Bath Clean Air Plan

Bath and North East Somerset Council

Economic Appraisal Modelling Report

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Contents

1. Introduction

Poor air quality is the largest known environmental risk to public health in the UK[1]. Investing in cleaner air and doing more to tackle air pollution are priorities for the EU and UK governments, as well as for Bath and North East Somerset Council (B&NES). B&NES has monitored and endeavoured to address air quality in Bath, and wider B&NES, since 2002. Despite this, Bath has ongoing exceedances of the legal limits for Nitrogen Dioxide (NO_2) and these are predicted to continue until 2025 without intervention.

In 2017 the government published a UK Air Quality Plan for Nitrogen Dioxide[2] setting out how compliance with the EU Limit Value for annual mean NO_2 will be reached across the UK in the shortest possible time. Due to forecast air quality exceedances, B&NES, along with 27 other Local Authorities, was directed by Minister Therese Coffey (Defra) and Minister Jesse Norman (DfT) in 2017 to produce a Clean Air Plan (CAP). The Plan must set out how B&NES will achieve sufficient air quality improvements in the shortest possible time. In line with Government guidance B&NES is working towards implementation of a Clean Air Zone (CAZ), including both charging and non-charging measures, in order to achieve sufficient improvement in air quality and public health.

Jacobs has been commissioned by B&NES to produce an Outline Business Case (OBC) and Full Business Case (FBC) for the delivery of the CAP; a package of measures which will bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in Bath. The OBC assessed the shortlist of options set out in the Strategic Outline Case[3,] and proposed a preferred option including details of delivery. The FBC develops the preferred option set out in the OBC, detailing the commercial, financial and management requirements to implement and operate the scheme. The OBC and FBC form a bid to central government for funding to implement the CAP.

1.1 Purpose of This Report

This Economic Appraisal Methodology Report (EAMR) is written to support the OBC and FBC and outlines the overarching framework and detailed analysis that underpins the economic appraisal for the Bath Clean Air Plan. It presents the key assumptions, approach and structure of the economic modelling that drives the cost-benefit analysis presented in the Economic Case of the OBC and FBC.

Within this context, the EAMR should be reviewed alongside the Economic Case presented in the main OBC and FBC documents. The Economic Case itself outlines the results of the economic appraisal, whilst this appendix presents the methodological underpinnings of the analyses.

[1] Public Health England (2014) Estimating local mortality burdens associated with particular air pollution. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution
[2] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017
[3] Bath and North East Somerset Council Clean Air Plan: Strategic Outline Case, March 2018 (http://www.bathnes.gov.uk/sites/default/files/siteimages/Environment/Pollution/strategic_outline_case_bath_28.03.2018_with_annexes.pdf)

2. Analytical Framework

2.1 Overarching Framework

The overarching framework for assessing the economic impacts of B&NES' Clean Air Plan is outlined in Figure 2.1 (at end of report). The flowchart presents a complex and interlinked series of inputs, processes and calculations that drive the economic model. Key inputs into the economic model can be split into three broad categories that are summarised as follows:

- Jacobs technical modelling processes (blue) and their outputs (purple), as required by JAQU's Evidence Package and pivoting from:
  - Stated preference surveys – commissioned specifically for this study, which determine behavioural responses to implementation of the Clean Air Zone;
  - Transport modelling – utilising local traffic survey data which, building on the stated preference surveys, provides data on traffic patterns with and without implementation of the Clean Air Plan;
  - Air quality modelling – utilising local air quality monitoring data which, building on the transport modelling, provides emissions data with and without implementation of the Clean Air Plan;
- Benchmark data recommended by JAQU (green), including:
  - Carbon prices and fuel costs, sourced from BEIS Carbon Tables;
  - Depreciation rates, informed by JAQU's National Data Inputs for Local Economic Models;
  - Vehicle prices, informed by ANPR data to identify the most common car types in B&NES, www.parkers.co.uk, www.Which.com and discussion with local bus and fleet operators;
  - Transaction costs by vehicle type and Euro Standard, informed by JAQU's National Data Inputs for Local Economic Models;
  - Average fuel consumption, informed by the formula and parameters provided in DfT's WebTAG databook.
- Jacobs economic modelling processes (yellow) that sit outside, but provide inputs to, the core Local Economic Model:
  - Transport user benefits assessment – which estimates the transport economic impacts associated with implementing the Clean Air Plan.
  - Financial modelling – which provides capital and operational cost data, as well as revenue data associated with implementing the Clean Air Plan.
  - Active Mode Appraisal Toolkit – which estimates the economic impacts associated with changes in the number of walking and cycling trips as a result of implementing the Clean Air Plan.
  - CoBALT analysis – which estimates the economic impacts associated with changes in the frequency and severity of accidents as a result of implementing the Clean Air Plan.

