MAY 2020

NORTH STAFFORDSHIRE LOCAL AIR QUALITY PLAN

UNAPPROVED OUTLINE BUSINESS CASE

APPENDIX 34 - E1 Economic Modelling Report

North Staffordshire Local Air Quality Plan - Economic Modelling Report (E1)

Report for Newcastle-under-Lyme Borough Council, Stoke-on-Trent City Council and Staffordshire County Council

ED 12487 | Issue Number 3 | Date 14/05/2020

Customer:

Stoke-on-Trent City Council, Newcastle-under-Lyme City Council, Staffordshire County Council

Customer reference:

Stoke CAZ Study

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Date:

14 May 2020

Ricardo Energy & Environment reference:

Ref: ED12487– Issue Number 3

Table of contents

1 Introduction

Newcastle-under-Lyme Borough Council (NuLBC) and Stoke-on-Trent City Council (SoTCC) were identified in the 2015 National Air Quality Plan as two of the 33 councils required to complete a Targeted Feasibility Study. The results of this feasibility study highlighted that compliance with NO_2 concentration limits would not be achieved in Stoke-on-Trent until 2023 and Newcastle-under-Lyme until 2026 without intervention. The feasibility study found that the introduction of measures designed to reduce air pollution along the A53 would bring forward compliance in Newcastle-under-Lyme by one year. The key areas identified in the Targeted Feasibility study that were modelled to exceed NO_2 limits in 2021 are along the A53 (Census IDs: 26555, 28732 and 74058).

In 2018, NULBC and SoTCC were issued a Ministerial Direction to produce a local air quality plan. This was required to consider a charging-based Clean Air Zone (CAZ) as a benchmark and a range of alternative measures able to achieve compliance within the shortest time possible.

Where actions are identified to tackle air pollution and achieve compliance with legal limits, these must be presented in a Business Case to JAQU, following HM Treasury's (HMT) Five Case model. A Strategic Outline Case (SOC) has already been submitted to JAQU.

One of the five cases is the Economics Case. This case must meet the following criteria (taken from the JAQU guidance: 'Business Cases for Local Plans'):

- Elements of the economic case are revisited, all changes to the underlying assumptions made in the SOC should be noted.
- The short list is to be assessed considering the benefits and costs in detail. Net Present Value (NPV) for each option should be considered to identify a preferred option; including a distributional analysis of the option.

Relevant annexes will include the full economic model with associated documentation, and the outputs of the scenario analysis of the air quality and transport modelling. This allows the assessment of the key Critical Success Factor on delivering compliance in the shortest possible time.

JAQU have shared with the Local Authorities detailed guidance around the methodologies and assumptions to adopt when appraising the options[1]. This guidance stipulates that deliverables to be provided by the Local Authority are:

1. SOC: options appraisal - within the SOC, detailing the case for change and a high-level assessment of the options being considered.
2. Economic Appraisal Methodology Report (E1).
3. The Economic Model (E2) and any linked documents (linked spreadsheets or user guide).
4. Write-up of the economic appraisal and results.
5. Distributional Analysis Methodology Report (E3).

This plan and supporting analysis must be developed in accordance with the HMT Green Book.

Sweco, together with Ricardo, have been commissioned by NuLBC and SoTCC to deliver the cost-benefit analysis and supporting model (E2), and the Economic Methodology Report (E1). This report sets out the detail of the methodology and data sources used to undertake the cost-benefit analysis of

[1] Latest version issued 27/11/17

the options. The purpose of this report is to meet deliverable E1 of the JAQU requirements as set out above.

The analysis inherently relies on other areas of the modelling undertaken to support the assessment of policy options, specifically the transport and air quality modelling undertaken outside of the scope of this project. This paper clearly references where the analysis has used the outputs of other modelling and describes how these outputs are used. However, it does not set out a detailed account of how this supporting modelling has been undertaken, which has been provided elsewhere (e.g. through the Modelling Needs Assessment reports).

This report sets out the approach and results of the core cost-benefit analysis (CBA) around the Preferred Option compared to a benchmark CAZ, as required by the Five Case Model. The CBA aims to identify, assess and place a monetary value on all impacts associated with a given policy option. In doing so, the impacts of a single option can be combined to judge the overall net effect. Options can be compared to assess which delivers the largest ‘net benefit’. Hence, it explores the economic case for the Preferred Option and Benchmark CAZ D by demonstrating the comparative value for money (VfM).

This report does not present outputs of the distributional analysis. These are presented separately in the accompanying Distributional Analysis Methodology Report (deliverable E3).

2 Definition of Modelled Options

2.1 Setting Out the Options

The analysis is defined by the options that are included in the Outline Business Case (OBC) which are described in Table 2-1 below.

Table 2-1: Shortlist for assessment

<table>
<tr><th>Scenario</th><th>Options appraised</th></tr>
<tr><td>Do Minimum</td><td>Providing an assessment of air pollutant concentrations with no further interventions</td></tr>
<tr><td>Preferred Option</td><td>The NSLAQP for Stoke-on-Trent and Newcastle-under-Lyme comprises of a package of measures:

A50 Victoria Road bus gate, operational Monday to Friday between 07:00-10:00 and 16:00-19:00. ANPR cameras will be used to restrict access except for buses, taxis and cyclists
A53 Etruria Road two-lane bus gate, operational Monday to Friday between 07:00-10:00 and 16:00-19:00. ANPR cameras will be used to restrict access except for buses, taxis and cyclists
Traffic management measures on roads to the east and west of Victoria Road, including:

Traffic calming
One-way restrictions
Speed restrictions
Weight restrictions
Extension of footways
Carriageway re-surfacing

Transport improvements along the A53 Etruria Road in the form of a review of signal times, signalised pedestrian crossing facilities and the relocation of a bus stop to avoid unnecessary queuing
Targeted bus retrofit programme where 75% of buses using Bucknall New Road and 100% of buses using Victoria Road will be retrofitted to achieve Euro VI emissions standards
Bus infrastructure improvements will be installed on routes that pass through or are parallel to the identified exceedance locations. The improvements will include Real Time Passenger Information (RTPI) screens, new bus shelters, accessible kerbs at bus stops and installation of CCTV at bus stops.

A ULEV exemption, allowing ultra-low emission vehicles to drive through the bus gates, will be assessed and if considered deliverable will be added to the preferred scheme in the Full Business Case (FBC). The local authorities will also seek further funding through the Clean Air Fund (CAF) for additional measures that will look to mitigate any impacts that might arise as a result of the scheme.

A separate Ministerial Direction concerns the retrofitting of buses operating along the A53 corridor. This is separately funded by JAQU and excluded from this Outline Business Case (OBC).</td></tr>
<tr><td>Benchmark CAZ D</td><td>As per JAQU guidance, a benchmark CAZ option has also been identified.

Based on the work undertaken during the options appraisal stage, the benchmark CAZ was defined as a class D. The boundary covers the main areas affected by NO_2 in Newcastle-under-Lyme and Stoke-on-Trent including Hanley, Victoria Road and east Newcastle-under-Lyme, as well as the A53 Etruria Road between Newcastle-</td></tr>
</table>

	under-Lyme and Hanley. The proposed charge rates for non-compliant vehicles would be: • Cars / Taxis £5 • LGVs £9 • HGVs £35 • Buses £5 The Benchmark CAZ D applies to the boundary shown in Figure 2.

Figure 1: Preferred Option plan

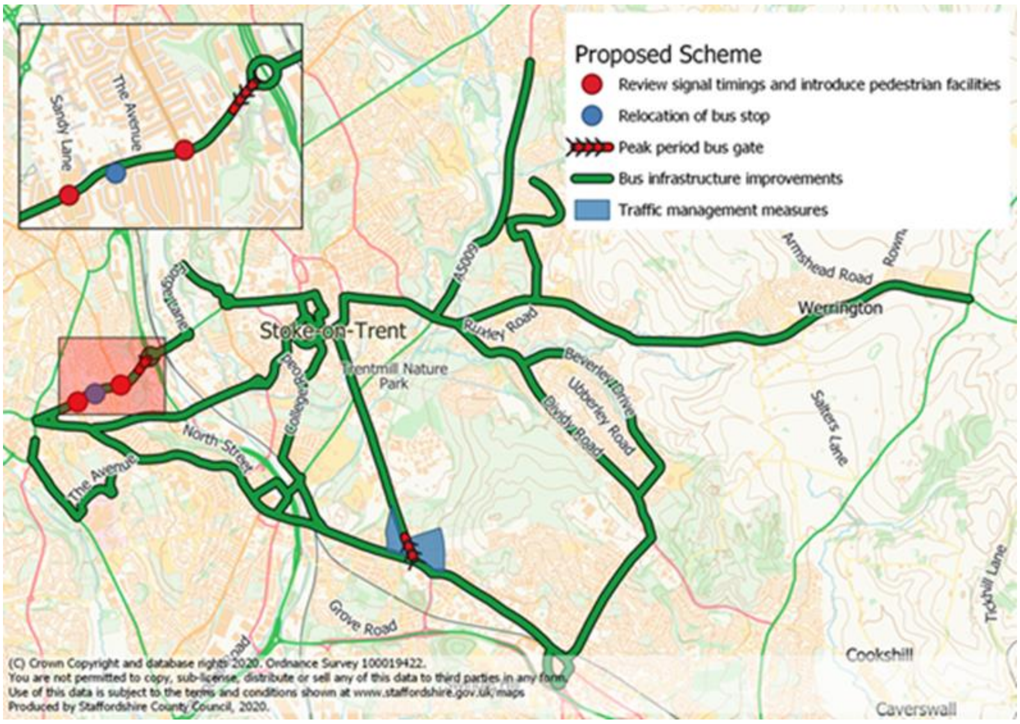
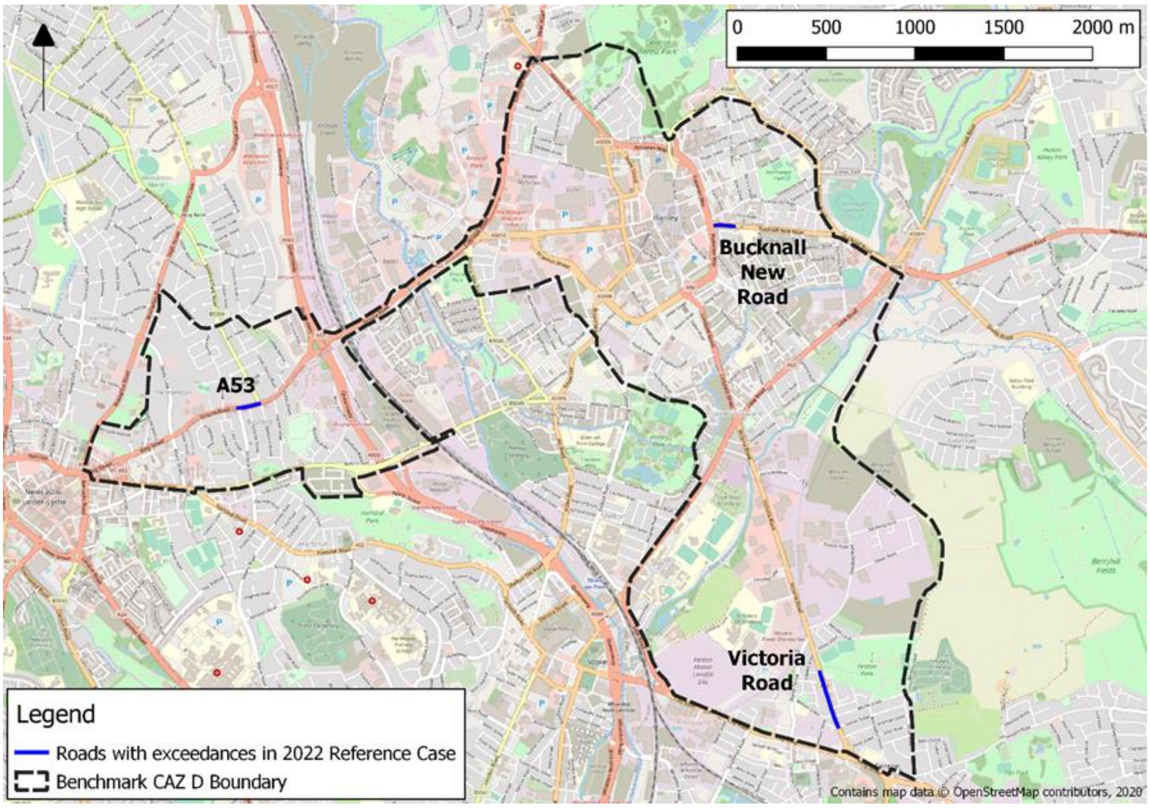


Figure 2: Area for the Benchmark CAZ D Option



2.2 CAZ Charges and Behavioural Response

The Benchmark CAZ D scheme covers buses, coaches, taxis (including private hire cars), LGVs, HGVs and cars, where vehicles not meeting the Euro 6/VI standard for diesel (or Euro 4 for petrol) are charged for entering the CAZ boundary. The charges for this assessment are presented in Table 2-2.

Table 2-2: Benchmark CAZ D Charging Scheme (all charges noted are daily applied on first entry to the charging zone)

Vehicle Type	Benchmark CAZ D Charge
Cars and Taxis	£5.00
LGVs	£9.00
HGVs	£35.00
Buses and Coaches	£5.00

Table 2-3 below shows the CAZ behavioural response assumptions adopted. These are the same as those applied in the transport model and are originally based on outputs of the stated preference (SP) survey conducted between 2 September and 2 October 2019 (See Stated Preference Survey Report[2]). For coaches, JAQU assumptions were used due to lack of granularity on separating coaches from buses in the transport model. A nominal charge has been set for buses so to mi

A nominal charge has been set for buses in order to avoid any change in the number of bus services. This was to avoid disproportionately impacting on deprived groups, particularly the elderly and disabled people, who often have greater reliance on public transport. Following consultation with the

[2] Sweco (2019). Air Quality Plan - Stated Preference Study Report – Unpublished.

bus operators it was determined that setting a significant daily charge would risk services being withdrawn. This would result in disadvantaged groups and vulnerable users not having an alternative mode of transport. This is in line with JAQU guidance which stipulates that if a local authority believes that introducing a CAZ will have an adverse effect on a particular group then a lower charge could be set. As a result of the nominal charge set, it is anticipated that bus operators would not upgrade their vehicles in response to the Benchmark CAZ D.

