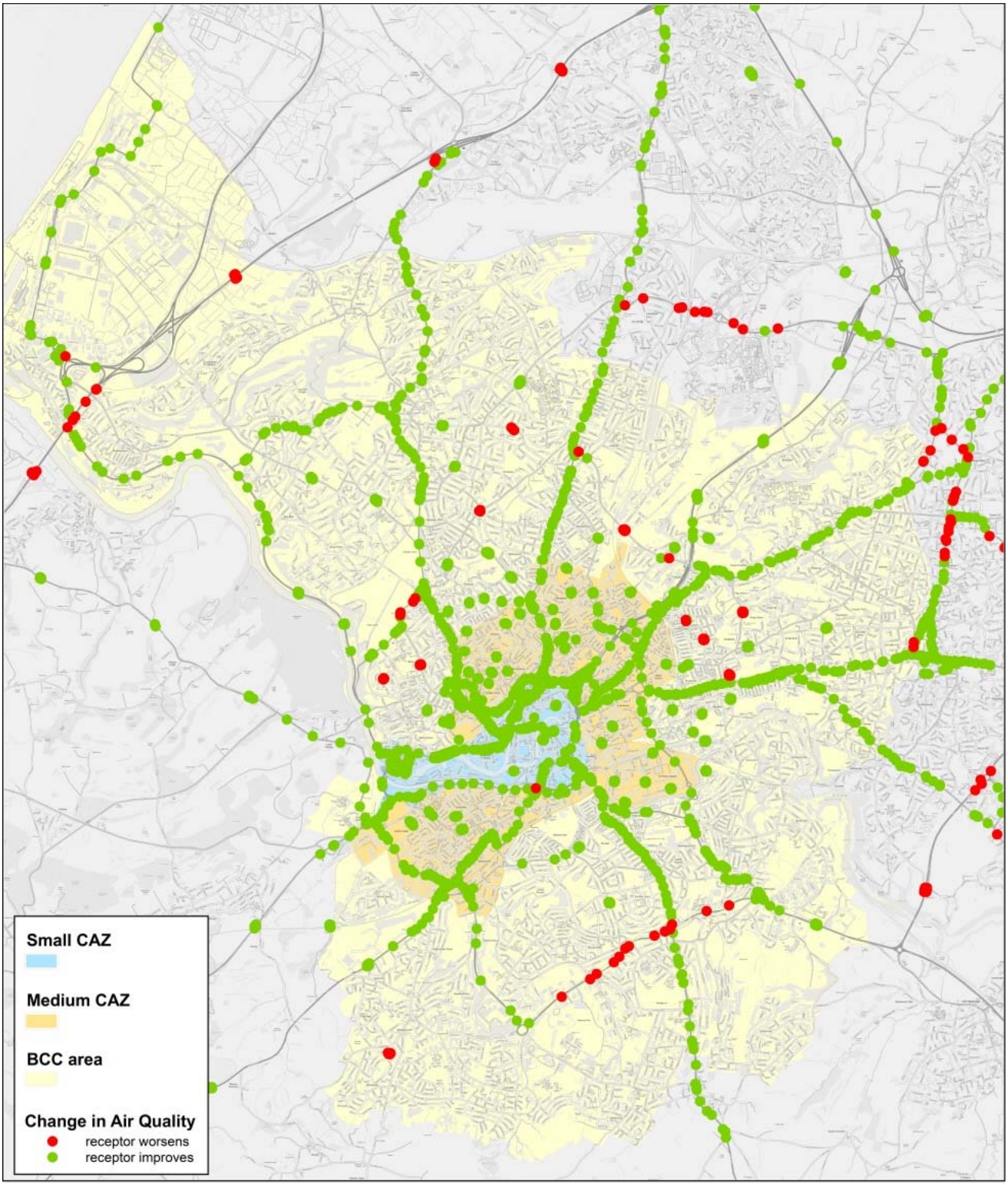

Figure 3.3: NO_2 impacts of Medium CAZ D + Option 1 (benchmark option)

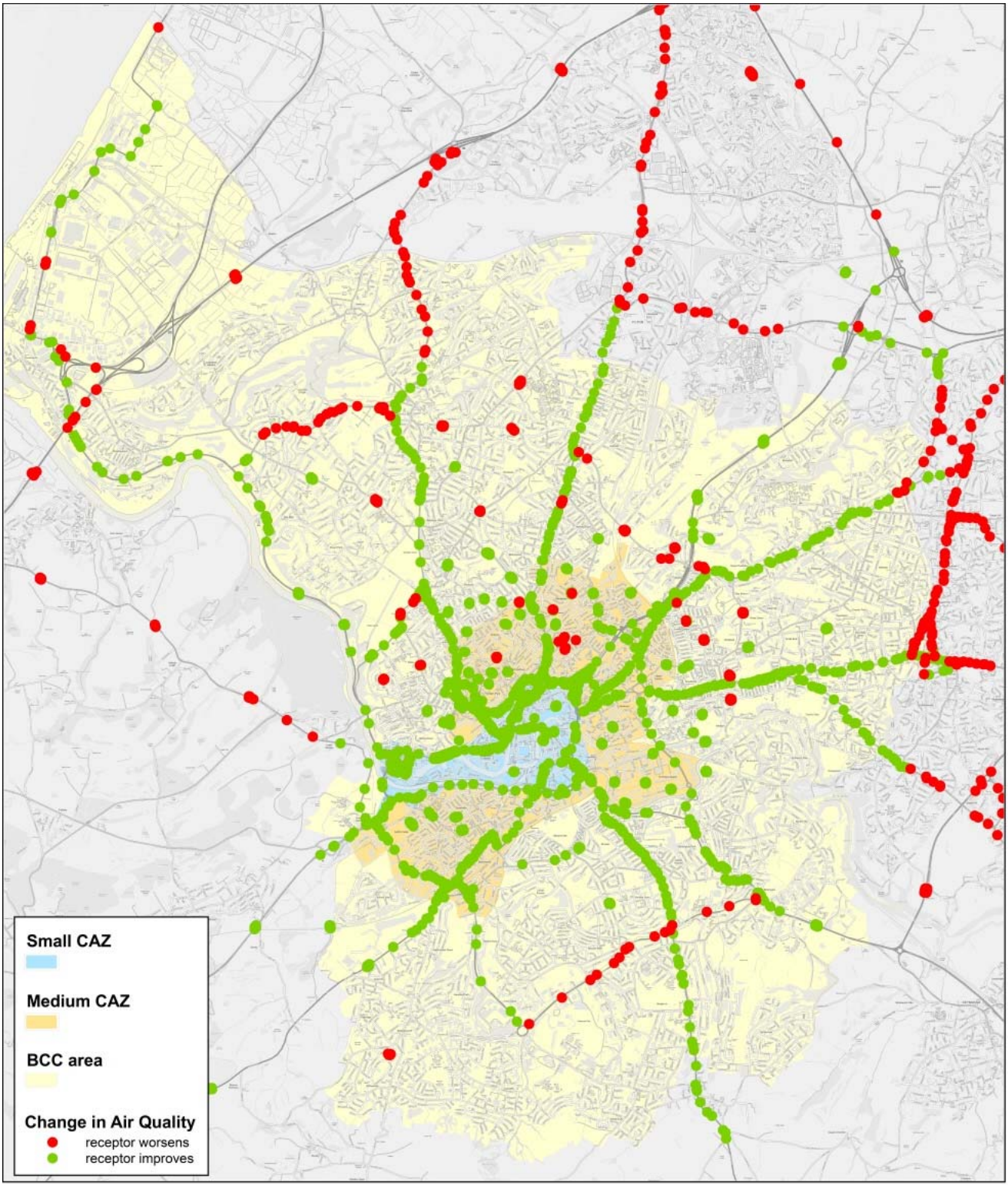

Figure 3.4: NO_2 impacts of the Hybrid Option

3.4.2.3 Medium CAZ D + Option 1 (benchmark option)

Whilst Options 1 & 2 were presented at public consultation, BCC further considered running a benchmark CAZ D type scenario as a comparison. The Medium CAZ D + scenario comprises the same measures as Option 1, but with the addition of a £9 charge for non-compliant cars that enter the area.

The source apportionment results presented in Table 6-1 indicates that diesel cars are a significant contributor to poor air quality, often the most significant source. Upgrading Option 1's CAZ C to a CAZ D has an immediate benefit, as the 65 non-compliances are reduced to 57 in the 2021.

Implementing a CAZ D instead of a CAZ C has additional benefits, as it also brings the compliance year forwards by 2 years (compared to Option 1), so that compliance is now achieved in 2027. In this case though, there are 12 receptors which prevent a compliance year of 2026. These are located on Park Street, Baldwin Street, Marlborough Street and Church Road. The non-compliances on Park Street, Marlborough Street and Church Road have been previously discussed, and the reasoning is relevant here. The only differences at these locations are that the Medium CAZ D leads to small improvements at these three locations, which bring compliance forward by a year compared to the CAZ C option.

However Baldwin Street is an example of a non-focused area that still presents issues in this scenario. There are two receptors at this location which are anticipated to be non-compliant in 2026. The largest contributors to the high modelled annual mean NO2 concentrations at this location are diesel cars, diesel LGVs and rigid HGVs, although it is likely that these are worsened by the presence of a canyon.

The purpose of the Medium CAZ D + was to act as a new benchmark case for future scenarios, and to compare previously assessed scenarios against.

3.4.2.4 Hybrid

The hybrid scenario combines all the aspects of Option 1, with Option 2 (i.e. Option 1 with a diesel car ban). It is similar to the Medium CAZ D + scenario, as it builds on previous solutions, but introduces a diesel car ban, rather than upgrading the CAZ C to CAZ D. It has slightly less immediate impact on compliance than the Medium CAZ D + scenario, as it reduces the number of non-compliances to 62. Similarly, it achieves a compliance year of 2027. The compliance date is attributed to exceedances on Church Road, so further work has been undertaken to refine the modelling at this location, as detailed in section 3.4.3.

3.4.3 Church Road Modelling and 2025 modelling

Since Church Road has been identified as a location that could potentially constrain scheme compliance and is outside the proposed scheme area, further investigation has been undertaken to review the traffic and air quality modelling at this location. This review highlighted that base year NO_2 concentrations and traffic flows at this location were higher than observed values. The base year GBATS model fits well to observed data at nearby locations where the model was originally validated, however the section of Church Road with the highest forecast NO_2 concentrations was not a link that was directly validated against traffic count data.