The various inputs listed above feed into the calculation of the economic impacts (black), split into a range of categories that are consistent with the impact categories listed in JAQU's Option Appraisal Guidance. The economic impacts are monetised at this stage, before being aggregated into a holistic Net Present Value (NPV) for the Clean Air Plan which acts as the key output of the economic model (orange).

2.2 Guidance, Data Sources and Key Assumptions

The economic analysis is underpinned by the following JAQU and cross-governmental guidance documents:

- JAQU Options Appraisal Guidance (2017)
- JAQU UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations (2017)
- HMT Green Book (updated 2018)
- DfT WebTAG (updated 2018)
- The following data sources were also utilised within the economic model to derive key assumptions:
- Transport model outputs (Jacobs internal analysis)
- Air Quality model outputs (Jacobs internal analysis)
- JAQU National Data Inputs for Local Economic Models (2017)
- B&NES ANPR data (2017)
- DfT WebTAG Databook (2018)
- B&NES taxi licensing data (2018)
- B&NES public transport data on fleet size, age and value based on discussion with local bus operators (2018)
- Department for Business, Energy and Industrial Strategy's Carbon Tables (2018)
- Vehicle prices, informed by ANPR data on most common car types in B&NES, www.parkers.co.uk, www.Which.com and discussion with local bus and fleet operators.

Other key assumptions adopted within the model include:

- Opening year of 2021 to reflect scheme opening.
- Appraisal period of ten years (2021-2030), in line with JAQU guidance.
- Presentation of monetised impacts in 2018 prices and values in line with JAQU guidance.
- Adoption of a 3.5% discount rate per annum over the appraisal period, in line with HM Treasury Green Book Guidance.
- Inflation adjustments in line with the WebTAG Databook GDP Deflator.

Additional impact-specific assumptions and parameters are presented in the relevant sections below. However, note that whilst this report provides a brief summary of the key behavioural, transport and air quality assumptions that drive the economic analysis, it does not attempt to re-state the methodological foundations or key outputs of any technical modelling. The following reports submitted as part of the OBC and FBC should be consulted for further details on these key data sources and assumptions:

- Behavioural Responses – FBC-30: Stated Preference Survey, Appendix L and FBC-16: Response Rates Technical Note within Appendix E of the FBC.
- Air Quality Technical Workstream – FBC-10 'AQ2 Local Plan Air Quality Modelling' and FBC-11 'AQ3 Air Quality Modelling Report' within Appendix D of this FBC.

Traffic Modelling Technical Workstream – FBC-12 'T2 Model Validation Report', FBC-13 'T3 Local Plan Transport Modelling Methodology Report ', FBC-14 'ANPR Data Analysis and Application', FBC-15 'LGV and HGV Validation', FBC-16 'Primary Behavioural Response Calculation Methodology' and FBC-17 'T4 Transport Modelling Forecast Report' within Appendix E of this FBC.

2.3 Structure of this Report

This report provides a step-by-step guide to the proposed approach to assessing each of the economic impact categories defined in Figure 2.1 and listed below:

- Health and Environmental Impacts
  - Greenhouse Gas Emissions – an assessment of the change in CO_2 emissions resulting from implementation of the preferred scheme.
  - PM/NOx Emissions – an assessment of the change in PM and NO_2 emissions resulting from implementation of the preferred scheme.
- Impacts on Transport Users
  - Transaction Costs - an assessment of time costs associated with looking for and purchasing new/replacement vehicles as a result of implementation of the preferred scheme.
  - Consumer Welfare Loss – an assessment of reduction in consumer surplus resulting from the earlier purchase of new/replacement vehicles or the decision to change travel behaviour in response to implementation of the preferred scheme.
  - Scrappage Costs – an assessment of the loss in asset value for vehicles that are scrapped earlier as a result of implementation of the preferred scheme.
  - Journey Time/Vehicle Operating Costs – an assessment of the change in travel times and vehicle-use costs as a result of implementation of the preferred scheme. The vehicle operating cost element is assumed to implicitly include fuel switch costs.
  - Accident Impacts – an assessment of the change in frequency and severity of accidents as a result of implementation of the preferred scheme.
  - Walking/Cycling Impacts – an assessment of the change in number of individuals travelling by active modes as a result of implementation of the preferred scheme.
- Costs to Local/Central Government – an analysis of the cost to set-up and operate the preferred scheme, considered in more detail as part of FBC-21 ‘Project Costs’ Appendix I of this FBC and FBC-33 ‘Finance Report’ Appendix W of this FBC.
  - Set-Up (Implementation) Costs – an assessment of the capital expenditure required to deliver the preferred scheme.
  - Running (Operational) Costs – an assessment of the ongoing operational expenditure required to deliver the preferred scheme.
- Note that financial impacts associated with CAZ charging have an overall net neutral impact from an economic perspective. This is because the CAZ charge acts an economic benefit to local/central government (in the form of revenue generation), but an economic cost to non-compliant vehicle users. The scale of the respective costs and benefits are equal therefore the impacts cancel each other out within the present analysis. Further information relating to the CAZ charge as a revenue source is provided in FBC-33 ‘Finance Report’ Appendix W of this FBC.
- Distributional and Equalities Impact Analysis – an analysis of potential varying impacts on different socio-economic groups, considered in detail as part of FBC-19 ‘Distributional and Equalities Impact Analysis’ Appendix G of this FBC.