All responses to the options are assumed to occur in 2022 for simplicity, although the Management Case forecasts that a Benchmark CAZ D would not be operational until May 2023. In practice, these upgrades (and their associated impacts) could occur before or after the implementation of the CAZ.

Upgrade is only one of many responses which non-compliant vehicles can adopt in response to the CAZ. Vehicles can also ‘cancel their trip’, ‘avoid the zone’ or ‘pay the charge’. Other possible responses were modelled endogenously within the transport model. Hence, it is assumed that these responses reflect the specific characteristics of the journeys and trip makers and are more appropriate than the standard JAQU national assumptions.

Table 2-3: Behavioural responses to the Benchmark CAZ D

<table>
<tr><th>Response</th><th>CAR</th><th>LGV</th><th>HGV</th><th>Bus</th><th>Coach</th><th>Taxis</th><th>Private Hire Car</th></tr>
<tr><td>Upgrade</td><td>45%</td><td>43%</td><td>66%</td><td>0%</td><td>41%</td><td>73%</td><td>73%</td></tr>
<tr><td>Cancel*</td><td rowspan="2">21%</td><td>2%</td><td>5%</td><td>0%</td><td>26%</td><td rowspan="2">24%</td><td rowspan="2">24%</td></tr>
<tr><td>Change mode*</td><td>0%</td><td>0%</td><td>0%</td><td>0%</td></tr>
<tr><td>Avoid</td><td>19%</td><td>27%</td><td>14%</td><td>0%</td><td>0%</td><td>0%</td><td>0%</td></tr>
<tr><td>Pay</td><td>15%</td><td>28%</td><td>15%</td><td>100%</td><td>33%</td><td>3%</td><td>3%</td></tr>
</table>

** For cars, taxis and PHC, the ratio between vehicles that cancel and those that change mode is not available.*

In addition to the above described primary behavioural responses to the CAZ, JAQU provides guidance on secondary behavioural responses. This sets out the proportions of people who, when upgrading their vehicle, buy a used or new vehicle, and whether they sell or scrap their old car:

- A proportion, 25%, of those people taking the upgrade response will scrap their old vehicle
- A proportion, 25%, of those people choosing to upgrade will buy a new vehicle
- A proportion, (75%*75%), of those people who elect to upgrade will sell their old vehicle and buy the cheapest unaffected one
- A proportion, (25%*75%), of those people who decide to upgrade will sell their old vehicle and buy the cheapest unaffected one of the same fuel type

3 Scope and Methodology

3.1 Impacts Assessed

Any scheme to tackle air quality will impact different parts of the environment, economy and society. The economic analysis seeks to quantify and value as many of these impacts as possible given the time, resource and modelling methodologies available.

JAQU have provided detailed guidance regarding the appraisal of options. This provides a steer for many of the key data inputs and assumptions that have framed the analysis undertaken.

The key guidance documents include:

- Options Appraisal – Guidance (2017)[3] (and preceding versions of this guidance)
- Third wave local authorities – guidance: options appraisal[4]
- National data inputs for Local Economic Models (2017)[5].

JAQU guidance sets the basis for the scope of impacts to be assessed. This report has adopted the same approach although in some cases, it has grouped impacts by the methodology taken to appraise them and, hence, may in places refer to different impacts using different terminology to that set out in the JAQU guidance.

A quantitative assessment of the impacts associated with the CAZ has been undertaken where possible. However, in some cases it has not been possible to complete a full quantitative assessment given limitations in the data available. Where impacts have not been assessed quantitatively, a qualitative assessment has been carried out. The results of the analysis are presented in Section 7.

The scope of impacts captured by the CBA, and their correspondence to the impact categories described in the JAQU guidance, are presented in Table 3-1.

Table 3-1: Impact description and mapping

Impact name (Relevant Option)	Description	JAQU reference
Upgrade costs (CAZ D)	The impact on those vehicles owners that respond to the Benchmark CAZ D. These are the upfront costs for vehicle owners associated with switching from a non-compliant to a compliant vehicle. In calculating upgrade costs, secondary behavioural responses on whether users buy a used or new vehicle, and whether they scrap or sell their old vehicle, are considered (See Section 2.2).	'Vehicle scrappage costs' and 'Consumer welfare impact' for 'upgrade vehicle response'
Vehicle Operating Cost (VOC) impacts (CAZ D and Preferred Option)	Those savings or additional costs that can result from the Benchmark CAZ D or Preferred Option. This includes both changes in fuel consumption and the associated cost and change in operating and maintenance costs. This can come about through additional distances travelled (handled by transport modelling and TUBA) or change in vehicle type (handled by REE model).	'Fuel switch costs'

[3] Unpublished – provided directly by JAQU to Local Authorities
[4] Ibid
[5] Ibid

Impact name (Relevant Option)	Description	JAQU reference
Implementation costs (CAPEX and Operating Costs) (CAZ D and Preferred Option)	Cost of upfront and ongoing activity and assets required to implement, monitor and enforce the Benchmark CAZ D and Preferred Option. Includes the cost of bus retrofits in the Preferred Option.	'Government costs'
Air quality emissions (CAZ D and Preferred Option	The impact on affected populations by a change in NO_X and $PM_{2.5}$ emissions as a result of the Benchmark CAZ D and Preferred Option.	'Health and environmental impact'
Greenhouse Gas impacts (CAZ D and Preferred Option)	The impact on affected populations by a change in greenhouse gas emissions that result from Benchmark CAZ D and the Preferred Option. This can come about through additional distances travelled or change in vehicle type.	'Greenhouse Gas impacts'
Travel Time (CAZ D and Preferred Option	The impact of the Benchmark CAZ D and Preferred Option on traffic flow and the subsequent impact on travel time experienced by affected populations.	'Traffic flow impact'
Welfare impacts (CAZ D)	Where vehicle users change their travel patterns in response to a charging CAZ, there will be a cost for the user associated with not being able to take their first preference. E.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (e.g. shopping trip to city centre). The vehicle user will miss out on the happiness / value that they would have gained from that trip, which is captured by this impact category.	Welfare impacts
User Charges (CAZ D)	The cost to road users from paying the CAZ charges. This category includes for impact on consumer welfare associated with the user not being able to take their first preference. E.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (e.g. shopping trip to city centre). The vehicle user will miss out on the happiness / value that they would have gained from that trip, which is captured by this impact category.	'Consumer welfare impact'
User Charge Revenues (CAZ D)	The revenue generated through charging the non-compliant cars to travel through the CAZ. This should have no net impact on the model, although will not net off completely due to central Government credit/debit card fees.	'Government costs'
PCN Charges and revenue (Preferred Option)	The cost to road users and revenue to public administration incurred from penalties from entering the bus gate restrictions. These are assumed to be equal as no credit/debit card fees have been accounted for.	'Government costs'
Indirect Taxes and Revenues (CAZ D and Preferred Option)	The impact on revenues generated by the VAT, excises and duties levied on goods and services. This should have no net impact on the model.	'Government costs'
Bus Stop/RTPI/CCTV Improvements (Preferred Option)	There will be a range of benefits associated with greater uptake of bus travel in the Preferred Option	TAG

3.2 Models developed

The approach is designed to be consistent with the HMT's Green Book guidance for appraisal[6]. It also draws upon guidance provided by the JAQU[7] to inform the assessment in accordance with Department for Transport's Transport Appraisal Guidance (TAG).

The analysis has deployed two complementary modelling systems to appraise the impacts:

1. **REE CAZ model:** The approach to assessing the impacts associated with upgrading vehicles (and associated vehicle operating costs (VOCs): Non-fuel VOCs, fuel and CO_2 impacts) and air quality impacts has been tested in multiple CAZ cities.

2. **TUBA:** Changes to travel time, such as that resulting from altered trips to avoid the Preferred Option bus gates or Benchmark CAZ D zone or changes in congestion resulting from the operation of the bus gates or Benchmark CAZ D zone, are taken from the transport model and monetised using TUBA analysis along with associated impacts on fuel and non-fuel vehicle operating costs.

Ricardo's economic model is used to combine and monetise all individual impacts across the models to calculate the overall net present value (NPV).

The way in which these impacts are relevant to the different policy options is shown in Table 3-2.

Table 3-2: Mapping of impacts to policy options

	Preferred Option	Benchmark CAZ D
TUBA Model		
Travel Time	✓	✓
Vehicle Operating Cost (VOC) Impacts (speed/distance)	✓	✓
User charges		✓
User charge revenue		✓
PCN charges	✓	
Implementation Costs	✓	✓
Indirect Tax Revenues	✓	✓
Greenhouse Gas Impacts (speed/distance)	✓	✓
REE CAZ Model		
Air Quality Emissions	✓	✓
Upgrade costs	✓ (Bus retrofits)	✓
Vehicle Operating Cost (VOC) Impacts (upgrades)		✓
Greenhouse Gas Impacts (upgrades)		✓
Bus Stop/RTPI/CCTV Improvements	✓	

3.3 Modelling years

The appraisal period for the economic modelling is 2022-2031, a 10 year period from implementation year, as per JAQU Guidance.

[6] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent
[7] JAQU Third Wave City Guidance

There are three key years used in the modelling work, as set out in Table 3-3 below. The base modelling year is 2019 as this allows use of the latest air quality and transport data. The future baseline is modelled for the assumed implementation year in 2022. Other years required for the analysis of the appraisal period are generated through projection rather than direct model tests, with 2025 being the third key year.

Table 3-3: Model years and appraisal period

Year	Description
2019	**Base year** – using latest available data on air quality and traffic (based on 2015 traffic model base year)
2022	**Implementation year** – latest date when the scheme is assumed to be in place.
2025	**Interim forecast year – used for interpolation/extrapolation of other forecast years**
2022-2031	**Appraisal period -** 10 years (from date that local implementation is estimated to begin)

As noted above, all responses to the options are assumed to occur in 2022 for simplicity and consistency with the transport and air quality, although the Management Case forecasts that a Benchmark CAZ D would not be operational until May 2023.

3.4 Developing the Fleet Baseline

The economic analysis uses ANPR data from 2019 to calculate the number of unique vehicles that enter the North Staffordshire area over a given year. This data is then used to calculate the number of vehicles that upgrade in response to the CAZ to determine the associated costs.

ANPR data splits the fleet into passenger cars, LGVs, HGVs, buses and taxis, including fuel type and Euro standard split. In the case of buses and taxis, licence data was provided by the Councils which has been used as the baseline fleet, and so ANPR data was not used.

Vehicle-specific scaling factors were applied to get the annual number of unique vehicles from the weekly ANPR survey data. In addition to this, the coverage of the ANPR cameras in the survey was considered and uplift factors applied to reflect the incomplete coverage of routes into the CAZ. Additionally, annual fleet growth rates derived from the transport model were applied, and finally 2022 Euro standard splits used in the air quality model were applied to arrive at the final numbers of unique vehicles in 2022 (Table 3-4).

The baseline taxi fleet was derived from licence data and annual uplift and projected turnover applied to derive the baseline 2022 fleet (Table 3-5).

Table 3-4: 2019 Weekly ANPR Survey Data on Unique Vehicles, and 2022 Estimated Baseline

Vehicle	Fuel	Euro	2019 (One Week ANPR Survey Count)	2022 (Annual)
Car	Petrol	Pre-Euro 1	632	0
Car	Petrol	Euro 1	444	0
Car	Petrol	Euro 2	1620	0
Car	Petrol	Euro 3	21990	5393
Car	Petrol	Euro 4	44989	36695
Car	Petrol	Euro 5	49134	80556
Car	Petrol	Euro 6	67541	200018
Car	**Petrol**	**Total**	**186350**	**322662**
Car	Diesel	Pre-Euro 1	60	0
Car	Diesel	Euro 1	133	0
Car	Diesel	Euro 2	419	0
Car	Diesel	Euro 3	11412	3479
Car	Diesel	Euro 4	32646	26771

Car	Diesel	Euro 5	66042	102534
Car	Diesel	Euro 6	70957	181772
Car	**Diesel**	**Total**	**181669**	**314557**
HGV	Diesel	Pre-Euro 1	54	0
HGV	Diesel	Euro 1	35	0
HGV	Diesel	Euro 2	191	25
HGV	Diesel	Euro 3	1376	945
HGV	Diesel	Euro 4	2534	2815
HGV	Diesel	Euro 5	9033	8122
HGV	Diesel	Euro 6	27582	87973
HGV	**Diesel**	**Total**	**40803**	**99880**
LGV	Petrol	Pre-Euro 1	95	0
LGV	Petrol	Euro 1	14	0
LGV	Petrol	Euro 2	8	0
LGV	Petrol	Euro 3	53	29
LGV	Petrol	Euro 4	153	196
LGV	Petrol	Euro 5	32	294
LGV	Petrol	Euro 6	77	449
LGV	**Petrol**	**Total**	**429**	**969**
LGV	Diesel	Pre-Euro 1	129	0
LGV	Diesel	Euro 1	186	0
LGV	Diesel	Euro 2	185	0
LGV	Diesel	Euro 3	2540	1419
LGV	Diesel	Euro 4	17220	17894
LGV	Diesel	Euro 5	32211	47931
LGV	Diesel	Euro 6	24140	105710
LGV	**Diesel**	**Total**	**76610**	**172953**

Table 3-5: 2019 Taxi Licence Data and estimated 2022 Baseline fleet

Vehicle	Fuel	Euro Standard	2019	2022
Taxis	Diesel	Pre-Euro 1	0	0
Taxis	Diesel	Euro 1	0	0
Taxis	Diesel	Euro 2	0	0
Taxis	Diesel	Euro 3	48	14
Taxis	Diesel	Euro 4	117	72
Taxis	Diesel	Euro 5	232	175
Taxis	Diesel	Euro 6	41	198
Taxis	**Diesel**	**Total**	**438**	**459**
Private Hire Car	Petrol	Pre-Euro 1	0	0
Private Hire Car	Petrol	Euro 1	0	0
Private Hire Car	Petrol	Euro 2	0	0
Private Hire Car	Petrol	Euro 3	3	2
Private Hire Car	Petrol	Euro 4	54	14
Private Hire Car	Petrol	Euro 5	55	30
Private Hire Car	Petrol	Euro 6	2	74
Private Hire Car	**Petrol**	**Total**	**114**	**120**

Private Hire Car	Diesel	Pre-Euro 1	0	0
Private Hire Car	Diesel	Euro 1	0	0
Private Hire Car	Diesel	Euro 2	0	0
Private Hire Car	Diesel	Euro 3	17	21
Private Hire Car	Diesel	Euro 4	420	164
Private Hire Car	Diesel	Euro 5	1192	627
Private Hire Car	Diesel	Euro 6	206	1112
Private Hire Car	**Diesel**	**Total**	**1835**	**1924**

3.4.1 Sense-check of Unique Vehicles

The number of unique vehicles travelling into the CAZ area is a critical intermediary output of the analysis and defines a large proportion of the resultant impacts seen in the model. There is no perfect source for the number of unique vehicles. However, as part of the quality assurance of the analysis the number of unique vehicles has been sense checked.