In order to identify more accurate NO_2 concentrations at this location, available traffic count data was reviewed and found that the observed traffic flows were higher than the modelled traffic flows. So adjustment factors were calculated and applied to the traffic model flows which in turn could then be re-tested in the air quality model.

In order to more accurately assess the year of compliance a 2025 test has been undertaken to reduce the need for interpolation of air quality results between 2021 and 2031. This has required the development of a 2025 forecast year baseline traffic model with which the scheme can be compared to. The Church Road adjustment of traffic flows has been applied in the 2025 model.

The 2025 traffic model was run to test the efficacy of the Hybrid scenario. In doing so, the reference case was also run for comparison with previous modelling results and to examine the current forecast of when BCC is likely to become naturally compliant with the NO_2 annual mean Limit Value. Indications are that with the Hybrid scenario compliance will be achieved in 2025. However, accounting for adjustment to the traffic flows on Church Road which was driving non-compliance outside of the Hybrid area of influence leads to a further reduction in the maximum concentration at 2025. An indicative estimation shows that this improvement in the maximum concentration to 33.6 µg/m^3 across the BCC study area could lead to an earlier compliance year of 2024. This would mean that the site driving compliance would become Marlborough Street (Receptor 12648).

3.5 Economic Modelling Approach

JAQU's Option Appraisal Guidance states that each shortlisted option identified at SOC stage should be subject to detailed assessment of their overall costs and benefits and their distributional impacts. The results from these assessments are intended to allow local authorities to identify the preferred option for a scheme based on its value to society, distributional impacts and achieving compliance in the shortest possible time. However, the Options Appraisal Guidance is also clear that only option packages that are likely to lead to compliance as quickly as possible will be accepted, using some pass/fail criteria as part of the Primary Critical Success Factors.

The economic analysis presented below is predicated on a comparative assessment of the four options.

The economic modelling approach is aligned with JAQU's Option Appraisal Guidance and gives full consideration to all of the economic impact types specified in that document. The results of the analysis are outlined in the following section; the overall framework and methodology applied to the analysis is presented in OBC-18 'Economic Methodology Report' in Appendix F of this OBC.

All the work in this section is based on the transport and air quality modelling work undertaken in 2021 and 2031 models, and not the 2025 work reported i Section 3.4.3

3.6 Economic Impacts

3.6.1 Health and Environmental Impacts

3.6.1.1 Greenhouse Gas Emissions

By changing travel behaviours (including number of trips, trip mode and vehicle type), the intervention options may influence the quantum of Greenhouse Gas (GHG) emissions generated by road transport. A change in GHG emissions, and CO_2 emissions in particular, could generate variable effects on climate change processes.

Based on air quality modelling outputs, the impact of the intervention options can be summarised as follows:

- Option 1 a modest reduction in GHG emissions over time relative to the baseline.
- Option 2 an increase in GHG emissions in 2021, potentially attributable to an increase in petrol vehicles (as replacement for banned diesel vehicles).
- Medium CAZ D + Option 1 a large reduction in GHG emissions over time relative to the baseline.
- Hybrid Option a modest reduction in GHG emissions over time relative to the baseline

Relative to their respective baseline scenarios, intervention Option 1, Medium CAZ D + Option 1 and the Hybrid Option will therefore initially reduce the quantum of CO_2 emissions released into the atmosphere before increasing emissions at a later date. Option 2 will result in a spike in emissions in 2021 before a reversion towards the baseline over time. This impact is monetised through the application of Department for Business, Energy and Industrial Strategy (BEIS) carbon prices.

The monetised impact of a change in GHG emissions is presented in Table 3-11, which demonstrates that the scheme will generate a net benefit in Option 1, Medium CAZ D + Option 1 and the Hybrid Option. A net negative impact is generated under Option 2, due to the early replacement of diesel cars with petrol cars.

Table 3-11: GHG impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Cumulative Difference in CO_2 Emissions, 2021-30 (tonnes)	-14,026	51,658	-193,832	-24,777
BEIS Carbon Prices, 2021-2030(£/tonne)	69.32-79.43	69.32-79.43	69.32-79.43	69.32-79.43
Present Value (PV) of Impact (£'s 2018 Prices and Values)	**1,063,125**	**-3,802,327**	**14,338,124**	**1,867,592**

3.6.1.2 Air Quality (PM/NO2) Emissions

Based on air quality modelling outputs, the intervention options are forecast to reduce the level of PM and NO_2 emissions across the appraisal period, contributing to an improvement in air quality. Improvements in air quality can lead to a range of public health, natural and built environment benefits. These benefits can be monetised through the application of JAQU's Damage Cost estimates.

The monetised impact of a change in air quality is presented in Table 3-12 which demonstrates that the intervention options could generate a benefit of up to £9.4 million over the ten-year appraisal period under Medium CAZ D + Option 1. The scale of benefit is highest for this option as it induces the largest switch to compliant vehicles.

Table 3-12: Air quality impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Cumulative Difference in NO_2 Emissions 2021-2030 (tonnes)	-258	-55	-114	-403
NO_2 Damage Costs 2021-2030 (£/tonne)	17,594-21,027	17,594-21,027	17,594-21,027	17,594-21,027
PV of NO_2 Change (£'s 2018 Prices and Values)	**4,786,903**	**1,045,323**	**1,882,924**	**7,587,199**
Cumulative Difference in PM Emissions 2021-2030 (tonnes)	-8	3	-21	-4
PM Damage Costs 2021-2030 (£/tonne)	335,598-401,070	335,598-401,070	335,598-401,070	335,598-401,070
PV of PM Change (£'s 2018 Prices and Values)	**2,848,653**	**-1,032,339**	**7,475,436**	**1,469,881**
Aggregate PV (£'s 2018 Prices and Values)	**7,635,556**	**12,984**	**9,358,360**	**9,057,080**

3.6.2 Impacts on Transport Users

3.6.2.1 Fuel Switch Impacts

The transport analysis assumes that some car drivers will switch fuel type from diesel to petrol, when upgrading their vehicle in response to the intervention option. The change in fuel switch costs is reflected in the change in

vehicle operating costs to the user, captured as part of the DfT's Transport User Benefits Assessment (TUBA). No additional or separate analysis is provided here.

3.6.2.2 Transaction Costs

Based on the traffic forecasting analysis, the intervention options will accelerate the rate at which vehicle owners' purchase or upgrade to compliant vehicles. Each upgrading transaction incurs time costs for vehicle owners relating to identifying and buying a compliant vehicle. By applying JAQU's recommended transaction cost data (provided as part of the National Data Inputs for Local Economic Models) to the number of vehicles anticipated to upgrade, Table 3-11 suggests that the scheme will impose a transaction cost of between £40,000 and £198,000 over the ten-year appraisal period. The scale of transaction costs is highest for Medium CAZ D + Option 1 as this option induces most vehicles to upgrade.

Table 3-13: Transaction cost impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Number of Vehicles Upgrading	14,190	6,437	30,036	20,628
Transaction Cost (£'s 2018 Prices and Values)	**111,535**	**39,603**	**198,315**	**151,145**

3.6.2.3 Consumer Welfare Impacts

The intervention options will affect consumer behaviour by inducing a change in travel behaviour for non-compliant vehicle trips (for example through upgrading vehicles, using alternative modes, cancelling journeys etc, as suggested by the stated preference survey, Section 3.3, and reflecting in traffic model forecasts). However, because consumers would have preferred their original action in the baseline, this change in behaviour leads to a consumer welfare impact. Two elements of analysis were identified to estimate aggregate consumer welfare loss as a result of intervention:

- Welfare loss associated with vehicles upgrading earlier
- Welfare loss associated with changing travel patterns or behaviours (i.e. mode shift, cancelled journeys, diverted journeys)

The cost of upgrading was estimated by establishing the average cost differential for upgrading a vehicle in the intervention scenario, compared to the baseline scenario. The cost differential was driven by the change in depreciation rates over time and therefore, the change in residual vehicle value between replacement and replaced vehicles, at the time of upgrading in the intervention scenario, relative to the baseline scenario. As vehicles were expected to upgrade earlier in the intervention scenario, the cost of upgrading is expected to be higher as the difference in value between replacement and replaced vehicles is also expected to be higher.

By applying the average cost differential for upgrading to the number of vehicles, upgrading (split by vehicle type [i.e. cars, LGVs, buses etc) and upgrade type [i.e. to new or used vehicles]) the consumer welfare loss associated with upgrading earlier is estimated to cost between £2.5 million and £40.1 million, as shown in Table 3-14. The upgrading cost for Medium CAZ D + Option 1 is highest due to the high volume of vehicles upgrading in this option. The fewest number of upgrades occur under Option 2, and involve a switch from diesel to petrol vehicles, hence the low upgrading cost for this option. Note that this figure reflects use of the 'rule of half' to estimate the average loss to each upgrader.

Table 3-14: Consumer welfare: cost of upgrading impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Number of Vehicles Upgrading	14,190	6,437	30,036	20,628
Consumer Welfare Loss (£'s 2018 Prices and Values)	**20,808,065**	**2,554,329**	**40,063,444**	**23,369,122**

The cost of changing travel behaviour was estimated by establishing the number of vehicle trips in the baseline that would be fundamentally changed in the intervention scenario. The cost of each individual trip cancelled, changed or switched to a new mode was assumed to be equal to half the cost of the charge, where a charge applied (i.e. only in the Medium area CAZ D intervention option).This approach, in line with JAQU's Options Appraisal Guidance, was adopted to reflect that only those trips that were valued at less than the cost of the charge were cancelled; any trips valued more than the charge were assumed to pay the charge. However, as it is not possible to value every trip that induced a behavioural response, each cancelled, changed or mode shifted trip was assumed to be valued at half the price of the charge.

For the diesel car exclusion options, traffic modelling assumes that all diesel cars adhere to the exclusion zone. Therefore, no charge applies that is comparable to the CAZ charge. Welfare loss from changing travel patterns of behaviour was therefore calculated by assuming all those individuals that cancel/change mode or avoid the exclusion zone value their total number of trips through the zone at half the value of the upgrade cost.