The following sections detail the proposed analytical approach to each economic impact category in turn, supported by targeted versions of Figure 2.1 that isolate the methodology utilised for each type of impact.

2.4 Options Assessed

The economic analysis presented in this report includes results for two separate scenarios:

- Baseline case – 2021-30 scenario without CAP
- The preferred intervention case – 2021-30 scenario with Class C CAZ (£9 for LGVs, taxis, £100 for HGVs, buses) with Traffic Management Measures:

A traffic management scheme has been developed for the area around Queens Square that is capable of limiting the flow of traffic into those areas that would otherwise exceed the legally permitted threshold during busy times of the day. To achieve this outcome, two new traffic light junctions are required. These are proposed at the Queens Square junctions with the A367 Chapel Row/ Princes Street and Queens Square Place.

3. Vehicle Fleet Composition

3.1 Base and Baseline Vehicle Fleet

The 2017 base vehicle fleet composition (measured in terms of daily trips) is provided by the transport modelling output data in Table 3-1. Table 3-2 outlines the 2020 baseline vehicle fleet composition, demonstrating an overall growth in vehicle trips per day, but a reduced number of non-compliant vehicle trips.

Table 3-1: Base Vehicle Fleet (AADT) in 2017

Euro Standard	Cars/Taxis (Petrol)	Cars/Taxis (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Buses/ Coaches
CAZ C with Traffic Management Measures							
Compliant	63,537	37,670	14	1,719	3,378	2,024	545
Non-Compliant	0	0	83	10,074	6,199	1,512	629

Source: Jacobs Transport Modelling

Table 3-2: Baseline Vehicle Fleet (AADT) in 2020

Euro Standard	Cars/Taxis (Petrol)	Cars/Taxis (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Buses/ Coaches
CAZ C with Traffic Management Measures							
Compliant	64,338	52,809	25	6,124	5,272	2,568	802
Non-Compliant	0	0	51	7,373	4,206	836	354

Source: Jacobs Transport Modelling

The 2020 baseline vehicle fleet composition is adopted as the key starting point for determining the change in vehicle fleet composition over the appraisal period.

3.2 Behavioural Response

The behavioural responses to the proposed scheme were derived through a stated preference survey undertaken in Spring 2018 (see FBC-30 'Stated Preference Survey Report' Appendix L of this FBC for more detail). The key primary behavioural response rates derived from the survey are replicated in Table 3-3.

Table 3-3: Primary Behavioural Response Rates

Response	Cars	Taxis	LGVs	HGVs Rigid	HGV Artic	Buses	Coaches
CAZ C with Traffic Management Measures							
Pay Charge/ Excluded	0.0%	4.1%	18.4%	13.8%	13.8%	0.0%	20.1%
Avoid Zone	0.0%	0.0%	11.7%	4.4%	4.4%	0.0%	0.0%
Cancel Journey/ Change Mode	0.0%	0.0%	3.6%	1.4%	1.4%	6.4%	11.5%
Replace Vehicle/ Upgrade	0.0%	95.9%	66.3%	80.4%	80.4%	93.6%	68.4%
Total	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Jacobs Transport Modelling

Note that the bus response rates listed in Table 3-3 were artificially adjusted within the model to reflect feedback received by First Group, the primary bus operator in B&NES. First Group indicated that 53 vehicles within their fleet would be upgraded to new vehicles as part of private match funding to complement the requested Clean Air Fund contribution for bus retrofitting. As such, rather than pivoting from 93.6% of bus trips being replaced/upgraded, the direct figure of 53 vehicles was adopted within the analysis.

In relation to the replace vehicle/upgrade behavioural choice, a secondary behavioural response assumption was adopted in line with JAQU guidance. Table 3-4 outlines the proportion of people replacing existing vehicles with new vehicles versus people replacing with used (same fuel) and used (switched fuel) vehicles.