The unique vehicles that resulted from the ANPR data and application of uplift factors were compared with the number of licenced vehicles in Stoke-on-Trent and Staffordshire according to DfT data[8]. The number of unique cars assumed to be affected by the proposed Benchmark CAZ D boundary is broadly similar to those registered in Stoke-on Trent and Staffordshire. In the case of LGVs and HGVs, the modelled baseline fleet is significantly greater than the numbers from licence data as a percentage. However, the West Midlands is densely populated with Birmingham nearby, and so it can be expected that goods vehicles will travel from outside Staffordshire and Stoke-on-Trent to businesses in the area.

Table 3-6: Registered vehicles in 2018 and the difference between the baseline model fleet (2019 fleet)

Vehicle	Stoke-on Trent	Staffordshire	2019 Modelled Fleet
Cars	110,800	463,600	552,000
LGVs	15,200	56,300	116,000
HGVs	2,400	12,500	102,184

3.5 Discounting

As recommended by JAQU, the model uses a 2018 price base year as the basis for all calculations. This means that past costs (for example vehicle costs) are inflated to 2018 values using HMT's GDP Deflator series.

Discounting future costs and benefits considers the time preference of society. Discounting is applied in accordance with HMT's Green Book guidance. The model applies a discount rate of 3.5% to all impacts, which are discounted back to 2019[9].

[8] https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2018
[9] Adjustment factors, TAG 2018.

4 Approach to assessing the impacts

4.1 Transport and Air Quality models

The Preferred Option and the Benchmark CAZ D have been modelled in the transport model to assess the potential displacement effects of vehicles. The North Staffordshire Multi-Modal (NSMM) transport model has been used to derive the required traffic forecasts to inform this economic appraisal. The traffic model provides flows for compliant vehicles (those meeting the CAZ standards naturally or through upgrade) and non-compliant vehicles (compliance in 2022 is provided by the air quality model, originally based on compliance from ANPR data in Table 3-4 and with fleet uplift and turnover assumptions applied).

The traffic data is then applied in the air quality model to assess the impacts of the scheme on emissions from compliant and non-compliant vehicles, and subsequently on air pollutant concentrations. The fleet for the 2022 vehicles uses the 2022 baseline fleet and applies baseline vehicle upgrade assumptions.

4.2 Ricardo Economic Upgrade Model

4.2.1 Air Quality Emissions

The key objective of the Preferred Option and Benchmark CAZ D is to reduce the emission (and subsequently concentrations) of air pollutant emissions from road transport sources in the three identified areas of exceedance. Reducing air pollutant emissions will have a range of subsequent benefits on human and environmental health, productivity and amenity.

The following approach to valuing the impacts associated with reductions in emissions is as follows:

1. Take quantities (tonnes) of emissions of NO_X and $PM_{2.5}$ from underlying air quality modelling undertaken by Ricardo for both option scenarios and do minimum baseline
2. Calculate the total emissions impact relative to baseline
3. Value the impact applying damage costs provided by JAQU

Damage cost values (based on the value of 'Urban big' as defined within recent Defra Guidance for Air Quality Damage Costs[10]) are applied to calculate the monetary benefit of the change in emissions. It is assumed that the benefit reduces over time as the baseline scenario naturally catches up to the Preferred Option and Benchmark CAZ D as per JAQU Guidance. This effect is simulated using 'impact extrapolation factor', as explained in Information Box #1 below.

Information Box #1: Impact extrapolation factors

For air pollutant (and other) impacts, detailed modelling of the effects of all options was only available for 2022. Hence a detailed assessment of the emissions impacts of all options over the full appraisal period was not available. A methodology was developed to extrapolate these impacts over the whole appraisal period.

The supporting evidence for the national plans[11] included scenarios run by JAQU which presented resulting concentrations in cities for the baseline and illustrative CAZ scenarios. This information was analysed to produce a factor with which impacts can be extrapolated over the appraisal period to simulate the erosion of the impacts of the Benchmark CAZ D, as the vehicle fleet naturally catches up

[10] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1902271109_Damage_cost_update_2018_FINAL_Issue_2_publication.pdf
[11] See 'Baseline and with Measures projections' available: https://uk-air.defra.gov.uk/library/no2ten/2017-no2-projections-from-2015-data

with the upgrades brought forward as part of the Benchmark CAZ D. The extrapolation factor is the difference in concentrations between baseline and Benchmark CAZ D scenario, expressed as a ratio relative to the difference in 2022.

In the Preferred Option, there are expected to also be a reduction in air quality benefits over time, but this will be less than in the Benchmark CAZ D, given the option does not incentivise bringing forward vehicle upgrades in the same way. For the Preferred Option, an average of the impact extrapolation factor and 1 was used to produce a more gradual erosion of effects.

The results of the analysis for 2022 are presented in Table 4-1. It should be noted that these are only impacts for a single year, and there is no application of extrapolation factors.

As noted above, it is assumed that both options are implemented in 2022. However, as set out in the Management Case, the Benchmark CAZ D can only be implemented from 2023. Hence the Preferred Option in practice will deliver emissions reductions and associated health benefits sooner. By assuming the Benchmark CAZ D begins to deliver emissions reductions in 2022, the analysis overstates the size of the air pollution benefits associated with this option.

Table 4-1: Air pollutant (NO_X and $PM_{2.5}$) impacts of the measures in 2022

Option	NO_X			$PM_{2.5}$		
	NO_X Emissions (t/ year All vehicles)	**Difference from Baseline (t)**	**Benefits per annum (£)**	**$PM_{2.5}$ Emissions (t/ year All vehicles)**	**Difference from Baseline (t)**	**Benefits per annum (£)**
Baseline 2022	1,629		-	285	-	
Preferred Option	1,616	-13	£230,099	285	0	0
Benchmark CAZ D	1,528	-101	£1,787,691	279	-6	£2,025,664

4.2.2 Vehicle Upgrade costs in Benchmark CAZ D

The costs associated with people who decide to upgrade their vehicle as a result of implementation of the Benchmark CAZ D is a critical impact category. The approach to estimating upgrade costs has been tested in a number of cities considering charging schemes.

The approach starts by calculating the number of vehicles to be upgraded. For the Benchmark CAZ D this is defined by applying behavioural responses to the non-compliant vehicles in the baseline. It is assumed that the oldest vehicles are the first to upgrade.

The cost to an owner of a change vehicle is then estimated through consideration of second order behavioural responses outlined in Section 2.2. Vehicle owners are assumed either to scrap and buy a new compliant vehicle, or to sell their non-compliant vehicle as used and replace with a used complaint vehicle. These transactions have the following impacts (With the impacts varying by transaction type):

- The lost residual value from scrapped vehicles (For those who elect to scrap their old vehicle)
- The resale value of an unwanted non-compliant vehicle based on the depreciated value of vehicle in 2022 (For those who choose to sell their old vehicle)
- New or used compliant vehicle purchase costs in 2022

These input values are combined to give the net cost.

Upgrades will also occur in the baseline and our approach to estimating these costs is very similar to that applied in the Benchmark CAZ D. The general assumption in the baseline is that the same upgrade decision will be undertaken as under the Benchmark CAZ D option but at a later date (defined by useful lives and ownership profiles). This future net cost is then discounted given it occurs in the future to allow comparison with costs under the Benchmark CAZ D option.

The upgrade cost assumptions, and the impacts associated with each second order behavioural response are set out in Table 4-2.

Table 4-2 – Upgrade cost second order behavioural response calculation and associated impacts

	Scenario	Scrap	Buy new	Sell & Buy Same Fuel	Sell & Buy Different Fuel
Numbers of vehicles	**CAZ**	25% of all vehicles upgraded JAQU behavioural response applied. Oldest vehicles scrapped first in 2022	25% of all vehicles upgraded JAQU behavioural response applied. Every vehicle scrapped is replaced with new vehicle in 2022	75% * 25% (for diesel) 75% for petrol JAQU behavioural response applied. Vehicles to be sold (those not scrapped) * behavioural response	75% * 75% (for diesel) 0% for petrol JAQU behavioural response applied. Vehicles to be sold (those not scrapped) * behavioural response
	Baseline	Vehicles scrapped under CAZ are scrapped in baseline post 202 when end useful life reached	Every vehicle scrapped replaced with new in year after 2022 at end of useful life of scrapped non-compliant vehicle	Same activity as CAZ scenario But some resell at end of ownership profile Some scrap when reach end useful life	Same activity as CAZ scenario But some resell at end of ownership profile Some scrap when reach end useful life
Costs	**CAZ**	Loss of residual value determined by remaining life of vehicle	Purchase cost of new compliant vehicle in 2022	Cost of compliant used vehicle less resale value of used non-compliant vehicle	Cost of compliant used vehicle less resale value of used non-compliant vehicle
	Baseline	No residual value of vehicles as they reach end useful life	Purchase cost of the same new vehicle in year post 2022 (real cost is same as CAZ scenario, but purchase delayed by remaining life of existing vehicle hence cost discounted to 2022)	Discounted cost of used compliant vehicle less resale value of existing vehicle (for those reaching end ownership profile) Discounted cost of used compliant vehicle (for those reaching end useful life) Resale/scrappage profile applied to vehicle depending on age of non-compliant vehicle	Discounted cost of used compliant vehicle less resale value of existing vehicle (for those reaching end ownership profile) Discounted cost of used compliant vehicle (for those reaching end useful life) Resale/scrappage profile applied to vehicle depending on age of non-compliant vehicle

The upgrade costs are calculated taking the difference in aggregate upgrade costs for the Benchmark CAZ D option and baseline scenario. The cost of upgrade is hence calculated as the marginal impact of people upgrading earlier than they would do if the Benchmark CAZ D was not in place. This is to say that a person would upgrade in the future anyway, what is the economic impact of the person upgrading in the implementation year relative to the cost in the future year.

Upgrade costs in the CBA are assessed using societal costs. As such, VAT and profit are excluded, and actual upgrade costs to users will be higher in practice.

4.2.3 Vehicle operating costs (Fuel and Non-Fuel VOC) and Greenhouse Gas Emissions associated with vehicle upgrades in the Preferred Option and Benchmark CAZ D

4.2.3.1 Benchmark CAZ

The Ricardo model takes into account changes in fuel and non-fuel vehicle operating costs (VOC) and greenhouse gas (GHG) impacts[12] associated with the upgraded fleet that has resulted from the option. (For changes in these metrics related to changes in trips and travel time/distance, outputs from the TUBA model were also used – see section 0).

The estimation of operating costs and GHG emissions focused on capturing the effect of upgrading vehicles switching vehicle-kilometres (vkm) travelled from one Euro class of vehicle to another. The following approach was taken:

1. Take numbers of vehicles upgraded from fleet upgrade calculations
2. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with data around the average annual fuel consumption and average annual operating costs per vehicle type and age[13]
    a. By applying average non-fuel VOC and fuel consumption over the full year and average vkm travelled per annum, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the Air Quality modelling domain.
3. Changes in fuel consumption are combined with changes in fuel prices.
4. Changes in fuel consumption are combined with emissions factors from the Department for Business, Energy & Industrial Strategy (BEIS)' Green Book Supplementary Guidance to calculate changes in GHG emissions (tCO_2e) [14]
5. Changes in GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary Guidance.

Note: for the effects associated with vehicle upgrades, these impacts are not forecast over the period using the extrapolation factor. This is because these impacts are associated with modelled vehicle upgrades. The model depicts the VOC costs and GHG emissions associated with the new vehicle, and with the vehicle replaced to identify the difference. Hence, the impacts are already depicted over the appraisal period and extrapolation is not required.

4.2.3.2 Preferred Option

In addition to the upgrades that occur as a result of the Benchmark CAZ D, the changes in VOCs and GHG emissions from bus retrofits in the Preferred Option have been calculated. These changes are calculated using the same methodology as described above and result in disbenefits due to retrofits extending the life of existing (older and less efficient) buses and pushing back upgrades to new vehicles with improved fuel consumption/GHG emissions.

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[12] Annual fuel consumption and VOC source: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)

[13] Consumption and VOC for general vehicle types came from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished). Data for hybrid vehicles came from: Ricardo Energy & Environment (forthcoming). Car Choice Model (CCM) summary report.

[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/602657/5._Data_tables_1-19_supporting_the_toolkit_and_the_guidance_2016.xlsx

4.2.4 Welfare Loss for the benchmark CAZ

Where vehicle users change their travel patterns, there will be a cost for the user associated with not being able to take their first preference, e.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (such as a shopping trip to the city centre). The vehicle user will miss the value or 'utility' that they would have gained from that trip and, hence, this represents a cost to the Benchmark CAZ D scenario.

The approach to assessing these impacts is consistent with the JAQU guidance and is as follows:

1. Take the number of trips which are cancelled from the transport model (for each scenario, split by vehicle type).
2. Scale up affected vehicles per day to affected vehicles per year
3. Combine the number of affected vehicles with half the CAZ charge
4. Extrapolate the impact in the first year over the appraisal period using the extrapolation factor.

This analysis therefore implicitly carries forward the proportion of transport users taking each alternative response modelled in the transport model.