Hence, two distinct approaches were identified:

- combining the number of vehicle trips changed with the adjusted charge to enter the zone for CAZ-related options
- combining the number of individuals induced to change travel patterns or behaviour (rather than trips) with the adjusted vehicle upgrade cost for diesel exclusion-related option

Following these approaches Table 3-15 indicates that the consumer welfare loss associated with changing travel patterns or behaviour could cost nearly £210 million over the ten-year appraisal period.

Table 3-15: Consumer welfare: cost of changing travel pattern or behaviour impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Number of Vehicles Trips Changed	99,320,285	n/a	270,146,638	n/a
Number of Individuals Changed	n/a	518,778	n/a	518,778
Consumer Welfare Loss (£'s 2018 Prices and Values)	**43,156,592**	**101,380,059**	**125,410,876**	**101,380,059**

3.6.2.4 Vehicle Scrappage Costs

As part of the upgrading process, it is assumed that the overall size of the vehicle fleet remains fixed. Therefore, for every new vehicle purchased, an older vehicle is scrapped. The differential in lost asset value associated with scrapping a vehicle earlier in the intervention case relative to the baseline case allows monetisation of this impact. By combining the number of vehicles expected to be scrapped in the intervention scenario by the average differential in lost asset value between the intervention and baseline scenarios, Table 3-16 demonstrates that vehicle scrappage costs could amount to between £1 million and £4 million across the ten-year appraisal period.

The scale of vehicle scrappage impacts is largest for the Medium CAZ D + Option 1 intervention option because the option will induce the scrappage of a greater number vehicles. Under Option 2, the switch from diesel to petrol vehicles is assumed to involve a switch to secondhand petrol vehicles only, hence no vehicle scrappage is envisaged.

Table 3-16: Vehicle scrappage cost impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Number of Vehicles Scrapped	1,457	0	5,419	1,457
Vehicle Scrappage Costs (£'s 2018 Prices and Values)	**991,998**	**0**	**4,214,605**	**994,288**

3.6.2.5 Journey Time/Vehicle Operating Costs

By influencing travel patterns and behaviours, the intervention options could also have an impact on transport economic efficiency (TEE), measured in terms of changes to journey time savings and vehicle operating costs. By reducing vehicle flows, increasing vehicle speeds and reducing congestion, travel time could be reduced alongside reduced running costs. Using DfT's TUBA software, the change in vehicle movements induced by the intervention options could contribute to benefits in the region of £7 million to £133 million, based on journey time and vehicle operating cost benefits for road users in Bristol (Table 3-14).

The variation in the scale of benefits can be explained as follows:

- Option 1 has lowest level of benefits, attributable to vehicles being forced to take longer distances with longer journey times.
- Option 2 has high level of benefits as removal of diesel cars from the city centre removes a lot of traffic from key roads, allowing other vehicles to take shorter distances with shorter journey times.
- Medium CAZ D + Option 1 has high level of benefits as compliant vehicles get greater travel time benefits as non-compliant vehicles change travel patterns or behavior. However, negative impact on non-compliant vehicles in terms of longer journey times.
- Hybrid Option had highest level of benefits as it broadly combines the benefits associated with Options 1 and 2.

Table 3-17: Journey time/vehicle operating cost impacts

TUBA Impact Category	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
PV Travel Time Impacts (2010 prices and values)	6,271,000	52,835,000	49,398,000	60,843,000
PV Vehicle Operating Costs (2010 prices and values)	-2,141,000	7,585,000	2,455,000	7,384,000
PV Total (£'s 2018 Prices and Values)	**7,656,696**	**117,299,301**	**96,480,584**	**133,047,139**

3.6.2.6 Accident Impacts

By changing travel patterns and behaviours, thus affecting vehicle trip numbers and speeds, the intervention options could influence the frequency and severity of accidents. The number of accidents and casualties is

expected to reduce under all intervention options, leading to an accident benefit of between £19.3m and £35.4m. Note that unlike other economic results presented in this report, this value represents present value of benefits in 2010 prices and values over a sixty year appraisal period, based on utilisation of DfT's CoBALT software (Table 3-18).

Table 3-18: Journey time/vehicle operating cost impacts

Accident Impact Category	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Reduction in Accident Costs (PV 2010 prices and values), 60 year appraisal period	19,301,261	34,245,000	24,049,853	35,374,298

3.6.2.7 Walking/Cycling Impacts

By inducing mode shift, the intervention options will increase the number of individuals making walking and cycling trips. This has a positive economic impact, primarily by improving general health of people, by walking and cycling more regularly, and by reducing absenteeism from work. Using the DfT's Active Mode Appraisal Toolkit, the forecast growth in the number of walking and cycling trips is expected to lead to a benefit of between £51 million and £55 million (Table 3-19).

The scale of impacts is greatest in the diesel car exclusion-related intervention options because more trips are induced to change mode relative to their alternative action in the baseline. This is partially driven by the fact that in the baseline for the diesel car exclusion options, use of diesel cars within the exclusion zone is maintained at a high level throughout the appraisal period. All of these trips become non-compliant in the intervention option. In comparison, the number of trips in the Medium CAZ D + Option 1 baseline option that would be non-compliant in the intervention option is initially higher, but drops markedly over the appraisal period as older cars are forecast to be replaced even in the absence of the intervention option.

For Option 1, no trips are assumed to switch to cycling and walking as no abstraction from taxi, LGVs or HGVs to active mode trips is anticipated.

Table 3-19: Walking/cycling impacts

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Number of Trips Changing Mode	0	21,804,878	15,033,049	21,804,878
Number of New Cycling Trips	0	1,635,366	1,127,479	1,635,366
Number of New Walking Trips	0	2,998,171	2,067,044	2,998,171
PV Total (£'s 2018 Prices and Values)	**0**	**14,516,822**	**9,767,765**	**14,516,822**

3.6.3 Costs to Central and Local Government

3.6.3.1 Scheme costs

Table 3-20 and Table 3- 21 provide a summary of the costs for the scheme costs, further details will be provided in the financial case.

Table 3-20: Estimated Scheme Costs for Medium CAZ D +Option 1 (benchmark option)

Item	Estimated Cost (2019 Prices)
Enforcement System	£22,955,403
Highway Works	£7,761,465
Non Charging Measures - Implementation Fund	£63,954,720
Non Charging Measures - Clean Air Fund	£63,921,600
Risk	£6,500,000
Total Scheme Capital Cost	**£165,093,188**
Operations	£27,303,452
Maintenance	£6,023,562
Communications	£2,129,685
Power (on street)	£1,112,729
CAZ Project Delivery and Ongoing Operational Management Team	£2,976,000
Monitoring and Evaluation	£1,401,928
Other	£5,405,479
Total Scheme Revenue Cost	**£46,352,835**

Note: The above cost estimates include optimism bias as defined in HMT Green Book for the relevant item classification.

Table 3-21: Estimated Scheme Costs for the Hybrid

Item	Estimated Cost (2019 Prices)
Enforcement System	£29,540,694
Street Works	£11,780,370
Non Charging Measures - Implementation Fund	£63,954,720
Non Charging Measures - Clean Air Fund	£63,921,600
Risk	£6,500,000
Total Scheme Capital Cost	**£175,697,384**
Operations	£20,856,467
Maintenance	£10,008,864
Communications	£2,729,295
Power (on street)	£1,486,916
CAZ Project Delivery and Ongoing Operational Management Team	£2,976,000
Monitoring and Evaluation	£1,401,928
Other	£5,447,975
Total Scheme Revenue Cost	**£44,907,445**

Note: The above cost estimates include optimism bias as defined in HMT Green Book for the relevant item classification.

3.6.3.2 Set-Up Costs

At this stage, only high-level capital costs are available for the Medium CAZ D+ Option 1 and Hybrid Options. options.

More detail on the derivation of these costs can be found within OBC-33 'Project Costs' in Appendix J of this OBC.

Impact	Medium CAZ D + Option 1	Hybrid
PV of Capital Costs (£'s 2018 Prices and Values)	£154,116,258	£164,015,388

3.6.3.3 Running Costs

As per the set-up costs, the operational costs associated with delivering the scheme for the Medium CAZ D+ Option 1 and Hybrid Options are summarised in Tables 3-10 and 3-21. Costs are greatest for the Medium CAZ D + Option 1 intervention option due to the need to make contributions to the Clean Air Zone central payment system on an ongoing basis. Note that revenue associated with CAZ charges and Penalty Charge Notices (PCNs) are ignored from the analysis on the basis that this economic benefit to local/central Government is neutralised by the economic cost to individuals of paying the charge/fine.

Impact	Medium CAZ D + Option 1	Hybrid
PV of Operational Costs (£'s 2018 Prices and Values)	£37,067,332	£35,414,363

3.6.4 Summary

By combining the economic impacts discussed in the previous sections, the intervention options could generate an NPV of between -£214m and -£229m, as shown in Table 3-22. The economic costs for all intervention options therefore outweigh the economic benefits by a considerable margin, particularly for the Hybrid option and the Medium CAZ D + Option 1. This is primarily driven by the loss in consumer welfare associated with changing travel patterns and behaviours, as well as onerous set up and running costs.

Table 3-22: NPV, economic impacts (2018 prices and values £)

Impact	Option 1	Option 2	Medium CAZ D + Option 1	Hybrid
Air Quality	£6,222,653	-£67,356	£7,899,887	£7,231,960
NO_x	£3,950,741	£818,436	£1,872,289	£6,097,188
PM	£2,271,912	-£885,792	£6,027,598	£1,134,773
Consumer Welfare	-£53,716,180	-£82,449,048	-£139,232,748	-£136,171,739
Behavioural Response: Replace Vehicle	-£18,649,791	-£2,278,606	-£35,950,240	-£20,934,908
Behavioural Response: Cancel Trip/Avoid Zone/Re-mode	-£35,066,389	-£80,170,442	-£103,282,508	-£115,236,830
Vehicle Scrappage	-£889,675	£0	-£3,791,119	-£891,863
Transactions	-£99,468	-£35,328	-£177,418	-£134,810
Traffic Flows	£6,193,115	£90,602,422	£77,755,832	£102,309,358
GHGs	£813,528	-£3,105,821	£11,584,765	£1,447,201
Set Up	Not assessed	Not assessed	-£154,116,258	-£164,015,388
Running Costs	Not assessed	Not assessed	-£37,067,332	-£35,414,363
Active Mode Impacts	£0	£11,221,650	£8,071,154	£11,221,650
*Accident Impacts**	*£19,301,261*	*£34,245,000*	*£24,049,853*	*£35,734,298*
Net Present Value (NPV), excluding Accident Impacts	**Not assessed**	**Not assessed**	**-£229,073,236**	**-£214,417,992**

*Note that Accident Impacts are based on a sixty year appraisal period and are presented in 2010 prices and values. These values are therefore not included in the NPV calculation. The NPV calculation will therefore appear worse than if the benefits associated with accident impacts were included.