Table 3-4: Secondary Behavioural Response Rates

Response	Fuel Type		Upgrade Type	
	Keep Same	Switch	Used	New
Car (Petrol)	100%	0%	75%	25%
Car (Diesel)	25%	75%	75%	25%
LGVs	100%	0%	100%	0%
Buses	100%	0%	100%	0%
HGV Rigid	100%	0%	100%	0%
HGV artic	100%	0%	100%	0%
Coaches	100%	0%	100%	0%
Taxis (Petrol)	100%	0%	75%	25%
Taxis (Diesel)	25%	75%	75%	25%

Source: JAQU Guidance

Again, note that the bus figures for 'upgrade type' were manually overridden based on First Group's data. All 53 buses upgraded to compliant standards will be upgraded via purchase of a new vehicle.

3.3 Upgrade in Vehicle Fleet

Future composition of the vehicle fleet was determined by applying the behavioural responses to the 2020 baseline vehicle fleet composition. Based on the behavioural responses outlined above, the vehicle fleet is expected to upgrade at an accelerated rate in the intervention case relative to the baseline. These behavioural responses were incorporated into the traffic modelling to forecast the scale of vehicle movements across the proposed CAZ cordon in 2021 (opening year) and 2031 (future year) under the intervention scenario. The rate of upgrading and consequent forecast for the scale of vehicle movement in the baseline across the same horizon years was estimated according to the EFT Toolkit outputs. The composition of the vehicle fleet in these years is presented in Table 3-5 to Table 3-8. Note that cars and taxis have been separated into discrete vehicle types within the analysis below based on the proportion of the car fleet that are taxis according to the traffic modelling analysis. Private hire vehicles are not differentiated from taxis or cars in the quantitative economic analysis below because there is no differentiation between charge rates for these vehicle types. Also note that there is no differentiation between buses and coaches in the tables below, because First Group have provided very specific advice about number of non-compliant buses and number of buses that will be upgraded, which feeds directly into the model.

Table 3-5: Vehicle Fleet (AADT) in 2021, Baseline

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Buses/ Coaches
CAZ C with Traffic Management Measures									
1	0	0	1	0	0	0	0	0	0
2	1,491	28	12	59	34	1	53	1	39
3	12,200	618	26	365	259	24	437	19	46
4	7,409	2,521	0	1,457	564	38	85	77	57
5	19,360	6,822	10	3,896	2,311	521	222	208	100
6	24,296	43,630	17	8,308	5,235	2,372	279	426	778
Compliant	**64,756**	**53,619**	**28**	**8,308**	**5,235**	**2,372**	**586**	**426**	**778**
Non-Compliant	**0**	**0**	**39**	**5,777**	**3,168**	**584**	**491**	**304**	**243**

Source: Jacobs Transport Modelling

Table 3-6: Vehicle Fleet (AADT) in 2021, Intervention Case

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Buses/ Coaches
CAZ C with Traffic Management Measures									
1	0	0	0	0	0	0	0	0	0
2	1,447	27	2	11	4	0	2	0	2
3	11,838	596	5	66	32	3	18	1	2
4	7,465	2,434	0	262	70	5	153	3	3
5	19,506	6,587	15	700	286	64	399	8	5
6	24,479	44,018	25	12,138	7,314	3,314	501	766	943
Compliant	**64,735**	**53,661**	**41**	**12,138**	**7,314**	**3,314**	**1,053**	**766**	**943**
Non-Compliant	**0**	**0**	**7**	**1,038**	**392**	**72**	**20**	**12**	**12**

Source: Jacobs Transport Modelling

Table 3-7: Vehicle Fleet (AADT) in 2031 Baseline

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Buses/ Coaches
CAZ C with Traffic Management Measures									
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	513	0	2	0	0	0	29	0	0
4	85	17	0	41	141	0	1	1	0
5	3,428	248	0	450	1,820	306	59	11	0
6	65,506	53,373	35	16,723	6,741	2,588	1,122	701	1,044
Compliant	**69,532**	**53,639**	**35**	**16,723**	**6,741**	**2,588**	**1,182**	**701**	**1,044**
Non-Compliant	**0**	**0**	**2**	**491**	**1,961**	**306**	**29**	**11**	**0**

Source: Jacobs Transport Modelling

Table 3-8: Vehicle Fleet (AADT) in 2031, Intervention Case

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Buses/ Coaches
CAZ C with Traffic Management Measures									
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	491	0	0	0	0	0	1	0	0
4	85	16	0	9	0	0	1	0	0
5	3,423	235	0	103	0	0	60	0	0
6	65,402	53,293	35	17,031	8,161	3,133	1,145	716	1,044
Compliant	**69,401**	**53,544**	**36**	**17,031**	**8,161**	**3,133**	**1,207**	**716**	**1,044**
Non-Compliant	**0**	**0**	**0**	**113**	**0**	**0**	**1**	**0**	**0**