There are a number of different impacts that the user will face associated with switching transport behaviour. Not just the utility of making the trip, but the time required to travel, the fuel, operating cost, comfort of the mode, etc. In theory, the user will consider all these impacts when considering the best way to make a trip and contrast them across alternatives. Under the Benchmark CAZ D scenario, users now face the additional cost of the CAZ charge and will therefore compare the net effect of all these supporting impacts, against the cost of the charge, and decide the appropriate course of action. This approach therefore should not only capture the utility change, but also the other impacts associated with changing behaviour and which are privately faced by the user.

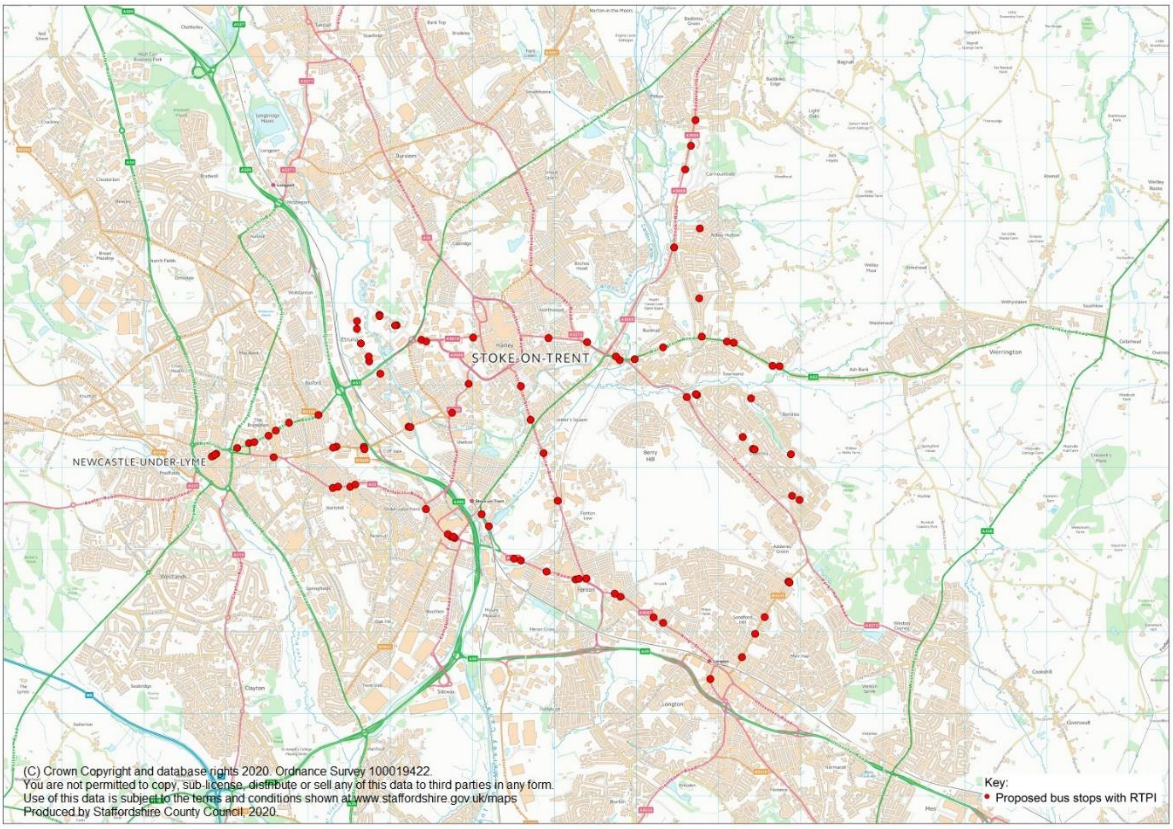
4.2.5 Bus Stop/RTPI/CCTV Improvements for the Preferred Option

SoTCC and SCC have proposed a range of interventions to the bus network infrastructure. The following interventions have been proposed and will be appraised as part of this economic assessment:

- Real time passenger information (RTPI) at bus shelters
- Addition of new shelters
- Accessible kerbs at bus stops
- Closed-circuit television (CCTV) cameras at bus shelters.

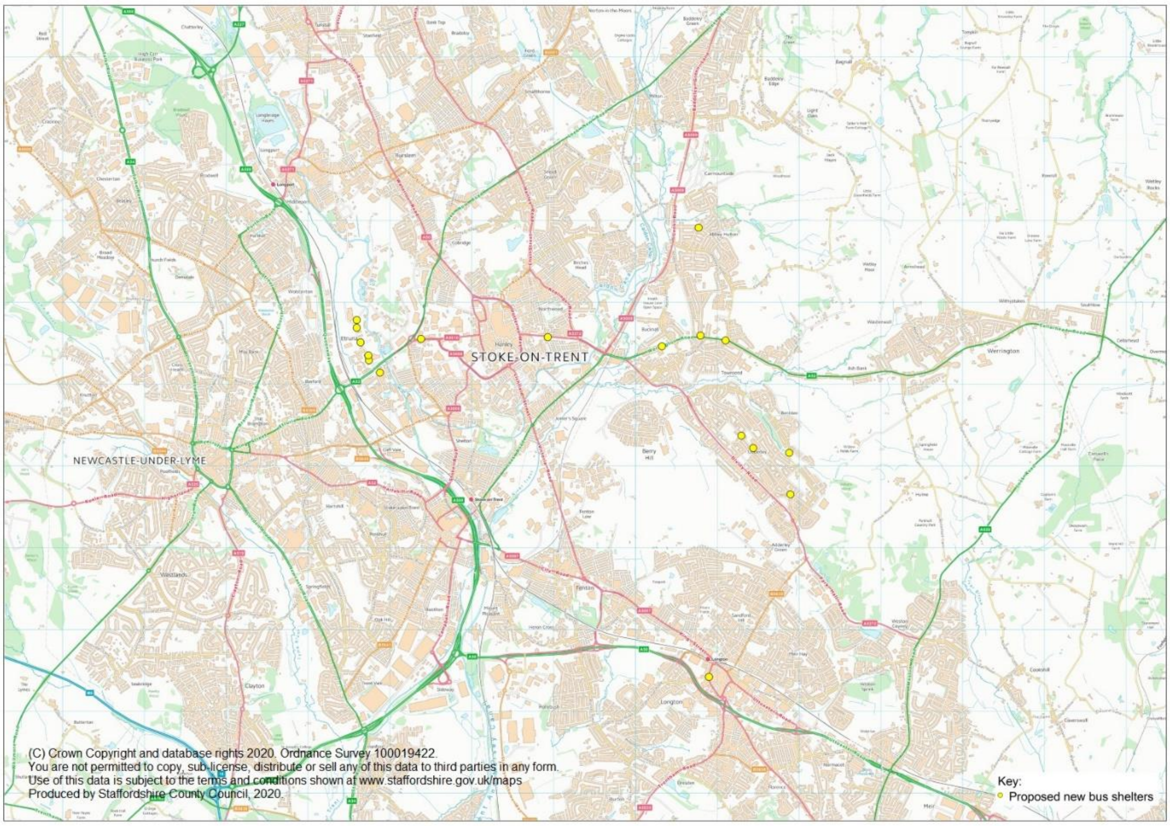
Bus stops with RTPI have been proposed for 89 locations within Stoke-on-Trent and for 12 locations within Staffordshire. A map of all proposed RTPI locations is shown in Figure 3 below.

Figure 3: Proposed RTPI bus stops within North Staffordshire



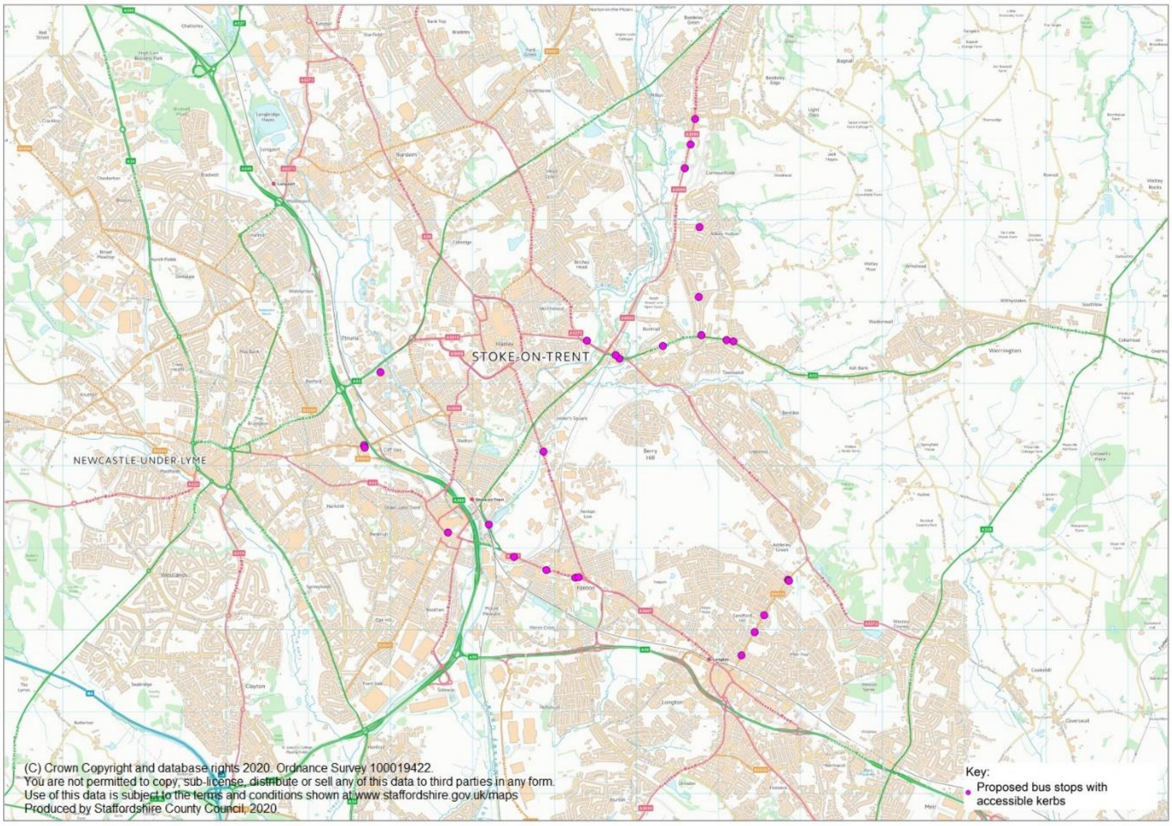
SoTCC have also proposed to add 17 new bus shelters, throughout Stoke-on-Trent. The location of the new bus shelters is shown below in Figure 4Figure 4.

Figure 4: Proposed locations of new bus shelters



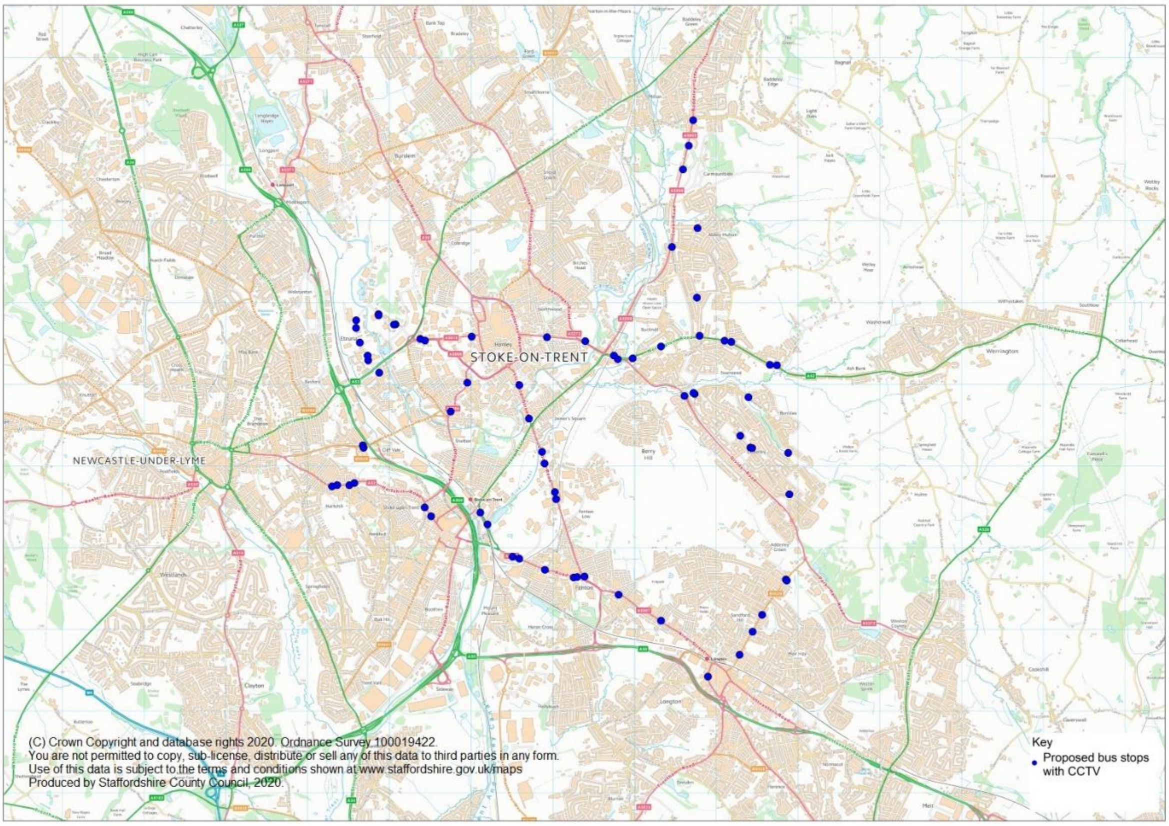
Accessible kerbs (Kassel kerbs) at bus stops have been proposed at 27 new locations as shown in Figure 5 Figure 5.