To provide scale context, these NPVs, have been compared to the forecast GVA in Bristol (forecast at £137 billion in present value terms [2018 prices and values] between 2021-30). Across the 10 year period assessed,

the NPV of the intervention options represent between -0.16% and -0.17% of present value GVA in Bristol over the same period. Overall, the Hybrid option (-0.16%) has a marginally less negative economic impact than the Medium CAZ D + Option 1 scenario (-0.17%).

3.7 Multi-criteria assessment

Allied to the economic modelling impacts monetised above, a multi-criteria assessment (MCA) was prepared to differentiate between the shortlisted options. This supports the economic modelling by outlining the differential impact of the shortlisted options on a range of economic actors not explicitly considered as part of the core economic modelling. This includes employment markets, income deprivation, businesses and economic sectors (e.g. retail/leisure). It also incorporates some economic impacts considered within the economic modelling above (e.g. consumer welfare loss, vehicle scrappage costs and transaction costs).

3.7.1 Introduction

The qualitative economic analysis of options follows a two-step approach:

- Step One –outlines the baseline position for Bristol's economy, covering a range of key economic indicators, in order to establish an economic narrative
- Step Two – multi-criteria assessment (MCA) of the potential impact of the various options on key economic indicators

The economic narrative established in Step One provides the context within which the MCA undertaken as part of Step Two is considered.

3.7.2 Step One: Economic Narrative

This section presents a brief economic narrative for the City of Bristol. It outlines key baseline economic indicators at both local authority level as well as for the varying spatial scales pertaining to the various Clean Air Plan options. The analysis contains a summary of the following indicators:

- Business count
- Employment data/labour market characteristics
- Deprivation analysis
- Vehicle compliance patterns

To establish the function and form of Bristol's economy in the context of the forthcoming Clean Air Plan. This information is utilised to develop the multi criteria assessment presented later in this report.

3.7.2.1 Business Count

Business count data from National Online Manpower Information System (NOMIS) provides an insight into the number and size of businesses in a given context area. Businesses are classified into various sizes based on the number of employees within that business. The data illustrates that the Bristol economy consist of 22,170 businesses, with 18,025 of these classified as micro-businesses. Micro-businesses make up a significant proportion (81%) of the market structure within the local authority, whilst SMEs account for 18% of all businesses within Bristol. Overall, micro and small businesses account for 96.3% of the business within Bristol. Table 3.23 below presents the distribution of businesses by type across Bristol.

Table 3.23: Business types within Bristol

	Business Type				
Context Area	Micro (0 to 9)	Small (10 to 49)	Medium-sized (50 to 249)	Large (250+)	Total
Bristol LA	18,025	3,320	700	125	22,170

summarises the business count data pertaining to the geographic scales directly affected by potential intervention options (i.e. small area CAZ[3] and medium area CAZ). Between 3,000 and 7,400 businesses are located within the small and medium boundaries respectively. These figures suggest that 13% of all Bristol businesses will be located within the small boundary and one-third will be located within the medium boundary.

The overarching theme, irrespective of the geographic scale, is that micro businesses make up the largest proportion of businesses. Further, combining micro and SME businesses reveals that around 99% of all businesses located within across the local authority and within small and medium boundaries employ fewer than 50 employees. Therefore, there is limited differentiation between the geographic scales from a business size perspective. That said, there are nearly 60% fewer micro businesses and SMEs within the small area CAZ boundary relative to the medium area CAZ boundary **.**

Business count data was also considered for two key sectors within the Bristol economy: tourism[4] and retail[5]. Table 3.24 reveals that for as per the economy-wide analysis, micro businesses in the retail sector comprise a majority of the market structure, irrespective of context area being analysed. Within the small area CAZ boundary, micro-businesses make up 71% of the businesses, this increases to 80% and 79% for the medium area CAZ and Bristol respectively. It should be noted that there is also a large presence of small retail businesses in the small CAZ area, 27%, this drops to 19% at the Medium area CAZ area and Bristol geographical measures. In total, all retail businesses at all geographic scales are defined as micro or SMEs. At a spatially disaggregated level, less than 40% of Bristol's retail businesses are located within the Medium area CAZ area, and only one-third of these are located within the small CAZ area.

Table 3.24: Retail businesses by type

Industry	Business Type				
Retail	Micro (0 to 9)	Small (10 to 49)	Medium-sized (50 to 249)	Large (250+)	Total
Small Area CAZ	180	70	5	0	255
Medium Area CAZ	605	140	10	0	755
Bristol	1,565	375	30	0	1,970

Similar patterns are evident within the tourism sector. Micro businesses make up majority of the market share, with 61% of tourism related business in the small area CAZ being micro. This increases to 77% and 75% for both the medium area CAZ and Bristol respectively. Small businesses in the small CAZ make up 36% of the market share, this is higher than the 23% in the medium area CAZ and 24% in Bristol. In total, all tourism businesses at all geographic scales are defined as micro or SMEs. At a spatially disaggregated level, less than 40% of Bristol's tourism businesses are located within the medium area CAZ boundary, but the majority of these

[3] Used as a proxy for small area over which the diesel car exclusion zone is applied
[4] The definition of tourism is based on ONS' 'workers in the tourism sector' report
[5] The definition of retail is based on the SIC category 47

(nearly 80%) are located within the small area CAZ boundary. This suggests a disproportionate number of tourism businesses are located within the small area CAZ boundary; this is understandable given that Bristol City Centre falls within this zone.

Table 3.25: Tourism businesses by type

Industry	Business Type				
Tourism	Micro (0 to 9)	Small (10 to 49)	Medium-sized (50 to 249)	Large (250+)	Total
Small Area CAZ	295	175	15	0	485
Medium Area CAZ	480	140	0	0	620
Bristol	1,270	405	15	0	1,690

3.7.2.2 Labour Market Characteristics

Employment density outlines the distribution of jobs across Lower Super Output Areas (LSOAs) that make up Bristol, as per data from the Business Register and Employment Survey (BRES). This data has been mapped and is presented as Figure 3.5. The analysis demonstrates that LSOAs that predominantly lie within the small CAZ boundary have the highest jobs density, with more than 2,000 employees per LSOA. Whilst the work illustrates that LSOAs outside the city centre generally have a lower jobs density. Overall, there is a clear concentration of employment within Bristol City Centre, which lies within the small area CAZ boundary. Nevertheless, because the medium area CAZ boundary includes the small area CAZ boundary, the total level of employment within the medium area CAZ boundary exceeds the smaller boundary.

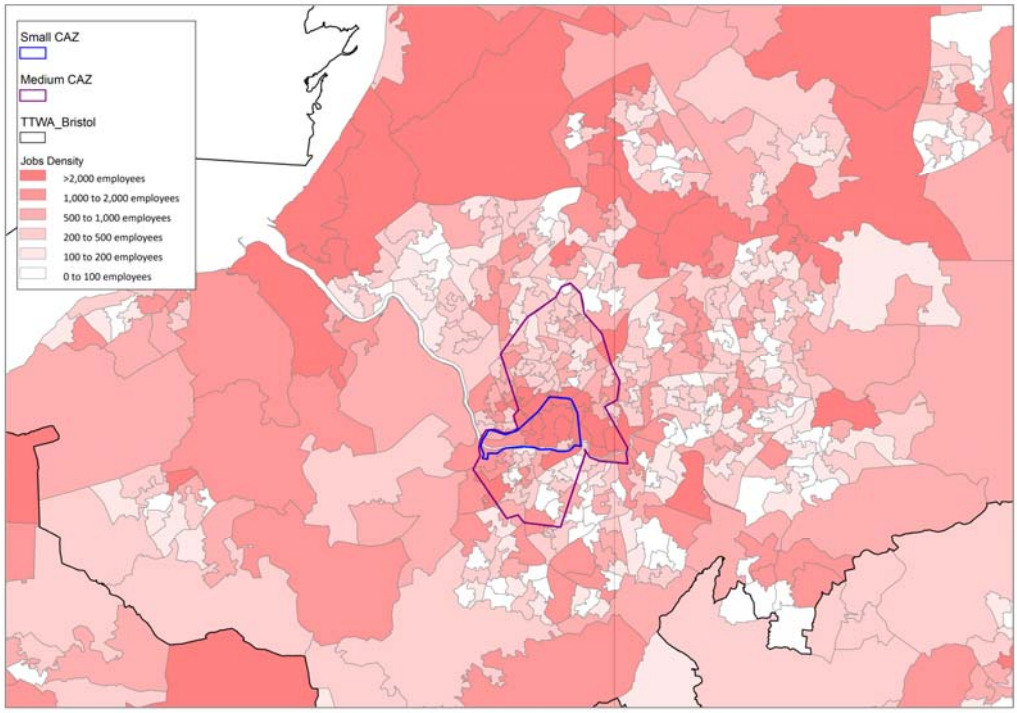

Figure 3.5: Employment Density in Bristol

The trends presented in Figure 3.5 are reflected in Table 3.26, which illustrates the sectoral profile of employment for Bristol and the focussed geographic scales, compared to national benchmarks. The analysis reveals that within the small area CAZ boundary the main industries of employment are business services (industrial sectors: J, K, L, M, and N). A larger proportion of individuals ,63%, are employed within these industries in the small area CAZ boundary relative to the medium area CAZ boundary (45%), Bristol local authority area (35%) and nationally (28%). These sectors tend to make a significant contribution to economic output and value added, as well as offering competitive salaries. As has been mentioned previously, the small CAZ boundary includes Bristol City Centre which is where the majority of business services jobs are located.