Source: Jacobs Transport Modelling

The data demonstrates that whilst traffic grows between 2021 and 2031, the volume of non-compliant vehicle trips actually falls across all scenarios. For the intervening years between 2021 and 2031, interpolation was undertaken to estimate the annual change in the vehicle fleet. Traffic flows for years between 2021 and 2031 were calculated using interpolation factors derived from traffic growth forecasts from TemPRO. To calculate the required vehicle & fuel types and euro standards the flows were split by a series of factors. Car and LGV compliant and non-compliant fuel splits were derived by adjusting WebTAG databook forecasts to account for locally observed ANPR data, the fuel splits for the intermediate years between 2021 and 2031 were taken directly from this process. Intermediate year splits between rigid and articulated for compliant and non-compliant HGVs were assumed to be a linear progression between the established 2021 and 2031 values. Euro standard splits were taken by utilising the fleet projection from observed ANPR data mechanism in the EFT for each year from 2021 to 2031.

Prior to 2021, a simplifying assumption is that the vehicle fleet composition is identical in both the baseline and intervention cases.

Based on this approach, the percentage reduction in non-compliant vehicle trips in the baseline and intervention is outlined in Table 3-9. The table clearly demonstrates that the number of non-compliant trips reduces at much quicker rate in the intervention case relative to the baseline. This is indicative of changing travel patterns and behaviours and accelerated upgrading of the vehicle fleet in the intervention case. This is a key input assumption driving the economic impacts discussed below.

Table 3-9: Percentage Reduction in Non-Compliant Trips in the Baseline (Relative to 2020)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline (relative to CAZ C)	23%	29%	35%	40%	46%	52%	57%	63%	69%	74%
CAZ C with Traffic Management Measures	89%	90%	91%	92%	93%	94%	95%	96%	97%	98%

Source: Jacobs Transport Modelling

4. Health and Environmental Impacts

4.1 Greenhouse Gas Emissions

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

The approach to estimating the economic impact of GHG emissions utilised the following data:

- Vehicle kilometres output from the traffic model.
- Euro splits as estimated by ANPR
- Behavioural responses estimated in the traffic model.
- CO_2 emissions per kilometre, by vehicle class, as provided by JAQU.
- This data was processed as part of the air quality modelling technical workstream to estimate the change in CO_2 emissions across the appraisal period for both the baseline and intervention scenarios (Table 4-1). Model data was made available for the opening year (2021) and future year (2031). Interpolation was undertaken for intervening years, based on fleet change and the anticipated reduction in non-compliant vehicles over time in both the baseline and intervention scenarios. The difference in emissions under the two scenarios was then calculated to determine the change in CO_2 emissions attributable to the intervention across the appraisal period

Table 4-1: Temporal Change in CO_2 Emissions (tonnes)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Baseline	49,186	49,339	49,492	49,645	49,798	49,951	50,104	50,257	50,410	50,563
Intervention	48,932	49,093	49,255	49,416	49,577	49,739	49,900	50,062	50,223	50,385
Difference	**254**	**246**	**237**	**229**	**221**	**212**	**204**	**196**	**187**	**179**

Source: Jacobs Air Quality Modelling

The difference in emissions was then multiplied by relevant carbon prices across the appraisal period (see Table 4-2, replicated from £/tCO_2e values in BEIS' Carbon Tables.

Table 4-2: Carbon Prices (£ per Tonne of CO_2 Emissions)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
£/tCO2e	£69.22	£70.35	£71.49	£72.62	£73.76	£74.89	£76.03	£77.16	£78.30	£79.43

Source: BEIS Carbon Tables (2017 prices)

The approach to analysis of GHG emissions is outlined in Figure 4.1 (see end of report).

4.2 Air Quality (PM/NO_2) Emissions

Poor air quality can have significant negative health impacts on human health. Specific impacts relating to NO_2 include[4]:

- High concentrations can lead to inflammation of the airways.
- Long-term exposure can increase symptoms of bronchitis in asthmatic children and reduced lung development and function.

More generally, a range of other public health issues are linked to poor air quality, as detailed below. These issues are believed to disproportionately affect 'at-risk' groups such older people, children and people with pre-existing respiratory and cardiovascular conditions[5].

- Long-term exposure to air pollution is linked to increases in premature death, associated with lung, heart and circulatory conditions
- Short term exposure can contribute to adverse health effects including exacerbation of asthma, effects on lung function and increases in hospital admissions.
- Other adverse health effects including diabetes, cognitive decline and dementia, and effects on the unborn child[6] are also linked to air pollution exposure.
- Exposure can exacerbate lung and heart disease in older people[7].
- Approximately 40,000 deaths can be attributed to NO_2 and fine particulate matter pollution in England every year[8].