Figure 5: Proposed locations of bus stops with accessible kerbs



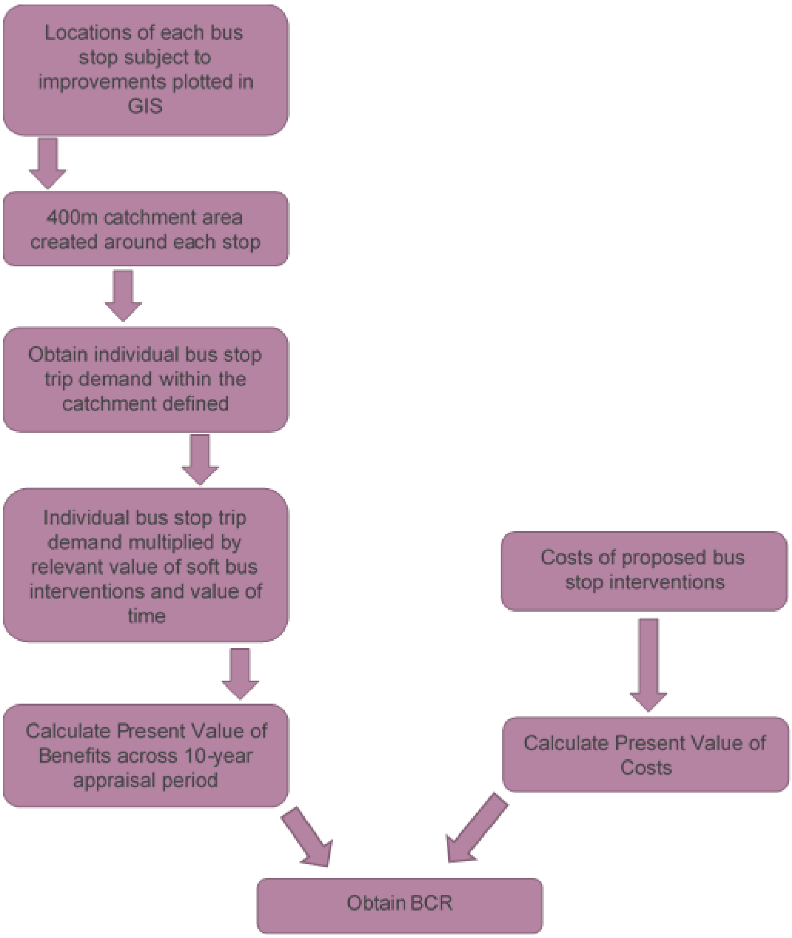
Finally, CCTV cameras at bus shelters has been proposed at 71 locations throughout Stoke-on-Trent, as shown in below in Figure 6.

Figure 6: Proposed locations of bus stops with CCTV



To be able to recognise the value for money of the proposed interventions, the methodology shown in Figure 7, was undertaken:

Figure 7: Appraisal methodology flow chart



The following assumptions have been used during the appraisal of the proposed interventions:

- Only origin trips (number of passengers boarding each bus stop) are assumed to benefit from the proposed interventions
- Trips are split by purpose according to default TAG values (May 2019 TAG Databook)
- Relevant values of time and values of soft bus interventions have been used from the latest TAG Databook (May 2019 TAG Databook)
- All monetary values are presented in 2018 prices and discounted to 2019 values
- The TAG M3.2.1 value for “New bus with low floor” has been used as a proxy for appraising accessible kerbs as there is no defined value for accessible kerbs
- The appraisal period is 10 years from the scheme opening year (2022) and includes an intermediate forecast year of 2025

Table 4-3 shows the present value of benefits and costs of all proposed interventions.

The combination of proposed interventions will generate a Present Value Benefit (PVB) of £34.8m and a Present Value Cost (PVC) of £3.12m across the 10-year appraisal period. This generates a BCR of 11.17, which according to the DfT’s Value for Money (VfM) framework is classed as very high value for money.

Table 4-3: Appraisal results of all proposed bus stop interventions

Benefits and Costs	£ (2018 Prices)
Present Value of Costs (PVC)	£3,119,434
Present Value of Benefits (PVB)	£34,844,455
NPV	£31,725,021
Benefit Cost Ratio (BCR)	11.17

4.2.6 Implementation Costs

Implementation costs have been calculated by Amey and are consistent with those presented in the Finance Case (albeit presented in a different price year and discounted for inclusion in the social CBA).

This captures all capex and opex required to implement the Preferred Option or the Benchmark CAZ D.

In addition, central optimism bias has been applied. Optimism bias is the proven tendency for appraisers to be too optimistic about project parameters including capital and operating costs. JAQU guidance suggests that optimism bias should be considered using The Green Book guidelines, which recommends applying overall percentage adjustments that vary depending on the type of project, and also depending on the stage of the project (reducing to a lower bound close to implementation).

For the options assessed, the optimism bias to apply was discussed with the Councils. For non-IT elements of the options, a central optimism bias of 15% is used based on TAG Unit A1.2 guidance for Stage 2 Road projects.

For implementation costs related to IT, a higher optimism bias of 105% is used given:

1) it is a midpoint between stage 1 and stage 3 as per TAG guidance for IT projects

2) the IT cost elements for the CAZ have been based on Birmingham's assumptions, which used an optimism bias of 100%. Uncertainty related to optimism bias for this project can therefore not be lower than 100%.

Table 4-4: Implementation Costs (£k 2018 price year, Discount year 2019, incl. optimism bias)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Preferred Option	10,124	451	451	451	451	749	451	451	451	451
Total	14,482									
Benchmark CAZ D	63,109	14,412	14,412	14,412	14,412	20,158	14,412	14,412	14,412	14,412
Total	198,561									

Bus retrofit costs in the Preferred Option will also comprise part of the implementation costs and hence are included. The upfront capex figures were provided by the Councils. Given retro-fit implies a change in lifetime of those buses (retrofitted buses must run for at least 5 years following retrofit), this measure will also have wider associated effects. To capture all upfront and VOC impacts of the bus retrofit, the CAZ economics model was used. In addition to the capital cost of retrofits themselves, the retrofits delay the purchase of new vehicles, unlike the Benchmark CAZ D which brings them forwards. This means the upgrade costs are less significant, and there is a greater cost associated with increased fuel and operating costs from extending the life of older buses (See Section 4.2.3).

4.3 TUBA - Travel Time, Fuel and Non-Fuel Vehicle Operating Costs, and CO_2 emissions (non-upgrade responses)

The impacts of the Preferred Option and Benchmark CAZ on travel times and vehicle operating costs have been assessed using the DfT's Transport User Benefits Appraisal (TUBA) program v1.9.13.

TUBA estimates the monetised impacts of transport schemes in terms of the costs and benefits experienced by users and providers of the transport system, and the associated indirect taxation revenue impacts. These costs and benefits are estimated by comparing transport conditions in the Do-Something (With Scheme) with those in Do-Minimum (Without Scheme) scenarios. To this end, TUBA uses information from transport models to:

- Calculate user benefits by vehicle type and for each element of journey cost (such as travel time and vehicle operating costs - fuel and non-fuel)
- Calculate the changes in the indirect tax income received by the government
- Calculate the changes in the GHG (CO_2) emissions

For the economic assessment, the user and provider related costs and benefits in each year produced by TUBA were given in 2010 prices and discount year, with a factor taken from TAG guidance to convert to a 2018 price base year and 2019 discount year, as per JAQU guidance. These factors are presented in Table 4-5.

Table 4-5: Conversion factors

	Conversion factors from 2010 prices and values
2018 Price Base Year	1.145
2019 Discount Year	1.363

TUBA provides a complete set of default economic parameters in its standard economics file, including values for variables such as values of time, vehicle operating cost data, tax rates and economic growth rates which have been used for this appraisal.

4.3.1 Modelled Years

The scheme related parameters defined in the TUBA scheme file were largely determined by the assumptions made in the derivation of appropriate traffic forecasts for the North Staffordshire Local Air Quality Plan; namely:

- First year – 2022 (scheme opening year).
- Last year – 2031 (10 years from opening year).
- Modelled forecast years – opening year of 2022 and intermediate forecast year of 2025

4.3.2 Time Periods and Annualisation Factors

The NSMM transport model represents single peak hours for the AM, Inter-Peak and PM and therefore there is the need to expand these single peak hours. Expansion factors have thus been derived to convert these peak hours to time slices / periods as required within TUBA.

The expansion factors have been derived from extensive traffic count information collected across the North Staffordshire conurbation. Observed traffic count information from neutral months were compared with average observed traffic count information for the whole year.

For the Benchmark CAZ scenario, the peak hour to TUBA time slice expansion factors were converted to annualisation factors based on 365 days per year. There was also the need to include the non-modelled off-peak (19:00 – 07:00hrs) within the TUBA assessment[15]. The similarity between the traffic in the inter-peak compared to that in the off-peak, allowed for the inter-peak model to be used when deriving off-peak user benefits within TUBA. This approach for the Benchmark CAZ was taken to ensure that the benefits of the scheme are directly comparable to the cost and revenue[16] due to the nature of the CAZ being operational 24hrs a day 365 days per year.

For the Preferred Option scenario, the peak hour to TUBA time slice expansion factors were converted to annualisation factors based on 253 working days per year. The off-peak and weekend have not been considered within the Preferred Option TUBA assessment because the impacts occurring in these periods are likely to be minimal due to the Preferred Option measures not being in place during these periods, apart from bus retrofitting.

The resultant annualisation factors are summarised in Table 4-6.

Table 4-6: Annualisation factors for TUBA time slices

Period	Modelled Peak-Hour	TUBA Time Slice	Peak-Hour to TUBA Time Slice Factor	No. of days	Annualisation Factor
Benchmark CAZ					
AM	08:00 - 09:00hrs	07:00 - 10:00hrs	2.131	365	778
Inter-Peak	14:00 - 15:00hrs	10:00 - 16:00hrs	5.693	365	2078
PM	17:00 - 18:00hrs	16:00 - 19:00hrs	2.400	365	876
Off-Peak	Based on Inter-Peak	19:00 - 07:00hrs	2.954	365	1078
Preferred Option					
AM	08:00 - 09:00hrs	07:00 - 10:00hrs	2.605	253	659
Inter-Peak	14:00 - 15:00hrs	10:00 - 16:00hrs	5.826	253	1474
PM	17:00 - 18:00hrs	16:00 - 19:00hrs	2.696	253	682

4.3.3 User Classes

Eight TUBA User Classes were specified as follows:

- User Class 1: Car compliant, all purposes, all person-types.
- User Class 2: Car non-compliant, all purposes, all person-types.
- User Class 3: Taxi compliant, business, all person-types.
- User Class 4: Taxi non-compliant, business, all person-types.

[15] Weekend and bank holidays have not been explicitly modelled, these time slices are included within the AM, IP, PM and OP annualisation factors presented.
[16] The peak hour to TUBA time slice factors used for the Benchmark CAZ TUBA assessment are identical to those used within the revenue calculations.

- User Class 5: Light Goods Vehicles (LGVs) compliant, all purposes, all person-types.
- User Class 6: Light Goods Vehicles (LGVs) non-compliant, all purposes, all person-types.
- User Class 7: Heavy Goods Vehicles (HGVs/OGVs) compliant, business, all person-types.
- User Class 8: Heavy Goods Vehicles (HGVs/OGVs) non-compliant, business, all person-types.

The data input into TUBA comprised of trip, average travel time and average travel distance matrices. These matrices were produced for each combination of the three modelled time periods, eight user classes and two forecast years for both the do-Minimum and do-Something scenarios.

Vehicle occupancies have been based on TUBA default values for all vehicle and user class types.

It should be noted that changes in public transport benefits have not been included within the assessment due to the nature of how these trips are represented and treated within the NSMM transport model. The NSMM transport model treats public transport trips as trip chains, thus a combination of walking, bus and rail trips without separating them. Therefore, it is not possible to extract data only relating to bus trips that are required for TUBA.

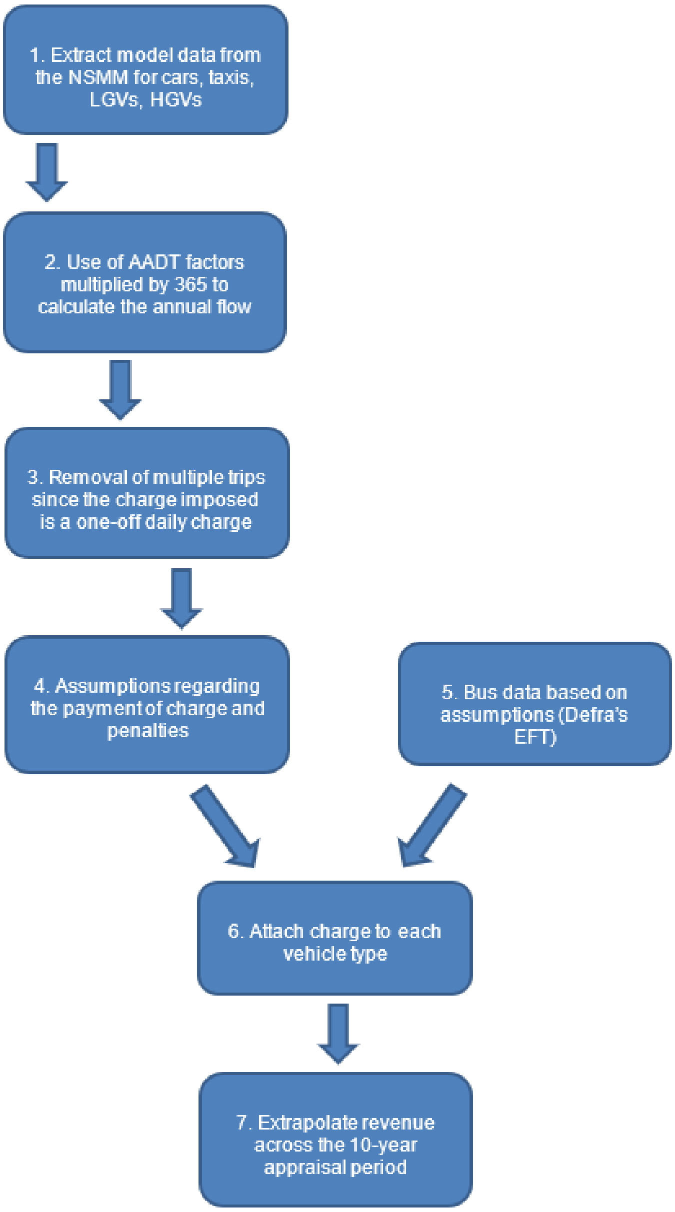
4.4 CAZ Charges and Revenues

Revenues from the Benchmark CAZ D have been calculated. This analysis is underpinned by the following:

- All impacts are presented in real terms in a 2018 price base year.
- All impacts are assessed over a 10-year appraisal period from 2022-2031.
- All impacts are discounted to 2019 applying a discount factor of 3.5%.
- All impacts are corrected to market prices.