Table 3.26: Proportion of individuals in industrial sectors by context area

Industrial Sectors	Small CAZ	Medium area CAZ	Bristol	England
Agriculture, forestry & fishing (A)	0%	0%	0%	1%
Mining, quarrying & utilities (B,D and E)	1%	2%	1%	1%
Manufacturing (C)	1%	2%	4%	8%
Construction (F)	1%	2%	4%	5%
Motor trades (Part G)	0%	1%	2%	2%
Wholesale (Part G)	0%	2%	4%	4%
Retail (Part G)	7%	7%	8%	9%
Transport & storage (inc postal) (H)	1%	3%	4%	5%
Accommodation & food services (I)	9%	8%	7%	7%
Information & communication (J)	10%	7%	6%	4%
Financial & insurance (K)	14%	10%	7%	4%
Property (L)	1%	1%	1%	2%
Professional, scientific & technical (M)	19%	15%	11%	9%
Business administration & support services (N)	17%	12%	10%	9%
Public administration & defence (O)	10%	7%	4%	4%
Education (P)	2%	7%	9%	9%
Health (Q)	3%	10%	15%	13%
Arts, entertainment, recreation & other services (R,S,T and U)	4%	4%	4%	5%

Focussing specifically on the previously defined retail and tourism sectors, over 4,400 and 4,600 individuals are employed within the tourism and retail sectors respectively within the small CAZ boundary. The number of employees in these sectors increases to over 11,000 in the retail sector and nearly 18,000 individuals in the tourism sector across the medium area CAZ boundary. At a spatially disaggregated level, more than 50% of all retail employment in Bristol is located within the Medium area CAZ boundary (less than half of which is also found in the small area CAZ boundary). Around 40% of all tourism jobs in Bristol are also located within the medium area CAZ boundary (only a quarter of which are also included in the small area CAZ boundary), Therefore based on employment, the medium area CAZ area is home to a disproportionate level of retail and tourism employees.

Table 3.27: Number of individuals employed across different sectors

Context Area	Retail	Tourism
Small Area CAZ	4,620	4,380
Medium Area CAZ	11,005	17,645
Bristol	20,050	45,695

3.7.2.3 Deprivation Analysis

Employment deprivation data from the Indices of Multiple Deprivation reveals that the majority of the LSOAs that lie within the small area CAZ are amongst the least deprived nationally, in terms of employment deprivation. This indicates the strong economic performance of the city centre which is encompassed by the small area CAZ. The medium area CAZ illustrates that there is a pocket of LSOAs to the north-west of the small area CAZ boundary that suffers from acute employment deprivation.

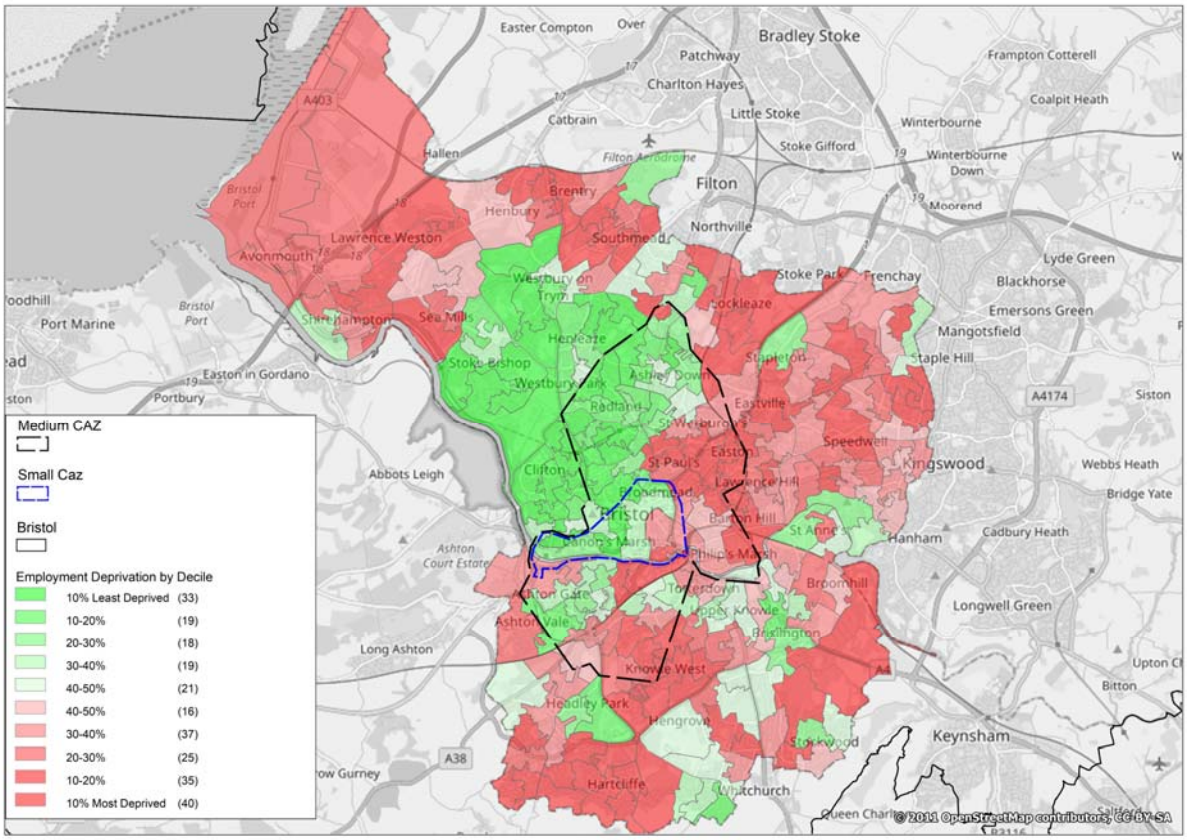

Figure 3.6: Employment Deprivation

Income deprivation data from the Indices of Multiple Deprivation reveals that overarching trends are consistent with employment deprivation patterns. Communities within the small area CAZ boundary are amongst the least income deprived in comparison to the communities nationally. However, there are few pockets of income

deprivation of varying degrees on the west side of the zone. For the medium area CAZ boundary, significant income deprivation is apparent in to the north-west of the small area CAZ boundary.

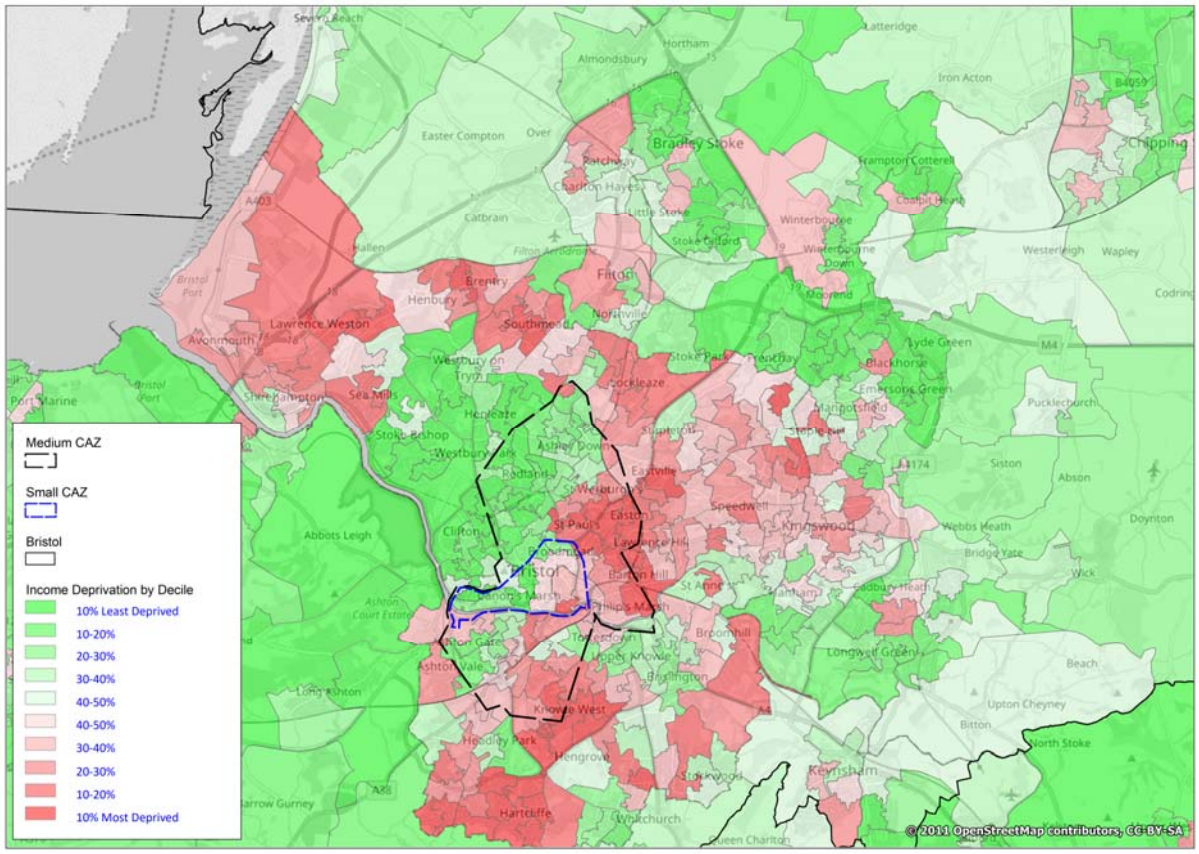

Figure 3.7: Income Deprivation

3.7.2.4 Vehicle Compliance Patterns

Cross-referencing those communities that fall within the two most income deprived quintiles with vehicle registration data reveals that there are large numbers of vehicles registered to properties in low-income areas that use diesel fuel and/or fail to meet current air quality standards within the small and Medium area CAZ areas. Table 3.28 reveals that there are 16,000 non-compliant cars and LGVs registered in low-income areas within the medium area CAZ boundary, as well as 13,000 diesel vehicles. Further, there are more than 350 non-compliant cars and LGVs registered in low-income areas within the small area CAZ boundary, as well as more than 300 diesel vehicles. These could be vulnerable to any future charge or punitive action against non-compliant vehicles within the medium or small area boundary.

Table 3.28: Number of Vehicles Registered to Communities within the Two Most Income Deprived Quintiles

Vehicles Registered in Two Most Income Deprived Quintiles	Small Ban Area	Medium CAZ Area
Non-Compliant Cars	282	9,675
Non-Compliant LGVs	72	6,126
Diesel Cars	234	5,905
Diesel LGVs	89	7,026

Overall, Figure 3.8 indicates that non-compliant vehicles and diesel vehicles are concentrated in the most deprived communities in Bristol.