In light of the causal link between poor air quality and poor public health, health experts believe that improvements in air quality can lead to a range of public health benefits, including:

- Reduced morbidity, leading to a reduction in public health expenditure (associated with hospital admissions and health care) and increased productivity through reduced work absenteeism;
- Reduced mortality, leading to a reduction in lost output and human costs

In addition, an improvement in air quality can also lead to positive externalities associated with the natural and built environment, including:

- Reduced impact on ecosystems (nature conservation and green spaces in B&NES) through a reduction in emissions of NO_2;
- Reduced impact on climate change through a reduction in NOx
- Reduced damage to townscape and the built environment (particularly relevant in Bath given the city's UNESCO World Heritage Site status), leading to a reduction in surface cleaning costs and amenity costs for residential, historical and cultural assets.

Within this context, the health and environmental impact associated with changes in PM/NO_2 emissions were estimated using the Damage Cost approach. The Damage Cost approach estimates the average societal costs associated with marginal changes in pollution emissions based on the range of potential impacts highlighted above. By changing travel behaviours (including number of trips, trip mode and vehicle type), the Plan may alter the scale of PM/NO_2 emissions generated by road transport.

The approach to estimating the economic impact of PM/NO_2 emissions utilised the following data:

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[4] Ambient (Outdoor) Air Quality and Health Fact Sheet. World Health Organisation (2016). Accessed February 2018.

[5] World Health Organization (2013) *Review of evidence on health aspects of air pollution – REVIHAAP Project.* http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report

[6] Royal College of Physicians (2016) '*Every breath we take: the lifelong impact of air pollution*', 2016 www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution

[7] Simoni et al., Adverse effects of outdoor pollution in the elderly, Journal of Thoracic Disease, January 2015 (URL:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4311079/)

[8] *Royal College of Physicians (2016) 'Every breath we take: the lifelong impact of air pollution'. 2016*

- Vehicle fleet data and vehicle kilometres outputs from the traffic model.
- Euro splits as estimated by ANPR
- Behavioural responses estimated in the traffic model.
- PM and NO_2 emissions per kilometre, by vehicle class, as provided by JAQU.

This data was processed as part of the air quality modelling technical workstream to estimate the change in PM/NO2 emissions across the appraisal period for both the baseline and intervention scenarios as shown in Table 4-3. Model data was made available for the opening year (2021) and future year (2031). Interpolation was undertaken for intervening years, based on fleet change and the anticipated reduction in non-compliant vehicles over time in both the baseline and intervention scenarios. The difference in emissions under the two scenarios was then calculated to determine the change in PM/NO2 emissions attributable to the intervention across the appraisal period

Table 4-3: Temporal Change in PM/NO_2 Emissions (tonnes)

NO_2	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Baseline	115.7	110.0	104.3	98.5	92.8	87.1	81.4	75.7	69.9	64.2
Intervention	86.3	82.8	79.3	75.8	72.3	68.8	65.3	61.8	58.3	54.8
Difference	29.4	27.2	25.0	22.7	20.5	18.3	16.1	13.8	11.6	9.4

PM	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Baseline	8.42	8.44	8.45	8.47	8.49	8.51	8.52	8.54	8.56	8.58
Intervention	8.44	8.46	8.48	8.50	8.52	8.54	8.56	8.58	8.60	8.62
Difference	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.04

Source: Jacobs Air Quality Modelling

The difference in emissions was then multiplied by relevant damage costs across the appraisal period (see Table 4-4, replicated from JAQU's interim figures from the 2017 NO2 Plan). Bath falls within the 'Urban Medium' area type according to DfT's classification system, therefore the damage cost relevant to 'Urban Medium' settings was utilised.

Table 4-4: Damage Costs (£ per Tonne)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NO_2	£4,927	£5,025	£5,126	£5,228	£5,333	£5,439	£5,548	£5,659	£5,772	£5,888
PM	£87,729	£89,484	£91,274	£93,099	£94,961	£96,860	£98,798	£100,773	£102,789	£104,845

Source: 2017 NO_2 Plan

The approach to analysis of PM/NO_2 emissions is outlined in Figure 4.2 (see end of report).

5. Impacts on Transport Users

5.1 Fuel Switch Costs

As road users upgrade to compliant vehicles and switch fuel types between petrol and diesel, individuals could face varying fuel costs in the intervention case relative to the baseline scenario. The change in fuel switch costs is reflected in the change in vehicle operating costs to the user, captured as part of the DfT's Transport User Benefits Assessment (TUBA) presented in Section 5.5. No additional or separate analysis is provided here.