The stages and process followed for the calculation of revenue is presented in Figure 8.

Figure 8: Revenue calculation



The Benchmark CAZ D includes a bounded area where charges will be levied on all non-compliant vehicles.

Step 1: Extract Model Data

Model data has been extracted from the NSMM transport model for the years 2022 and 2025. The NSMM model provided the traffic flows for cars, taxis, LGVs and HGVs for the modelled time periods of AM, IP and PM.

Step 2: Calculate annualised flow

The private car vehicle type data was segmented by income into three categories in order to reflect how demand responses to a CAZ charge varies by household income. The three income ranges were chosen to reflect an evenly distributed demand across the groups as recommended in the TAG. These are:

- Income Band 1: £0 - £20,000.
- Income Band 2: £20,000 - £40,000.
- Income Band 3: > £40,000.

Behavioural responses were derived from the statistical models based on SP survey data and used to model the future behavioural patterns of users in response to a CAZ charge. In order to calculate the journey purpose splits for work and non-work travel, the split factors as per TAG Data Book – Table A 1.3.4 (Percentage of Vehicle Trips) were used. These behavioural responses and split factors are outlined in Table 4-7.

Table 4-7: Purpose split factors

Split Factors					
Mode	**Trip Purpose**	**Time Slice**			
		AM	**IP**	**PM**	**OP**
Car	Business	7.0%	7.2%	5.1%	4.3%
	Commuting	38.3%	11.3%	32.6%	28.8%
	Other	54.7%	81.5%	62.3%	66.9%
LGV	Personal	12.0%	12.0%	12.0%	12.0%
	Freight	88.0%	88.0%	88.0%	88.0%

The factors used to convert the modelled time periods to average annual equivalents are the following,

- $AM = 2.131 * 365 \Rightarrow AM = 778$
- $IP = 5.693 * 365 \Rightarrow IP = 2078$
- $PM = 2.400 * 365 \Rightarrow PM = 876$
- $OP = 2.954 * 365 \Rightarrow OP = 1078$

It should be noted that the off-peak time period was not included in the model and thus, inter-peak traffic data was used to simulate off-peak. Factors have been derived from traffic count data across the year.

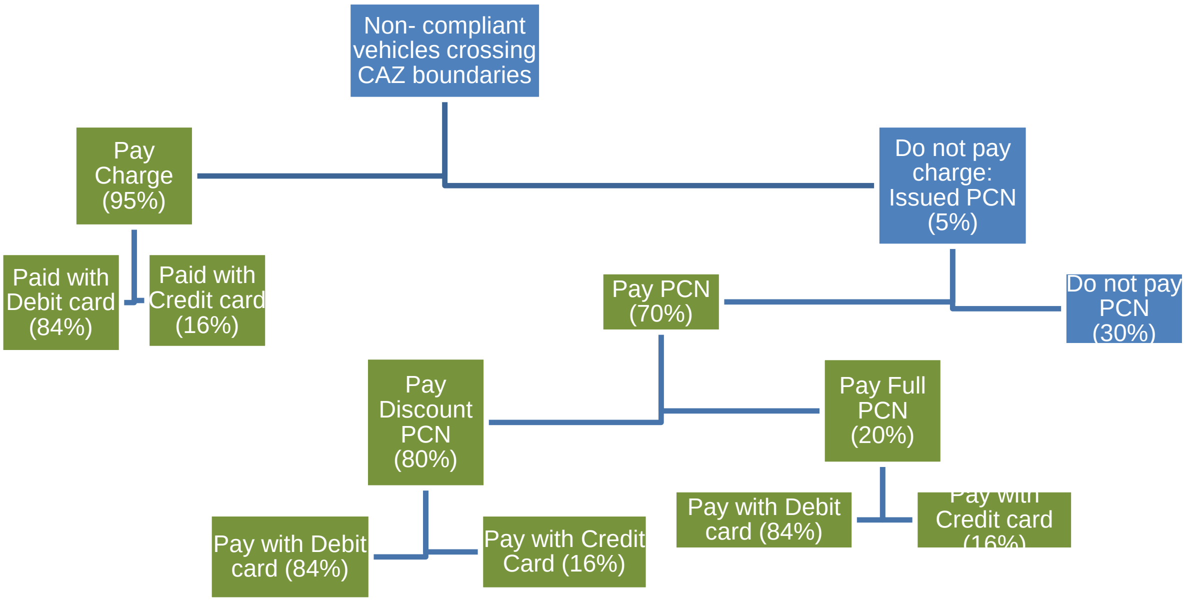
Step 3: Removal of multiple cross-boundary trips

Trips crossing the CAZ boundaries more than once have been removed since the charge imposed is a one-off daily charge. The removal of the multiple trips has been based on the origin/destination (OD) matrices provided from the NSMM transport model.

Step 4: Payment and Revenue Assumptions

The calculation of Benchmark CAZ D revenue was based on the assumptions represented in Figure 9.

Figure 9: Benchmark CAZ D charge revenue assumptions



The proportion of non-compliant vehicle owners that enter, exit or move within the boundaries without paying the daily charge will be subject to a penalty charge notice (PCN), which accounts for £60 if paid within 14 days or £120 if paid after this time period. Table 4-8 shows the penalty charges per vehicle type.

Table 4-8: Penalty charge per vehicle type

Mode	Penalty Charge	
	Discounted	Full
Car	£60.00	£120.00
Taxi	£60.00	£120.00
LGV	£60.00	£120.00
HGV	£60.00	£120.00
Bus	£60.00	£120.00

Users can pay this penalty as well as the daily CAZ charge either through a debit or a credit card. The card processing fees are shown in Table 4-9. The local authorities are expected to cover the cost of these fees and so this has been deducted from the overall revenue generated from the CAZ. Subsequently, the cost of the CAZ charge to the user differs from the revenue generated to the local authority.

Table 4-9: Card payment fees

Payment Card	Card Payment Fee
Debit Card	Charge * 0.45% + £0.11
Credit Card	Charge * 0.78% + £0.11

Step 5: Bus data

The bus fleet composition has been based on assumptions rather than model data. From the total current bus fleet, Sweco have calculated that 51% of vehicles are non-compliant in 2022 while in the year 2025, that percentage has been presumed to drop to 26% according to the Defra Emission Factors Toolkit (EFT) - due to the upgrade of a proportion of bus vehicles to compliancy.

Stage 6: Calculate charges

Table 4-10 notes the proposed daily charge for each non-compliant vehicle, by vehicle type, entering, exiting or moving within the CAZ boundary. These charges are based on the results of the statistical models developed using the SP data and are set at a point where a rising CAZ charge gives the greatest positive return. In addition, a comparison with the CAZ charges proposed in Bath and Birmingham was undertaken and consideration made on the basis that in comparison, North Staffordshire is a comparatively poorer region.

Table 4-10 Benchmark CAZ D charge by vehicle type

Vehicle Type	Benchmark CAZ D charge (including VAT)
Car	£5.00
Taxi	£5.00
LGV	£9.00
HGV	£35.00
Bus	£5.00

Stage 7: Extrapolate over ten-year appraisal period

Through the ten-year appraisal period, it is expected that due to a greater amount of non-compliant vehicles in the early years of the charging CAZ's operation, the revenue generated from these charges will be high. This revenue will gradually decline over time as more and more vehicle owners upgrade their vehicles to achieve compliancy. It has been assumed that revenue in the year 2031 will be £0, as this is when decommissioning will commence.

The charge to the user can be noted in Table 4-11 while the total estimated revenue generated from the Benchmark CAZ D is represented in Table 4-12. It is worth noting that the revenue calculated and presented is estimated for 2022 to ensure consistency with the traffic model and across the economic analysis, even though in reality the CAZ is likely to not open until 2023.

Table 4-11: Benchmark CAZ D cost to the user (£m)

Annualised Cost to User (£millions)									
	Car			**Taxi**	**LGV**		**HGV**	**Bus**	
Year	**Business**	**Commuting**	**Other**		**Personal**	**Freight**			**Total**
2022	£1.35	£7.17	£17.15	£0.01	£2.06	£13.16	£1.95	£0.16	£43.00
2023	£1.18	£6.25	£14.97	£0.01	£1.86	£11.92	£1.42	£0.13	£37.75
2024	£1.02	£5.39	£12.91	£0.01	£1.68	£10.76	£0.92	£0.10	£32.79
2025	£0.87	£4.59	£10.98	£0.01	£1.51	£9.66	£0.46	£0.07	£28.13
2026	£0.70	£3.69	£8.84	£0.00	£1.22	£7.78	£0.37	£0.06	£22.65
2027	£0.54	£2.85	£6.83	£0.00	£0.94	£6.01	£0.28	£0.04	£17.51
2028	£0.39	£2.07	£4.95	£0.00	£0.68	£4.36	£0.21	£0.03	£12.69
2029	£0.25	£1.33	£3.19	£0.00	£0.44	£2.81	£0.13	£0.02	£8.17
2030	£0.12	£0.64	£1.54	£0.00	£0.21	£1.36	£0.06	£0.01	£3.95
2031	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00

(Discounted impact (PV) from 2022-31, 2018 prices, discounted to 2019, in market prices)

Table 4-12: Benchmark CAZ D revenue to the Local and central Government (£m)

Annualised Revenue to LA (£millions)									
	Car			Taxi	LGV		HGV	Bus	
Year	Business	Commuting	Other		Personal	Freight			Total
2022	£1.33	£7.03	£16.84	£0.01	£2.03	£12.96	£1.94	£0.15	£42.29
2023	£1.16	£6.14	£14.70	£0.01	£1.84	£11.75	£1.41	£0.12	£37.12
2024	£1.00	£5.30	£12.68	£0.01	£1.66	£10.60	£0.91	£0.09	£32.25
2025	£0.85	£4.50	£10.78	£0.01	£1.49	£9.51	£0.45	£0.07	£27.66
2026	£0.68	£3.62	£8.68	£0.00	£1.20	£7.66	£0.36	£0.06	£22.27
2027	£0.53	£2.80	£6.71	£0.00	£0.93	£5.92	£0.28	£0.04	£17.21
2028	£0.38	£2.03	£4.86	£0.00	£0.67	£4.29	£0.20	£0.03	£12.47
2029	£0.25	£1.31	£3.13	£0.00	£0.43	£2.76	£0.13	£0.02	£8.04
2030	£0.12	£0.63	£1.51	£0.00	£0.21	£1.34	£0.06	£0.01	£3.88
2031	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00

(Discounted impact (PV) from 2022-31, 2018 prices, discounted to 2019, in market prices, £)

4.5 No Upgrade Sensitivity

It is recommended by JAQU that a behavioural response sensitivity test should be tested through a scenario in which 0% of vehicle users upgrade as a result of the CAZ. This scenario has been modelled in the transport model (refer to the T2 report for details on the modelling) and subsequently run through TUBA to understand the implications of such a behavioural response on the economics. The results of this sensitivity are reported in Section 6.1.

5 Results

5.1 Summary of results

The results of the economic analysis are summarised in Table 5-1 and Figure 10.

Figure 10: PV of impacts and NPV of Preferred Option and Benchmark CAZ D (£m 2018 prices)

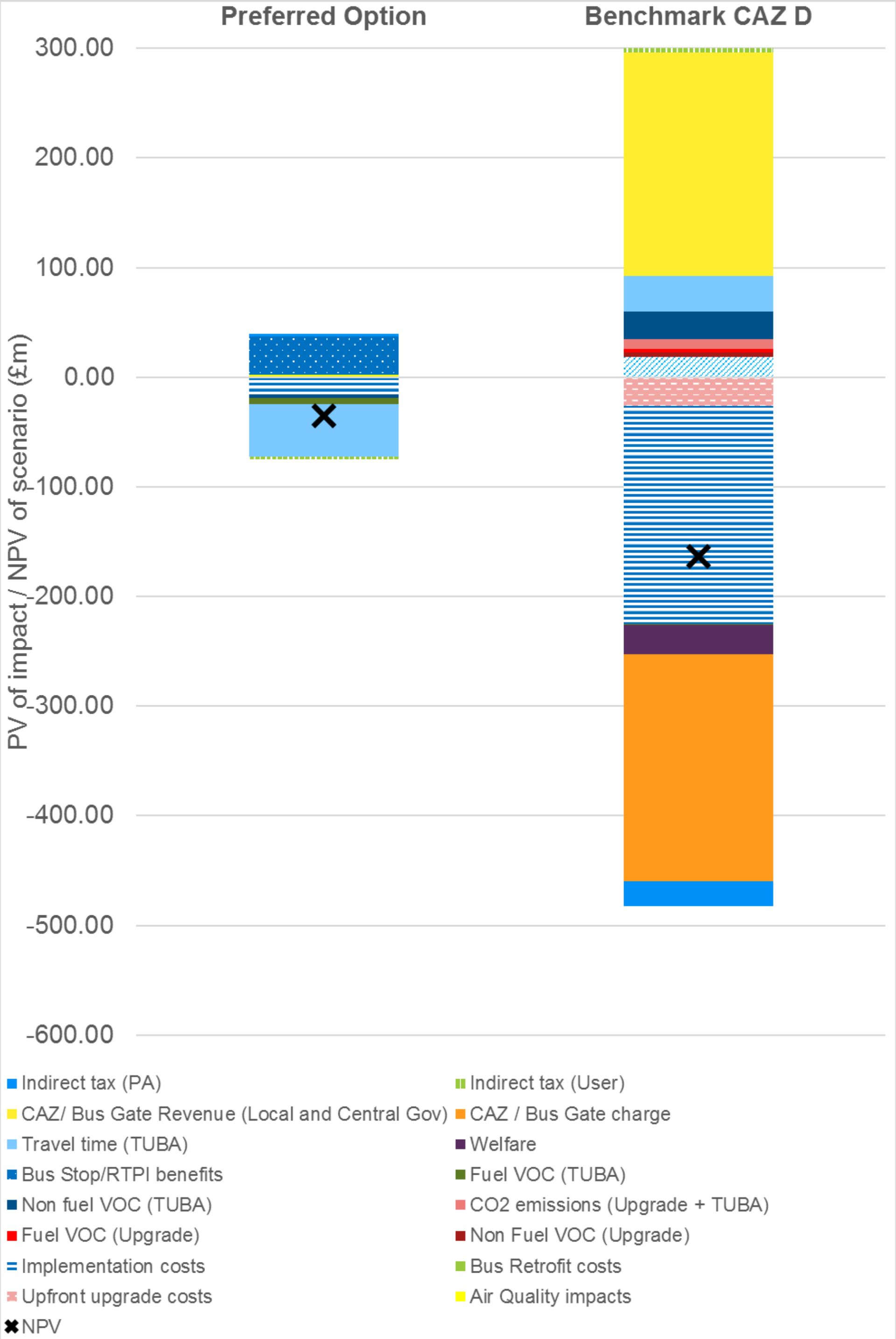


Table 5-1: Monetised impacts for Preferred Option and Benchmark CAZ D (£m)