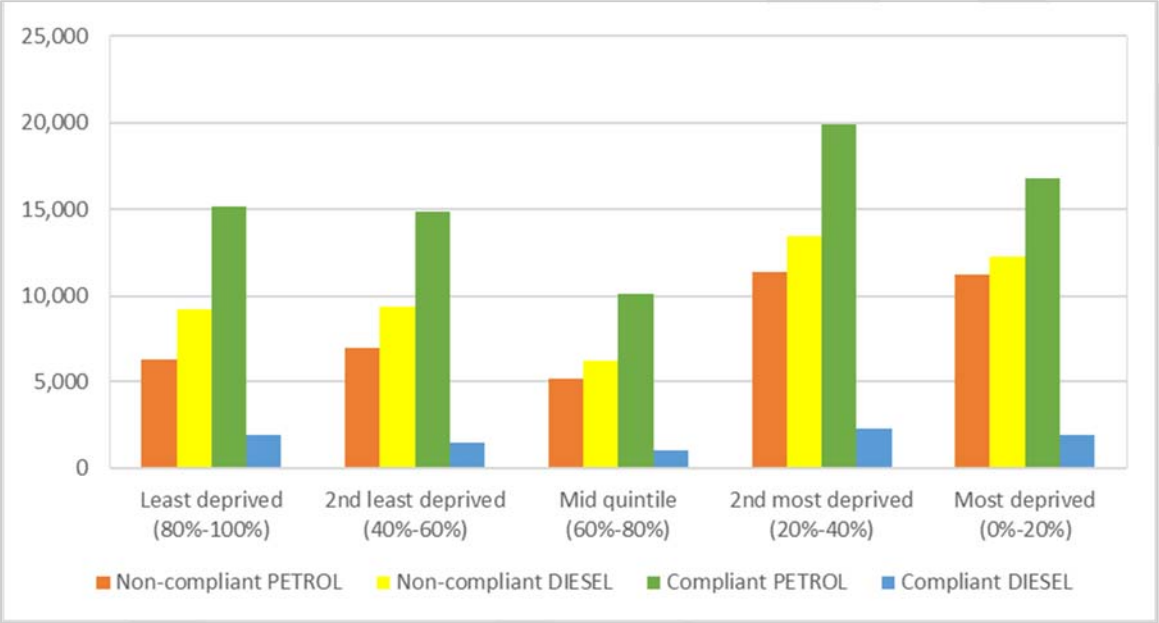

Figure 3.8: Vehicles Registered in Bristol LA by Category, Deprivation and Zone

The number of LGVs registered within an LSOA is reflective of certain types of business activity occurring within it (e.g. tradespeople, courier services, sole-proprietors). LGV registration data reveals that 86% of LGVs that are registered within the small area CAZ boundary are non-compliant with regulations. Whilst 88% of those in the medium area CAZ and 90% of those registered in Bristol are non-compliant.

Table 3.29: Proportion of compliant and non-compliant LGVs[6]

	Compliant		Non Compliant	
Context area	Petrol	Diesel	Petrol	Diesel
Small area CAZ	0	58	0	361
Medium area CAZ	5	1,225	151	8,643
Bristol	10	2,562	341	22,048

Whilst vehicle registration is not a sound proxy for the business activities and patterns of LGV users, the data gives an indication of the number of LGV users that are based in certain areas. The analysis suggests that only a small proportion of the non-compliant LGV owners within Bristol are based in the small area CAZ boundary. However, the medium area CAZ boundary extends across nearly 9,000 non-compliant LGVs, amounting to around 40% of all non-compliant LGVs in the whole of Bristol.

3.7.3 Step Two: Multi-Criteria Assessment

3.7.3.1 MCA Methodology

Based on the key issues identified in the economic narrative above, combined with key transport impacts anticipated as a result of intervention, this section presents an MCA of the shortlisted Clean Air Plan options. The MCA provides qualitative information about each shortlisted option based on the impact of that option on various key economic indicators:

- Deprivation / income
- Businesses - SMEs
- Businesses – LGVs/HGVs
- Businesses – Taxis
- Consumer Welfare costs
- Vehicle Scrappage costs
- Transaction costs
- Effects to the employment market
- Retail/tourism

The MCA uses a combination of qualitative and quantitative analysis to assess the relative impact of each option against the above indicators. Broadly speaking, qualitative judgements are based on:

- The geographical extent of the options, with options covering a wider area assumed to affect more economic receptors (i.e. businesses, employees) than smaller areas.
- Whether the options impose absolute restrictions and/or charges on economic receptors, with absolute restrictions considered to have greater impact than charges.

Quantitative judgements are informed by the baseline data presented in Section 3.6.2, alongside transport modelling data which provides an indication of the scale of any changes to travel patterns and behaviours induced by the various options.

[6] For this analysis the LSOA E01014623 has been excluded as its deemed to be an outlier.

Table 3.30: MCA Criteria

Economic Indicator	MCA Criteria
Deprivation / income	The Indices of Multiple Deprivation ranks lower super output areas according to the extent of income deprivation within that area. Options which extend across and therefore directly affect communities with high levels of income deprivation will score badly. Further, Options that indirectly affect communities with high levels of income deprivation (e.g. affecting Journey to Work patterns based on the Census 2011) will also score badly.
Businesses - SMEs	SMEs are considered to be particularly vulnerable to changes in economic conditions. Options that extend over and therefore directly affect a larger number of SMEs will score badly. Options that indirectly affect travel choices for a larger number of customers/suppliers/employees of SMEs will also score badly.
Businesses – LGVs/HGVs	LGVs/HGVs act as the main mode of transport for many economic activities. Options that extend over and therefore directly affect a greater number of registered addresses for LGVs/HGVs will score badly. Options that indirectly affect travel supplier/delivery patterns for most businesses will also score badly. Options that do not discriminate against LGVs/HGVs will score best.
Businesses – Taxis	Taxis are typically older and fail to meet current air quality standards. Taxis are therefore vulnerable to options that introduce a CAZ D. Options that affect a wider geographical area are likely to affect a greater number of taxis and will therefore score badly. Options that include retrofitting/upgrades for taxis will alleviate air quality non-compliance and therefore score well.
Consumer Welfare costs	Consumer welfare loss is associated with two elements: 1) the additional cost of upgrading sooner rather later, relating to reduced impact of depreciation on vehicle values. Options resulting in more upgrades will induce a greater welfare loss. 2) the cost of changing travel behaviour to avoid zone, cancel journey, change mode, change destination. This cost is valued at half the cost of the CAZ charge, otherwise individuals would continue to make the same journey using the same behaviours. Options resulting in more changes in travel behaviours will induce a greater welfare loss.
Vehicle Scrappage costs	Vehicle scrappage costs capture the loss in asset value associated with scrapping a vehicle earlier than would otherwise be the case without intervention. This results in vehicles being scrapped when they have greater residual value. JAQU assumes that 25% of all upgrades will result in a new vehicle being purchased. For every new vehicle purchased, JAQU's working assumption is that an older vehicle within the fleet will be scrapped. Options resulting in more upgrades will induce more new vehicles being purchased resulting in a greater number of scrapped vehicles and therefore higher vehicle scrappage costs. Options that necessitate scrappage of newer, more valuable vehicles will also generate higher vehicle scrappage costs.
Transaction costs	Some policies, will bring forward vehicle owners' decisions to purchase newer, cleaner vehicles. This will result in a cost to these owners in having to locate a vehicle that is to their taste. This type of expense is termed, in economics, a transaction (or search) cost. Options resulting in more upgrades will induce greater transaction costs.
Effects to the employment market	By influencing travel patterns and behaviours, the options could fundamentally alter the structure of the labour market by encouraging labour supply to look at labour demand in other locations. Options that trigger the greatest change in travel behaviour (measured in terms of change in the number of employment trips that avoid zone, cancel journey/change mode/change destination) will score badly, as by implication, labour will be working elsewhere suggesting a change in jobs density as a result of the option. Options that affect a greater number of jobs will also score badly.
Retail/ tourism	The retail and tourism sectors are core activities within Bristol's economy. Options that extend over and therefore directly affect a larger level of employment and business will score badly. Options that will affect travel patterns of customers/suppliers/employees will also score badly.

3.7.4 MCA Outputs

Table 3.30 presents the output of the MCA, based on qualitative and quantitative appraisal of the impact of each option on each economic indicator. This is a relative assessment of one option against the other. The analysis is structured on a combined geographical area and intervention-type basis:

- Both Option 1 and Medium CAZ D + Option 1 having some areas of common performance as a result of their shared 'Medium Area' geographical boundary and CAZ-based intervention. Any specific variation in impact is highlighted as appropriate;
- Option 2 is focused on a small area only and adopts a diesel ban intervention type;
- The Hybrid Option has a more complex set of impacts combining elements of Option 1 (Medium Area Class 3 CAZ) and Option 2 (Small Area Diesel Car Ban).

The analysis demonstrates that the small area/diesel ban option performs better than the Medium Area CAZ D option. This is because the former does not discriminate against key economic receptors (e.g. taxis/HGVs) and has the potential to directly affect a lower number of residents relative other options. The Medium Area CAZ D option is least preferred; due to its wider geographic coverage it is anticipated to impact on a greater number of economic receptors than other options, even though it does not propose an absolute ban on any particular vehicle type. Medium Area CAZ C also outperforms Medium Area CAZ D as it does not affect car users; however it does affect taxis and HGVs unlike the diesel ban options. The Hybrid Option outperforms Medium Area CAZ D as whilst it does affect some cars as well as taxis and HGVs, the impact on cars is over a smaller geographic area.

Differences between options against economic indicators are set out in Table 3.31.