5.2 Transaction Costs

The Plan could accelerate the rate at which vehicle owners' purchase or upgrade to compliant vehicles. As well as financial costs associated with each transaction (the economic impact of which is discussed under Sections 5.3 and 5.4), each transaction also incurs time costs for vehicle owners relating to identifying and buying a compliant vehicle.

Based on the upgrade data outlined above, Table 5-1 outlines the number of vehicles induced to upgrade earlier than they otherwise planned to, as a result of the intervention.

Table 5-1: Upgraded Fleet by Vehicle Type and Euro Standard

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
CAZ C with Traffic Management Measures						
Car Petrol	0	0	0	0	0	0
Car Diesel	0	0	0	0	0	0
PHV Petrol	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0
Taxi Petrol	0	54	442	0	0	0
Taxi Diesel	0	1	19	76	205	0
LGV petrol	0	4	10	0	0	0
LGV diesel	0	21	129	513	1,372	0
Rigid HGV	0	287	2,164	0	0	0
Artic HGV	0	1	24	37	511	0
Buses	0	9	10	12	22	0

Source: Jacobs Transport Modelling

The vehicle type and Euro Standard-specific transaction costs applied to this mix of upgraded vehicles is presented in Table 5-2.

Table 5-2: Weighted Transaction Costs by Euro Standard

Euro Standard	Weighted Transaction Costs		
	Car/Taxi	LGV	HGV
Euro 5	£6	£10	£7
Euro 4	£3	£8	£8
Euro 3	£3	£10	£7
Euro 2	£6	£12	£6
Euro 1	£6	£12	£6

Source: JAQU's National Data Inputs for Local Economic Models

The approach to analysis of transaction costs is outlined in Figure 5.1 (see end of report).

5.3 Consumer Welfare Loss

The proposed scheme will change consumers behaviour by inducing a change in travel behaviours (e.g. through upgrading vehicles, using alternative modes, cancelling journeys etc). However, because consumers would have preferred their original action in the baseline, this change in behaviour leads to a consumer welfare impact. Two elements of analysis have been identified to estimate aggregate consumer welfare loss as a result of intervention:

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

5.3.1 Replacing Vehicles

As noted above, the intervention scenario leads to accelerated reduction in non-compliant trips which is indicative of an acceleration of vehicle replacement (see Table 3-9). By accelerating the vehicle replacement process, the proposed scheme will impose a financial cost on vehicle owners driven by the impact of depreciation on replacement and replaced vehicles. Depreciation affects two components of the vehicle replacement process in the intervention case:

- Additional cost of compliant vehicles bought earlier than otherwise intended.
- Additional value of non-compliant vehicle sold.

The difference between these two values and the extent to which this difference diminishes over time, act as a proxy for consumer welfare change as a result of the proposed scheme. The net difference is driven by changes in depreciation rates over time, as highlighted in Table 5-3.

Table 5-3: Depreciation Rates by Year

Vehicle type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Petrol cars	37%	18%	16%	16%	16%	16%	16%	16%	16%	16%
Diesel cars	37%	18%	16%	16%	16%	16%	16%	16%	16%	16%
Petrol vans	37%	18%	16%	16%	16%	16%	16%	16%	16%	16%
Diesel vans	37%	18%	16%	16%	16%	16%	16%	16%	16%	16%
Rigid HGVs	35%	18%	18%	18%	18%	18%	18%	18%	18%	18%
Articulated HGVs	35%	18%	18%	18%	18%	18%	18%	18%	18%	18%
Buses	35%	18%	18%	18%	18%	18%	18%	18%	18%	18%
Taxis	37%	18%	16%	16%	16%	16%	16%	16%	16%	16%
Coaches	35%	18%	18%	18%	18%	18%	18%	18%	18%	18%

Source: JAQU's National Data Inputs for Local Economic Models

As depreciation rates are higher in earlier years, depreciation acts to narrow the gap between the value of compliant vehicles purchased and non-compliant vehicles sold over time. This means vehicle owners induced to replace their vehicle earlier experience greater welfare loss as the net difference in value of replacement and replaced vehicles is higher, thus implying a higher cost of upgrading. As a result, the cost of upgrading is expected to be greater in the intervention case, as vehicle owners upgrade sooner than in the baseline.

The total number of vehicle owners who replace their vehicle in response to the proposed scheme is a function of the frequency of trips made by each vehicle owner. Vehicles that make regular trips into the CAZ zone are more likely to be replaced than vehicles who rarely enter the zone, as the cumulative cost of CAZ charges resulting from frequent trips into the CAZ becomes more expensive than the average cost to upgrade to a compliant vehicle.

To determine the number of vehicles that upgrade, the daily frequency of non-compliant vehicle entries into the CAZ in 2021 under the baseline scenario was estimated by adjusting 2017 ANPR data. The frequency data was converted to number of trips by multiplying the number of vehicles by their frequency of entry according to ANPR data. The analysis, pivoting from ANPR data captured over a two-week period was assumed to be representative of annual trip patterns.