	Preferred	Benchmark CAZ D
AQ impacts	£2.34	£18.87
Upgrade costs	£-	-£26.40
Bus Retrofits	-£0.77	£-
Implementation costs	-£14.48	-£198.56
Non-fuel VOC (Upgrade)	£-	£4.09
Fuel consumption (Upgrade)	£-	£3.13
CO_2 emissions (Upgrade and TUBA)	-£0.52	£8.45
Non fuel VOC (TUBA)	-£3.37	£25.15
Fuel VOC (TUBA)	-£4.99	-£0.78
Bus Stop/RTPI	£34.84	£-
Welfare	£-	-£27.05
Travel time (TUBA)	-£48.26	£32.99
CAZ Charge/ Bus Gate Charge	-£0.40	-£206.64
CAZ Revenue/ Bus Gate Charge Revenue	£0.40	£203.19
Indirect tax (User)	-£2.27	£23.40
Indirect tax (Public Administration)	£2.27	-£23.40
NPV	**-£35.22**	**-£163.56**

Notes: +ve values denote benefit / -ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2019; cumulative discounted impact (PV) and NPV from 2022-31 (10-year appraisal period)

5.2 Impact comparison

Air Quality Impacts

- Both policy options show a benefit in health improvements caused by reduced emissions of air pollutants.
- The benefits of the Benchmark CAZ D are significantly greater than those of Preferred Option (£18.87m and £2.34m respectively).

Costs and Benefits associated with vehicle upgrades in the Benchmark CAZ D

- The Benchmark CAZ D is associated with high vehicle upgrade costs (£26.4m over the 10 year appraisal period) which outweigh additional benefits in fuel (£3.13), non-fuel VOC (£4.09m) and CO_2 (£3m - Note value in table includes TUBA CO_2 benefits) benefits associated with the vehicle upgrades.
- There are no upgrade costs associated with Preferred Option given no vehicles are anticipated to upgrade in response to this measure. That said, there is a small additional cost associated with bus retrofits.

Implementation costs

- The implementation costs are far greater in the Benchmark CAZ D scenario (£198.56m) compared with Preferred Option (£14.48m), which has a large impact on the overall NPV of this option.

Welfare costs under Benchmark CAZ D

- The welfare costs represent the costs associated with individuals not being able (or not choosing) to travel into the CAZ zone who otherwise would do, i.e., people that cancel their trip.

- The Benchmark CAZ D is associated with a large welfare impact associated with cancelled trips, valued at £27.05m over the 10-year appraisal period.
- The welfare impact is assumed to be half the cost of entering the zone.

Additional trip costs (captures impacts associated with non-upgrade responses, i.e. changes in travel time, fuel and non-fuel VOC and CO_2)

- Outputs from the TUBA modelling show a large benefit in the Benchmark CAZ D option associated with non-fuel vehicle operating costs (£25.15m) and travel time (£32.99m).
    - This occurs due to reduced congestion and improved trip times for vehicles travelling in the CAZ zone as some non-compliant vehicles re-route or cancel journeys in the CAZ area. Although non-compliant vehicles that choose to reroute face a disbenefit of increased travel time and non-fuel vehicle operating cost, the benefit to vehicles continuing to travel inside the CAZ outweighs the disbenefit to non-compliant.
- Conversely, for the Preferred Option the TUBA outputs indicate an increase (or disbenefit) in fuel vehicle operating costs (£5.0m), non-fuel vehicle operating costs (£3.4m) and particularly travel time (£48.26m).
    - This is due to rerouted trips that occur during the peak periods when the bus gates are in operation. Unlike under the Benchmark CAZ D, where charges are faced by non-compliant vehicles, the road closures affect all cars, LGVs and HGVs, irrespective of compliance.

Bus infrastructure improvements

- Deliver a significant benefit under the Preferred Option (£34.84m)

CAZ and PCN charges and revenues, and indirect taxes

- CAZ charges and revenues under the Benchmark CAZ D are the most significant impacts in the CBA. However, given the charge is a cost to users, and the revenue a benefit to Public Administration, these impacts mostly net off (save for a slight difference due to transaction costs of paying the charges).
- Bus gate (PCN) charges under the Preferred Option are significantly smaller, but again net off as a cost to user but revenue benefit to Public Administration
    - IN practice, there will be a transaction cost to these revenue flows through credit and debit card charges, so in practice these flows will not precisely net off between users and government accounts. These transaction costs are not currently reflected for bus gate charges (but are reflected for CAZ charges)
- Conversely, indirect taxes have an opposite and equal impact on users and for Public Administration, but again these impacts net off in the overall CBA.

6 Sensitivity analysis

Economic modelling approximates the real world and it is inevitable that there will be uncertainty around the inputs that form the model. Failing to accurately predict future states of the world, using input values developed in different locations or using expert judgement where no data is available are all potential sources of uncertainty in assumptions and input values. Those assumptions and input values where uncertainty is greater and potentially significant have been identified (i.e. could have a material effect on the results of the quantitative analysis and could affect the comparison of options).

To determine whether these uncertainties have a significant impact on the recommendations made in this report a sensitivity analysis was undertaken. The sensitivity analysis involves developing lower and upper bounds for significant assumptions and input values used in the analysis. If the recommendations stand up to this 'stress testing', the robustness of the analysis is confirmed.

The resultant NPV for each scenario is considerable but the difference in NPV between scenarios is relatively small. Therefore, it is critical that changes in assumptions and input values within sensible bounds do not change the recommendations.

The sensitivity analysis is constructed around the following key inputs:

- Behavioural responses to a charging zone – i.e. a 0% upgrade scenario under the Benchmark CAZ D
- Damage costs
- Carbon prices
- Scrappage costs
- Welfare impacts
- Optimism bias.

6.1 Behavioural Assumptions (Benchmark CAZ D only)

The behavioural assumptions define the response of vehicle owners to the implementation of the CAZ charge. The impacts of the CAZ will critically depend on the behavioural responses of transport users.

It is recommended by JAQU that behavioural response sensitivity be tested through a scenario in which 0% of vehicle users upgrade as a result of the CAZ. The behavioural responses of people to this scenario was derived from the statistical model created the Stated Preference survey data, by setting the upgrade to compliant option equal to zero while maintaining the same proportions for the other responses. These responses are represented in Table 6-1.

Table 6-1: Behavioural demand responses by vehicle type to Benchmark CAZ D charges in the No upgrade scenario

Demand response	Car			LGV	HGV	Taxi
	Income Band					
	1	2	3			
Change route	23%	20%	17%	47%	41%	0%
Change destination	16%	15%	12%	0%	0%	0%
Pay charge	27%	27%	27%	49%	44%	11%
Cancel trip / Mode shift	34%	38%	44%	4%	15%	89%

This scenario has been modelled in the transport and air quality models and impacts the economics through changes in air quality benefits, TUBA outputs on travel time, fuel and non-fuel operating costs as well as removing costs and secondary benefits associated with vehicle upgrades. The impact on the NPV of this scenario is shown in Table 6-2.

There is a large impact on NPV largely due to the removal of vehicle upgrade costs. Interestingly the NPV of the Benchmark CAZ D option becomes less negative. There is a reduction in upgrade costs and increase in travel time benefits (assumingly as more vehicles cancel trip and congestion in the CAZ area improves even more so). This impact outweighs the reduction in air pollutant and VOC benefits from upgrades and the increase in welfare costs associated with a higher level of cancelled trips.

This shows that while the results are highly sensitive to the behavioural response assumptions, it does not change the overall result, with the Benchmark CAZ D still having a more negative NPV than the Preferred Option.

Table 6-2: Sensitivity Analysis for Behavioural Response to the Benchmark CAZ D (£m 2018)

	Benchmark CAZ D		Benchmark CAZ D 0% Upgrade	
AQ impacts	£	2.34	£	14.11
Upgrade costs	£	-	£	-
Bus retrofits	-£	0.77	£	-
Implementation costs	-£	14.48	-£	198.56
Non-fuel VOCs (Upgrade)	£	-	£	-
Fuel consumption (Upgrade)	£	-	£	-
CO_2 emissions (Upgrade and TUBA)	-£	0.52	-£	0.52
Non fuel VOC (TUBA)	-£	3.37	£	47.62
Fuel VOC (TUBA)	-£	4.99	£	0.83
Bus Stop/RTPI	£	34.84	£	-
Welfare	£	-	-£	53.89
Travel time (TUBA)	-£	48.26	£	81.01
CAZ Charge	-£	0.40	-£	391.49
CAZ Revenue	£	0.40	£	385.02
Indirect tax (User)	-£	2.27	£	42.05
Indirect tax (Public Administration)	£	2.27	-£	42.05
NPV	-£	163.56	-£	115.88

The annualised cost to users as well as the annualised revenue generated from the no upgrade scenario were based on the same assumptions used for the Benchmark CAZ D scenario and are shown in Table 6-3 and Table 6-4, respectively.

Table 6-3: Annualised Cost to User derived from the No upgrade scenario (£m)

Annualised Cost to User (£m)									
	Car			Taxi	LGV		HGV	Bus	
Year	Business	Commuting	Other		Personal	Freight			Total
2022	£2.56	£13.56	£32.45	£0.03	£3.73	£23.88	£6.49	£0.16	£82.86
2023	£2.24	£11.83	£28.32	£0.03	£3.36	£21.51	£4.77	£0.13	£72.18
2024	£1.93	£10.20	£24.43	£0.02	£3.01	£19.27	£3.17	£0.10	£62.13
2025	£1.64	£8.68	£20.77	£0.02	£2.68	£17.16	£1.66	£0.07	£52.68
2026	£1.32	£6.99	£16.72	£0.02	£2.16	£13.81	£1.34	£0.06	£42.41
2027	£1.02	£5.40	£12.93	£0.01	£1.67	£10.68	£1.03	£0.04	£32.78
2028	£0.74	£3.91	£9.37	£0.01	£1.21	£7.74	£0.75	£0.03	£23.76
2029	£0.48	£2.52	£6.03	£0.01	£0.78	£4.98	£0.48	£0.02	£15.30
2030	£0.23	£1.22	£2.91	£0.00	£0.38	£2.41	£0.23	£0.01	£7.39
2031	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00

(Discounted impact (PV) from 2022-31, 2018 prices, discounted to 2019, in market prices)

Table 6-4: Annualised Revenue to Local and central Government in the No Upgrade scenario (£m)

Annualised Revenue to LA (£m)									
	Car			Taxi	LGV		HGV	Bus	
Year	Business	Commuting	Other		Personal	Freight			Total
2022	£2.51	£13.31	£31.86	£0.03	£3.68	£23.53	£6.44	£0.15	£81.51
2023	£2.19	£11.61	£27.80	£0.03	£3.32	£21.19	£4.73	£0.12	£71.00
2024	£1.89	£10.02	£23.98	£0.02	£2.97	£18.98	£3.14	£0.09	£61.10
2025	£1.61	£8.52	£20.39	£0.02	£2.65	£16.90	£1.65	£0.07	£51.80
2026	£1.29	£6.86	£16.42	£0.02	£2.13	£13.61	£1.33	£0.06	£41.71
2027	£1.00	£5.30	£12.69	£0.01	£1.65	£10.52	£1.03	£0.04	£32.24
2028	£0.72	£3.84	£9.19	£0.01	£1.19	£7.62	£0.74	£0.03	£23.36
2029	£0.47	£2.47	£5.92	£0.01	£0.77	£4.91	£0.48	£0.02	£15.05
2030	£0.23	£1.20	£2.86	£0.00	£0.37	£2.37	£0.23	£0.01	£7.27
2031	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00

(Discounted impact (PV) from 2022-31, 2018 prices, discounted to 2019, in market prices)

6.2 Damage costs

The economic costs associated with air quality are driven by the damage costs supplied by JAQU. The damage costs applied in this case are those for 'urban big' and are applied to all PM and NO_X emissions reductions for the Preferred Option and Benchmark CAZ D. This is not a value that has been tailored to the circumstances in North Staffordshire – hence, this is one source of uncertainty. Furthermore, there are underlying uncertainties in the methodologies and techniques used to construct the damage costs (e.g. impacts included, valuation of endpoints, etc.) which should be reflected in the analysis.

Upper and lower bound damage costs are taken from the UK Air Quality damage cost update 2019[17].

This analysis demonstrates that both scenarios are sensitive to damage costs, particularly the Benchmark CAZ D due to the larger air quality reductions that are valued. Although the results are sensitive to damage costs the relative weighting of the options remains unchanged, with the Preferred Option retaining a significantly less negative NPV.