Table 3.31: Differences between options against economic indicators

Economic Indicator	Geographical Area/Option	
	Medium Area/CAZ	Small Area/Diesel Ban
Deprivation / income	General This option will extend across and therefore directly affect areas north-west and south of Bristol City Centre, which have a higher concentration of income deprivation. CAZ D- specific A high number of non-compliant vehicles (c. 10,000 cars and c. 6,000 LGVs) are registered to households in low-income areas within this boundary and will be charged. Low income households are least likely to be able to afford the charge or to upgrade their vehicle. Further, a high number of residents of low income areas within Bristol that lie outside the Medium Area CAZ boundary are required to travel into the medium Area CAZ boundary for work (9,500 employees). They could face additional charges that could affect employment and therefore exacerbate income deprivation. CAZ C – specific	This option will extend across areas to the west of Bristol City Centre, which have a high concentration of income deprivation. The extent of non-compliant vehicles registered within the area is significantly less than for the medium area CAZ (though nearly 250 diesel cars will be banned). Low-income households are least likely to be able to upgrade their vehicle, and the diesel ban is absolute. Further, a moderate number of residents of low income areas within Bristol that lie outside the small area CAZ boundary are required to travel into the small area CAZ boundary for work (5,100 employees). They could face a complete ban on travel which could affect employment and therefore exacerbate income deprivation.

Table 3.31: Differences between options against economic indicators

Economic Indicator	Geographical Area/Option	
	Medium Area/CAZ	Small Area/Diesel Ban
	Fewer non-compliant vehicles are registered to households in low-income area, as cars are compliant under a CAZ C.	
Businesses - SMEs	General This option will extend across and therefore directly affect the largest number of SMEs (7,300 businesses with less than 50 employees). CAZ D - Specific As the option charges non-compliant cars as well as other forms of non-compliant vehicles, employees and customers for SMEs may be affected as well as suppliers. That said, there is no outright ban on diesel cars. CAZ C – Specific Employees and customers likely to be less affected relative to CAZ D.	This option extends across a smaller area and will therefore directly affect fewer SMEs (3,000 businesses with less than 50 employees). However, rather than charging non-compliant cars, the option restricts access within the small area CAZ boundary. In the absence of a charging CAZ and any restriction on non-compliant HGVs/LGVs, suppliers will not be affected by the option.
Businesses – LGVs/HGVs	General A high number of non-compliant LGVs are registered within the medium area CAZ and are therefore directly affected by medium area CAZ C (8,800 vehicles) via imposition of charges. Further, nearly 7,400 businesses are located within the medium boundary; their operations (in terms of suppliers/deliveries made by LGVs/HGVs) could be affected. LGVs and HGVs will be impacted equally under both CAZ options.	This option does not impose absolute restrictions or charges on HGVs and LGVs, meaning such vehicles are unaffected.
Businesses – Taxis	General Non-compliant taxis will be charged for entering the medium area CAZ boundary. As the Medium area CAZ covers a wide geographical area, a significant number of taxi trips within Bristol are likely to be affected (including trips to/from Bristol City Centre), so a large portion of the (non-compliant) taxi fleet could be affected. Taxis will be impacted equally under both CAZ options.	This option will only impose a ban on cars. Taxis are unaffected.
Consumer Welfare costs	CAZ D	PV negative impact of £82m

Table 3.31: Differences between options against economic indicators

Economic Indicator	Geographical Area/Option	
	Medium Area/CAZ	Small Area/Diesel Ban
	PV negative impact of £139m CAZ C PV negative impact of £54m	
Vehicle Scrappage costs	CAZ D PV negative impact of £3.8m CAZ C PV negative impact of £0.9m	No scrappage envisaged as diesel vehicles upgrade to secondhand petrol vehicles
Transaction costs	CAZ D PV negative impact of £177k CAZ C PV negative impact of £99k	PV negative impact of £135k
Effects to the employment market	These option involve a smaller number of daily trips avoiding the zone, cancelling journey/changing mode/changing destination. This is because the scale of trips required to cancel/change mode/avoid zone falls rapidly across the appraisal period in the baseline, as older vehicles would be phased out anyway. This implies that supply patterns are least influenced by this option.	This option involves a high number of daily trips avoiding the zone, cancelling journey/changing mode/changing destination. This is because under the baseline, all diesel-car based trips would still continue to take place. This implies that labour supply patterns are significantly influenced by this option.
Retail/ tourism	General Focused on the medium area CAZ boundary, this option extends across and therefore directly impacts a higher number of retail/tourism jobs and businesses than the small area option (c. 28,000 employees and 1,400 businesses). Both CAZ C and CAZ D designation will impose charges on LGVs/HGVs, thus making supplies/deliveries to retail and tourism businesses more expensive/difficult. CAZ D Further, some employees, customers and tourists may be deterred from travelling to the medium area CAZ area due to the charge on all non-compliant vehicles. That said, there are no absolute restrictions on car use.	Focused on the small area CAZ boundary, this option extends across and therefore directly impacts a lower number of retail/tourism jobs than the medium area CAZ option (c. 9,000 employees and 700 businesses). However, some employees, customers and tourists may be prevented from travelling to the small area CAZ area due to the absolute restriction on diesel cars. That said, LGVs/HGVs will not be restricted or charged for access, meaning such vehicles are unaffected.

Table 3.31: Differences between options against economic indicators

Economic Indicator	Geographical Area/Option	
	Medium Area/CAZ	Small Area/Diesel Ban
	CAZ C Employees, customers and tourists are less likely to be affected relative to CAZ D.	

3.8 Distributional and Equalities Assessment

3.8.1 Overview of approach

The distributional and equalities analysis has been conducted relating to the locations where the benefits/disbenefits accrue and it has been mapped to the individuals that live in those areas. The analysis represents the relative distribution of impacts on socio-economic quintiles compared to the quintiles' population share across the Bristol City Council area. The assessment is presented in the distributional and equalities analysis report appended to the OBC (Reference Appendix H OBC-31). The key conclusions from this work are:

- Air quality benefits are felt by all neighbourhoods. The positive impacts of improved air quality disproportionately fall on the least income deprived communities alongside those communities with the most children and elderly residents.
- Accessibility impacts are adverse across the full range of relevant socio-economic groups. Accessibility impacts fall most heavily on the middle quintiles of income deprived communities, those communities with the most children and those communities that have the lowest proportions of females. Further, impacts are disproportionately felt by those communities towards the higher quintiles in terms of concentration of ethnic minorities, middle quintiles for disabled residents and more evenly for elderly residents.
- Affordability impacts are adverse across the full range of relevant socio-economic and business groups. Impacts are disproportionately felt by the most income deprived communities. They also fall on businesses operating non-compliant LGVs and HGVs who are either based in the CAZ areas or operate within central Bristol.

3.8.2 Summary distributional impacts by option

3.8.2.1 Option 1 – Medium area CAZ 'C'

Table 3-32 and Table 3-33 show summary results for Option 1 (Medium area CAZ 'C' plus other complementary measures).

Table 3-32: Distributional impacts: 1 – Option 1

Quintiles >>>	1 (most)	2	3	4	5 (least)	Even distrbtn?
Air quality impacts						
Low income households – NO_2	✓	✓✓	✓✓	✓✓✓	✓✓	Yes
Low income households – PM10	✓	✓✓	✓✓	✓✓	✓✓	Yes
Children – NO_2	✓✓✓	✓✓✓	✓✓	✓	✓	No

Table 3-32: Distributional impacts: 1 – Option 1

Quintiles >>>	1 (most)	2	3	4	5 (least)	Even distrbtn?
Children – PM10	✓✓	✓✓	✓✓	✓✓	✓	Yes
Elderly residents – NO_2	✓✓✓	✓	✓✓	✓✓	✓✓	Yes
Elderly residents – PM10	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Accessibility (time benefit) impacts						
Low income households	×	×	×	××	×××	No
Children	×××	✓✓✓	✓✓✓	✓	×	No
Elderly residents	×××	×	✓✓	✓✓✓	✓✓✓	No
Disabled residents	×××	××	××	✓✓✓	✓	No
Women	×××	×××	✓✓✓	×	✓✓✓	No
Ethnic minorities	×	××	×	××	×××	No
Affordability (vehicle operating cost) impacts						
Low income households	×	×××	✓✓✓	×	×××	No

Table 3-33: Summary impact: 1 – Option 1

Social or Business Group	Air Quality		Accessibility		Affordability	
	Net positive impact	Even distribution	Net positive impact	Even distribution	Net positive impact	Even distribution
Deprivation / income	✓	✓	×	×	×	×
Children	✓	×	×	×		
Elderly people	✓	✓	×	×		
Disabled people			×	×		
Women			×	×		
Ethnic minorities			×	×		
Businesses – SMEs					×	✓
Businesses – LGVs/HGVs					×	×
Businesses – taxis					×	✓

3.8.2.2 Option 2 – Small area CAZ with 8-hour diesel car ban

Table 3-34 and Table 3-35 show summary results for Option 2 (Small area CAZ with 8-hour diesel ban).

Table 3-34: Distributional impacts: 2 – Option 2

Quintiles >>>	1 (most)	2	3	4	5 (least)	Even distrbtn?
Air quality impacts						
Low income households – NO_2	✗	✗✗✗	✗	✗✗	✓	No
Low income households – PM10	✓	✓✓	✓✓	✓✓✓	✓✓	Yes
Children – NO_2	✓	✗✗✗	✗✗✗	✗✗✗	✗	No
Children – PM10	✓✓✓	✓✓	✓✓	✓	✓✓	Yes
Elderly residents – NO_2	✓	✗	✗	✗✗✗	✗✗✗	No
Elderly residents – PM10	✓✓✓	✓	✓✓	✗✗✗	✗	No
Accessibility (time benefit) impacts						
Low income households	✓	✓✓	✓✓✓	✓✓	✓✓	Yes
Children	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	Yes
Elderly residents	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Disabled residents	✓✓✓	✓✓	✓✓	✓✓	✓	Yes
Women	✓✓✓	✓✓	✓✓	✓✓	✓	Yes
Ethnic minorities	✓✓	✓✓	✓✓	✓✓	✓✓✓	Yes
Affordability (vehicle operating cost) impacts						
Low income households	✓	✓✓	✓✓✓	✓✓	✓✓	Yes

Table 3-35: Summary impact: 2 – Option 2

Social or Business Group	Air Quality		Accessibility		Affordability	
	Net positive impact	Even distribution	Net positive impact	Even distribution	Net positive impact	Even distribution
Deprivation / income	✗	✗	✓	✓	✓	✓
Children	✗	✗	✓	✗		
Elderly people	✗	✗	✓	✓		
Disabled people			✓	✓		
Women			✓	✓		
Ethnic minorities			✓	✓		
Businesses – SMEs					✗	✓
Businesses – LGVs/HGVs					✗	✗
Businesses – taxis					✗	✓

3.8.2.3 Medium area CAZ 'D'

Table 3-36 and Table 3-37 show summary results for the third option, Medium area CAZ 'D' (plus complementary measures).

Table 3-36: Distributional impacts: 3 – Medium area CAZ 'D'

Quintiles >>>	1 (most)	2	3	4	5 (least)	Even distrbtn?
Air quality impacts						
Low income households – NO_2	✓	✓✓	✓✓	✓✓	✓✓	Yes
Low income households – PM10	✓	✓✓	✓✓	✓✓	✓✓	Yes
Children – NO_2	✓✓	✓✓✓	✓✓	✓✓	✓	Yes
Children – PM10	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Elderly residents – NO_2	✓✓✓	✓✓	✓✓	✓✓	✓✓	Ye
Elderly residents – PM10	✓✓	✓✓	✓✓✓	✓✓	✓✓	Yes
Accessibility (time benefit) impacts						
Low income households	✓	✓✓	✓✓✓	✓✓	✓	Yes
Children	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	Yes
Elderly residents	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Disabled residents	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Women	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Ethnic minorities	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Affordability (vehicle operating cost) impacts						
Low income households	×	×××	✓✓✓	×	×××	No

Table 3-37: Summary impact: 3 – Medium area CAZ 'D'

Social or Business Group	Air Quality		Accessibility		Affordability	
	Net positive impact	Even distribution	Net positive impact	Even distribution	Net positive impact	Even distribution
Deprivation / income	✓	✓	✓	✓	×	×
Children	✓	✓	✓	×		
Elderly people	✓	✓	✓	✓		
Disabled people			✓	✓		
Women			✓	✓		
Ethnic minorities			✓	✓		
Businesses – SMEs					×	✓

Businesses – LGVs/HGVs					✗	✗
Businesses – taxis					✗	✓

3.8.2.4 Hybrid (of options 1 and 2).

Table 3-38 and Table 3-39 show summary results for the fourth CAP option being considered; the hybrid option (a combination of elements from Options 1 and 2).

Table 3-38: Distributional impacts: 4 – Hybrid option

Quintiles >>>	1 (most)	2	3	4	5 (least)	Even distrbtn?
Air quality impacts						
Low income households – NO_2	✓	✓✓	✓✓	✓✓✓	✓✓	Yes
Low income households – PM10	✓	✓✓	✓✓✓	✓✓✓	✓	Yes
Children – NO_2	✓✓✓	✓✓✓	✓✓	✓	✓	No
Children – PM10	✓✓✓	✓✓✓	✓✓✓	✓	✓	No
Elderly residents – NO_2	✓✓✓	✓	✓✓	✓	✓✓	Yes
Elderly residents – PM10	✓✓✓	✓	✓✓	✓	✗	No
Accessibility (time benefit) impacts						
Low income households	✓	✓✓	✓✓✓	✓✓	✓✓	Yes
Children	✓✓✓	✓✓✓	✓✓✓	✓✓	✓	Yes
Elderly residents	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Disabled residents	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Women	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Ethnic minorities	✓✓	✓✓	✓✓	✓✓	✓✓	Yes
Affordability (vehicle operating cost) impacts						
Low income households	✓✓✓	✗✗✗	✓✓✓	✓✓	✗✗✗	No

Table 3-39: Summary impact: 4 – Hybrid option

Social or Business Group	Air Quality		Accessibility		Affordability	
	Net positive impact	Even distribution	Net positive impact	Even distribution	Net positive impact	Even distribution
Deprivation / income	✓	✓	✓	✓	✓	✗
Children	✓	✓	✓	✗		
Elderly people	✓	✓	✓	✓		

Disabled people			✓	✓		
Women			✓	✓		
Ethnic minorities			✓	✓		
Businesses – SMEs					✗	✓
Businesses – LGVs/HGVs					✗	✗
Businesses – taxis					✗	✓

3.8.2.5 Summary of distributional impacts

Table 3-40 provides a brief qualitative summary of the distributional impacts of the four CAP options.

Table 3-40: Summary distributional impacts

	1: Option 1	2: Option 2	3: Medium area CAZ 'D'	4: Hybrid option
Air quality	Improvements across the city for both NO_2 and PM10. Distribution impact is generally even across social groups, though impacts on children are a little uneven.	Air quality improves in some areas but worsens in others. With improvements focused on the Small CAZ area, distributional impact is uneven for a number of groups.	Improvements across the city for both NO_2 and PM10. Distribution impact is generally even across social groups.	Improvements across the city for both NO_2 and PM10, though not as much as either options 1 or 2. Distribution impact is generally even across social groups, with slightly uneven impacts on younger and older residents.
Accessibility	Time benefit calculations indicate a mix of positive and negative benefits, so the distributional impact is uneven. Trip-making propensity by people with non-compliant cars related to the Medium CAZ area is evenly distributed.	Time benefit calculations indicate mostly positive benefits; the distributional impact is not particularly even though. Trip-making propensity by people with non-compliant cars related to the Small CAZ area is slightly less evenly distributed than the Medium area.	Time benefit calculations indicate mostly positive benefits; the distributional impact is not particularly even though. Trip-making propensity by people with non-compliant cars related to the Medium CAZ area is evenly distributed.	Time benefit calculations indicate mostly positive benefits, the distributional impact is reasonably even. Trip-making propensity by non-compliant cars related to the Medium CAZ area is evenly distributed, but the option also includes measures related to the Small CAZ area for which trip-making propensity is less evenly distributed.
Affordability	Vehicle operating cost benefits are a mixture of positive and negative values. Distribution is not particularly even.	Vehicle operating cost benefits are positive and the distributional is reasonably even.	Vehicle operating cost benefits are a mixture of positive and negative values. Distribution is not particularly even.	Vehicle operating cost benefits are a mixture of positive and negative values. Distribution is not particularly even.
Businesses	Option has direct impact on costs of LGV/HGV reliant businesses. Trips by non-compliant LGV/HGV reliant businesses are reasonably spread around the city. The Medium CAZ area impacts more than the Small CAZ on such trips.	Option has less direct impact on LGV/HGV reliant businesses. Area of impact is smaller, but Small CAZ diesel car ban could deter customer trips and impact on taxi availability.	Option has direct impact on costs of LGV/HGV reliant businesses. Trips by non-compliant LGV/HGV reliant businesses are reasonably spread around the city. The Medium CAZ area impacts more than the Small CAZ.	Option has direct impact on costs of LGV/HGV reliant businesses. Trips by non-compliant LGV/HGV reliant businesses are reasonably spread around the city. Inclusion of Small CAZ area measures potentially impacts more than the Medium CAZ area alone.
Car owners	Impact on car owners is limited with CAZ 'C', so distributional impact is likewise limited and even.	Impact on diesel owners is significant with a ban. Distribution of diesel ownership is even across income groups. However, (in)ability to react to	Impact on all non-compliant car owners. Distribution of non-compliant car ownerships is slightly skewed to lower income	Impact on all non-compliant car owners and owners of diesel cars. Distribution of non-compliant car ownerships is slightly skewed to lower income groups, but ability to

Table 3-40: Summary distributional impacts

	1: Option 1	2: Option 2	3: Medium area CAZ 'D'	4: Hybrid option
		restrictions is unevenly felt by lower income groups (e.g. with fewer multi-car households).	groups, but ability to react to charges more so (such as households with more than one vehicle).	react to charges more so (such as households with more than one vehicle).

Table 3-41 indicates some of the potential mitigation target groups that could arise from the four potential CAP options.

Table 3-41: Summary distributional impacts – potential mitigation targets

Potential mitigation target group [a]	1: Option 1	2: Option 2	3: Medium area CAZ 'D'	4: Hybrid option
Residents				
Residents of the Medium CAZ area (outside the Small CAZ area)	✗	✗	✓	✗
Residents of the Small CAZ area	✗	✓	✓	✓
Specific trip needs				
Disabled people – blue badge	✗	✓ [b]	✓	✓ [b]
Disabled people – with specialist vehicle adaptions	✗	✓ [b]	✓	✓ [b]
Out-patient access to hospital	✗	✓ [b]	✓	✓ [b]
Car owners				
Low income non-compliant petrol car owners	✗	✗	✓	✗
Low-income non-compliant diesel car owners	✗	✓	✓	✓
Low-income compliant diesel car owners	✗	✓	✗	✓
1-car households	✗	✓	✗	✓
Businesses				
SMEs located in the Medium CAZ area (outside the Small CAZ area)	✓	✗	✓	✓
SMEs located in the Small CAZ area	✓	✓	✓	✓
LGV/HGV-dependent businesses, not specifically located in the Medium CAZ area (outside Small CAZ area) but that need to travel into it	✓	✗	✓	✓
LGV/HGV-dependent businesses not specifically located in the Small CAZ area but that need to travel into it	✓	✓	✓	✓
Taxi owners/drivers – BCC registered	✓	✓ [c]	✓	✓
Taxi owners/drivers – other authority registration	✓	✓ [c]	✓	✓

Note:

Groups that could be potential mitigation targets are cross-referenced with the four CAP options; '✓' indicates there is the potential for mitigation to be sought by or on behalf of the group, though not necessarily that it would be granted as part of implementing the CAP; '✗' indicates that it is less likely that any mitigation would applicable to this group/option. However, both are indicative, and neither a positive nor negative indication in this table is a definitive indicator of future proposals.

With a destination in the Small CAZ area and owning/using a diesel car.

Diesel-powered only.

3.9 Environmental Appraisal Report

An Environmental Appraisal report has been prepared for the hybrid option. This work concluded that the implementation of a hybrid Option is anticipated to reduce air pollution across the city centre, the wider SGC administrative area and potentially beyond. However, it is recommended that signage should be designed and installed with viewpoints in mind, particularly near Clifton Suspension Bridge, due to their historic importance and visual amenity value.

The Environmental Appraisal Report is contained in Appendix T to the OBC.

3.10 Sensitivity Analysis

To understand the sensitivity of the assessment to changes in model assumptions, as series of sensitivity tests have been undertaken on the hybrid option (using the 2021 and 2031 models) see Table 3-42 for a summary of this work. The Sensitivity Analysis is reported in Appendix P to the OBC.

Table 3-42: Sensitivity tests

Test	Section Number	Summary	Key Results
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.
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.

Test	Section Number	Summary	Key Results
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 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.