Table 6-5: Damage Cost Sensitivity analysis - NPV result (£m 2018 prices)

	Sensitivity	Preferred Option	Benchmark CAZ D
Damage cost	Low	-37.25	-179.53
	Central	-35.22	-163.56
	High	-29.15	-117.62

6.3 Carbon Price

The carbon price is used to value the climate-mitigation benefits of reducing Greenhouse Gas emissions as an indirect effect of the air quality measures. The carbon price is based on the BEIS guidance, and rapidly increases in the study period opposed to the relatively stagnant development of real-world carbon prices in the preceding decade. BEIS guidance provides low and high prices for carbon which are applied to both CO_2 impacts from vehicle upgrades and from the TUBA analysis. The results are shown in Table 6-6 and reveal that the results are not very sensitive to carbon prices.

Table 6-6 – Carbon price sensitivity analysis – NPV result (£m 2018 prices)

	Sensitivity	Preferred Option	Benchmark CAZ D
Carbon price	Low	-34.92	-168.12
	Central	-35.22	-163.56
	High	-35.51	-158.99

6.4 Welfare costs (rule of half, Benchmark CAZ D only)

The welfare costs are calculated through taking half of the charge which users who avoid/cancel their trip would pay to enter the CAZ. This 'rule of half' assumption can be tested by assuming either no 'halving' and having all cancel/avoid actions be worth the full charge value and having no welfare costs at all. While this has a notable effect on the overall NPV of the Benchmark CAZ D option, this sensitivity is not high enough to change the relative comparison of the two options, with the Preferred Option still having a substantially less negative NPV.

[17] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1902271109_Damage_cost_update_2018_FINAL_Issue_2_publication.pdf

Table 6-7 - Welfare sensitivity analysis – NPV result (£m 2018 prices)

	Sensitivity	Benchmark CAZ D
Welfare cost	Low 0%	-136.51
	Central 50%	-163.56
	High 100%	-190.6

6.5 Scrappage costs and Vehicle upgrade assumptions (Benchmark CAZ D only)

If vehicles are scrapped as a result of any proposed policies, the impacts of this will depend on vehicle values, depreciation rates and counterfactual upgrade assumptions. All of these values could be very uncertain. JAQU's guidance suggests three sensitivities could be tested:

1. Adjust the fixed assumption on the proportion of 'upgraded' vehicles that are scrapped: The CAZ charge could cause the value of a non-compliant vehicle to depreciate by less, leading to less vehicles to be scrapped and vice versa. Range tested 20 to 30% vehicles scrapped
2. Adjust the values of the vehicles: Higher vehicles values lead to an increase in scrappage cost and vice versa. Range tested +/- 10% on vehicle values
3. Adjust depreciation rates: If the value of a vehicle falls more quickly, then the cost of scrapping this vehicle will reduce more quickly too.

From previous CAZ work, of these impacts only the adjustment of the scrappage behavioural response had a significant effect on results, and as such this has been tested also in this study. The impact of this sensitivity analysis is shown to be small on the overall NPV for the Benchmark CAZ D as shown in Table 6-8.

Table 6-8: Scrappage value sensitivity analysis - NPV result (£m 2018 prices)

	Sensitivity	Benchmark CAZ D
Scrap Proportion	Low 20%	-155.06
	Central 25%	-163.56
	High 30%	-178.16

6.6 Optimism bias

Optimism bias represents a systematic tendency for appraisers to be overly optimistic in their assessment of schemes, in particular regarding the costs (and time) associated with implementing a policy. An adjustment for optimism bias has already been included in the estimation of implementation costs. This is the most important adjustment and, hence, has been included as part of the core analysis given costs have been estimated directly for scheme implementation.

As a sensitivity, we vary the adjustment for optimism bias. TAG provides an upper and lower bound for optimism bias to be used.

- For non-IT elements, a lower bound of 3% and an upper bound of 44% is used.
- For IT elements, a lower bound of 10% and an upper bound of 200% is used.

The results are presented in Table 6-9. Adjusting for this does not provide a significant change in NPV for either option, although there is more of an effect on Benchmark CAZ D due to higher implementation costs.

Table 6-9: – Optimism bias sensitivity analysis - NPV result (£m 2018 prices)

	Sensitivity	Preferred Option	Benchmark CAZ D
Optimism bias	Low	-33.69	-87.13
	Central	-35.22	-163.56
	High	-38.87	-246.4

6.7 Conclusion

Although the sensitivity analysis shows that the NPV of each option is sensitive to the assumptions, it demonstrates that the uncertainty around parameters does not influence the relative comparison of the options in terms of NPV.

However, there are several important conclusions to draw specific to each option:

- The Benchmark CAZ D is highly sensitive to assumptions on first order behavioural responses, due to the high upgrade costs in this option. However, even at a 0% upgrade assumption, the NPV of this option is still more negative than the Preferred Option.
- The Benchmark CAZ D is also more sensitive to damage costs due to the larger air quality impacts of this option, although as above this does not affect the overall relative comparison of the two options.
- Other sensitivities have generally lower impacts on both options and do not significantly change the NPVs.

7 Wider impacts

The approach has sought to quantify and monetise the impacts associated with the Preferred Option and the Benchmark CAZ D. However, in some cases due to limitations in data or methodologies available, it has not been possible to assess all impacts quantitatively. In this case, these impacts have instead been assessed qualitatively and the results are presented in this section.

Through the development of the methodology, a number of impacts were identified as being unquantifiable. Specially:

a) Air Quality impacts outside modelling domain
b) Active travel benefits
c) Noise / accidents / infrastructure effects associated with charging and non-charging measures

Further several impacts were identified as associated with the Benchmark CAZ D but were deprioritised for assessment as less significant effects. These include:

- Transaction costs: associated with upgrading vehicles.
- Welfare (utility) loss associated with upgrading vehicles.

These impacts are explored in detail below, and a summary is presented in Table 7-1.

a) Emissions impacts outside modelling domain from upgraded vehicles: Health benefits from reduced air pollutant emissions due to vehicle upgrades have been calculated using outputs of the transport and air quality modelling. In reality, there will also be benefits in air quality outside the modelled domain as vehicles travel outside of it, in particular those who upgrade in response to the Benchmark CAZ D. These will scale in line with the number of vehicles replaced.

The value of emissions impacts outside the modelled zone could be significant. However, there is downside risk here too. The majority of upgraded vehicles are swapped (i.e. sold as a used vehicle and replaced with a compliant used vehicle). Where these vehicles are relocated outside the CAZ domain but remain operational in the fleet, this would simply have the effect of displacing emissions elsewhere – emission reductions achieved in the CAZ area would be offset against increases in emissions in other places. This would reduce the overall emissions impacts of the Benchmark CAZ D, and as a consequence could also reduce improvements in health. By focusing only on the Stoke-on-Trent and Newcastle-under-Lyme urban area, the central case simply captures the benefits of emissions reductions in the CAZ and the surrounding area, and does not consider increases in emissions elsewhere, akin to assuming the swapped non-compliant vehicles either exit the fleet or are used in a way where there is no or only limited exposure to their emissions.

It is uncertain what will happen to non-compliant vehicles swapped in the analysis. At one extreme, if all non-compliant vehicles exit the fleet and/or are used in a way with no, limited, or at least lower exposure to emissions (e.g. in rural areas or a greater proportion of mileage on motorways), the air quality benefits could be several times greater than those in the central analysis. However, at the other extreme, if non-compliant vehicles are swapped and undertake similar mileage in a comparable urban centre, the emissions impacts could be much smaller (but so too arguably should be other effects[18]).

The actual result is likely to be somewhere between the two, and the central case may offer an appropriate central point – it does not capture potential additional benefits where non-compliant vehicles are scrapped and their full mileage replaced by new, compliant vehicles (i.e. the 25% scrapped), but it

[18] If we adopt this more 'UK-wide' view for emissions impacts, we probably also should do so for costs. Where a used non-compliant vehicle is swapped for a used compliant, this represents a cost in the economic model as the compliant vehicle is typically more expensive than the non-compliant. In practice, there will also be a net benefit for the owner on the other side of the transaction, which buys the cheaper non-compliant vehicle in replacement of the more expensive compliant vehicle, which is not captured in the model. Hence if the emissions (and wider operational) benefits are to be 'netted-off' in this way, so too would the upgrade costs.

does not also capture where non-compliant vehicles are sold as used and undertake mileage outside the CAZ.

This uncertainty will not affect the Preferred Option in the same way. The air quality modelling domain has been designed to capture re-routing effects so should capture all associated air quality impacts. The only upgrade response would occur in response to potential exemptions for ULEVs on the bus gates which may encourage greater take up of these vehicles, but the impact is likely to be marginal.

Hence the potential impacts for the Benchmark CAZ D will be greater due to the greater impact on vehicle upgrades.

b) Active travel benefits: Although active transport is not directly incentivised in either of the options, modal shift from personal car use to active travel through walking and cycling is a further impact. According to transport modelling approximately 14,600 vehicles users will switch from private car to either walking, cycling or bus travel. Active travel has health benefits through reduction in all-cause mortality but will also have an impact through increased accidents. These effects have not been monetised as they are likely to be small and are covered in more detail in the Health Impact Assessment (HIA) included in the E3 Report.

c) Noise / accidents / infrastructure impacts associated with changes in traffic flows: Some further impacts resulting from changes to transport flows in both options have not been quantitatively assessed. This includes impacts on noise resulting from changes in magnitude of traffic flows, changes in numbers of accidents resulting from changes in vkm travelled due to trip rerouting and cancelling, and impacts on infrastructure such as long-term wear and tear to road surfaces. These impacts are low, have not been monetised, and are covered in more detail in the distributional analyses. The results of the TUBA analysis has shown that the Preferred Option has a more prominent impact on trip rerouting so impacts are likely to be larger in this option. In the HIA, it has been found that the Benchmark CAZ D may reduce accidents due to reductions in traffic flows at accident hotspots, while the Preferred Option may increase accidents. Effects on noise and traffic infrastructure are likely to be negligible due to the marginal impact on traffic flows.

Table 7-1 Wider impacts of the Options

Impact Category	Preferred Option	Benchmark CAZ D
AQ impacts outside modelling domain (NO_X and PM)	-	✓✓/××
Active travel benefits	✓	✓ (but larger than Preferred Option)
Noise/accidents/infrastructure	×/✓	✓

Key: Each impact is assigned a scoring – these attempts to judge the size and direction of impacts between different options, and the overall size / importance of impact relative to other impacts assessed both qualitatively and quantitatively. '✓✓' denotes large benefit associated with option; '✓' denotes small benefit; '-' denotes no significant impact; '×' denotes small cost; '××' denotes large cost; and '✓/×' denotes where there are costs and benefits ('✓✓/××' where there could be either large costs or benefits), with no discernible overall net effect.

In summary, the impacts not captured by the quantitative analysis include:

- Both options will deliver additional air quality emission reductions outside the modelling domain, but these are likely to be more significant in the Benchmark CAZ D but could both increase or reduce existing assessment of impacts.
- Both options could have impacts on active travel, but these impacts are likely to be small relative to the overall assessment.
- Upgrading of vehicles in the Benchmark CAZ D option will carry transaction costs which scale with the number of vehicles upgraded.

- Both options have effects on accidents and infrastructure. In the case of the Benchmark CAZ D, traffic is reduced in the CAZ and some trips are cancelled, however traffic may increase outside of the CAZ due to rerouted trips. In the case of the Preferred Option the peak traffic restriction generally leads to increased congestion and more rerouted trips leading to increased vkm travelled.

8 Commentary of results and conclusions

Cost-benefit analysis (CBA) has been performed on the two options under consideration: the Preferred Option and the Benchmark CAZ D. It is important to state that the CBA is only part of the evidence base. In particular, it does not help assess the primary critical success factor of whether the options achieve compliance and which achieves this quickest.

That said, the CBA is a useful tool to weigh up all impacts across society (both costs and benefits) that may be associated with each measure. This helps assess the balance of impacts for each measure alone (to assess whether an option will deliver an overall benefit or cost for society on its own), and to compare between the measures.

Both options deliver a net cost, i.e. costs outweigh the benefits from a perspective of the whole of society. However, given legal limits must be met and some action taken to achieve compliance, assessing against a ‘do-nothing’ baseline is perhaps not the most informative comparison. Instead the focus should lie on the relative comparison between the options and which minimises costs or maximises benefits whilst also achieving compliance.

The Preferred Option has a less negative (Net Present Value) NPV than the Benchmark CAZ D and, hence represents a lower cost or less burdensome option to achieve compliance.

The Preferred Option creates re-routing during the peak travel restriction, that results in a large cost of increased travel time. This alongside implementation costs outweigh the benefits of the option, which include significant benefits through improvements in bus travel and small improvements in air quality, resulting in a net negative cost overall.

The Benchmark CAZ D will deliver greater improvements in air quality than the Preferred Option (although the Preferred Option in practice will begin to deliver emissions reductions and associated health benefits sooner as it can be implemented a year earlier – something not reflected in this modelling), and is not affected by the same re-routing and increased travel time disbenefit. In fact, travel times are likely to reduce under the Benchmark CAZ D associated with a reduction in non-compliant traffic and, hence, congestion in the CAZ zone, delivering a large benefit. However, these benefits are outweighed by significantly higher implementation costs of the Benchmark CAZ D, the cost of vehicle upgrades and welfare loss from those who choose to cancel their trips as a result of the Benchmark CAZ D.

Although the sensitivity analysis shows that the NPV of each option is sensitive to the assumptions, it demonstrates that the uncertainty around parameters does not influence the relative comparison of the options in terms of NPV. Furthermore, the complementary qualitative analysis has not identified any impacts that have not been quantified which could affect the balance of costs and benefits.

It is also important to note that the CBA only assesses impacts in aggregate and does not reveal any distributional pattern to these impacts. This is explored further in the Distributional Analysis Methodology Report (E3). Most notably:

- The Benchmark CAZ D has higher costs falling largely on vehicle users/owners. Households and businesses will bear the majority of these costs.
- Poorer households are more likely to own older cars and be less likely to upgrade their vehicles, meaning they may be forced to pay a CAZ charge.
- The costs to businesses will be significantly greater under the Benchmark CAZ D and may put many businesses at risk of going out of business, particularly those that require regular entry into the CAZ zone, and smaller businesses with less capital.

The outputs of both the CBA and distributional analysis should be considered alongside the other components of the evidence base when selecting the best option to achieve compliance.

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