Based on the response rates noted in Table 3-3, the number of trips upgrading was converted to a number of vehicles that upgrade by assuming that those vehicles that enter the CAZ zone with the highest frequency (i.e. those vehicles that make the most trips on separate days over the two-week period) are the first to upgrade. The first vehicles to upgrade are those entering the CAZ with the highest frequency because these vehicles would incur the CAZ charge most regularly. As such, from a financial perspective, regular entrants would rationally upgrade earlier than irregular entrants. This approach estimated the number of vehicles that upgrade, relative to the number of vehicle trips that upgrade, as outlined in Table 5-4.

Table 5-4: Vehicle Upgrade Response Rate Estimates

Vehicle Type	CAZ C with Traffic Management Measures	
	Trips	Vehicles
Car	0%	0%
LGV	66%	28%
Rigid HGV	80%	59%
Artic HGV	80%	69%
Taxi	96%	82%
Bus	100%	100%

Source: Jacobs Economic Modelling

As noted above, the First Group bus operator provided detailed and specific information on the upgrade response rate for buses. Therefore, the value outlined in Table 5-4 was manually overridden to reflect the proposed upgrading to new vehicles of 100% of their 53 non-compliant vehicles.

Based on the response rates outlined in Table 3-3 and the interpolation approach described in Section 3.3, the number and timing of vehicles upgrading in the intervention scenario is outlined in Table 5-5.

Table 5-5: Rate of Vehicle Upgrading

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	0	0	0	0	0	0	0	0	0	0
PHV Petrol	0	0	0	0	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0	0	0	0	0
Taxi Petrol	482	1	1	1	2	2	2	2	2	2
Taxi Diesel	291	1	1	1	1	1	1	1	1	1
LGV petrol	13	0	0	0	0	0	0	0	0	0
LGV diesel	1,797	27	27	27	27	27	26	26	26	26
Rigid HGV	2,244	23	23	23	23	24	23	23	23	23
Artic HGV	527	6	6	5	5	5	5	5	5	4

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Buses/Coaches	53	0	0	0	0	0	0	0	0	0
Total	5,406	58	58	58	58	58	56	56	56	56

Source: Jacobs Economic Modelling

The average cost of replacing a vehicle by vehicle type and year is estimated by calculating the cost differential between upgrading in 2021 and all other years in the appraisal period, based on the residual value of replacement and replaced vehicles in each year (informed by the depreciation rates presented in Table 5-3). Current (2018) values for the replacement and replaced vehicles reflect current market prices sourced from industry databases, weighted by:

- The popularity of certain brands/models in B&NES (based on ANPR data); and,
- JAQU-defined depreciation rates to capture the reduction in value over time

These values were assumed to remain consistent in 2021, with all residual values for older cars pivoting from the value of the new vehicles listed in Table 5-6 and the appropriate depreciation rate.

Table 5-6: Market Value of New Vehicles

	Market Value of New Vehicle	Source
Cars (Petrol)	19,818	ANPR data on most popular models combined with https://www.which.co.uk/reviews/new-and-used-cars/article/petrol-vs-diesel-cars-which-is-better
Cars (Diesel)	17,588	ANPR data on most popular models combined with https://www.which.co.uk/reviews/new-and-used-cars/article/petrol-vs-diesel-cars-which-is-better
PHV Petrol	19,818	Assumed same as car
PHV Diesel	17,588	Assumed same as car
Taxi Petrol	19,818	Assumed same as car
Taxi Diesel	17,588	Assumed same as car
LGV petrol	20,215	Road Haulage Association on the LGV and HGV operating costs, 2018
LGV diesel	20,215	Road Haulage Association on the LGV and HGV operating costs, 2018
Rigid HGV	67,774	Road Haulage Association on the LGV and HGV operating costs, 2018
Artic HGV	81,495	Road Haulage Association on the LGV and HGV operating costs, 2018
Buses	184,048	Discussions with local operators and JAQU's Early Measures Fund for Local NO2 Compliance Report

Source: Jacobs Transport Modelling

This cost differential for upgrading was then multiplied by the differential proportion of vehicles assumed to upgrade in each year (taken from Table 3-9). A factor of 50%[9] was also applied to arrive at a cost differential for upgrading for each vehicle type and Euro Standard for every year of the appraisal period. The annual values were then summed. The summed values for each Euro Standard were then converted to a weighted average upgrade cost differential covering all Euro Standards, using the Euro Standard mix of the non-compliant component of the vehicle fleet (as set out in Table 5-7).

[9] The factor reflects half of the difference between the market value of the replaced and replacement vehicle, assuming a linear demand curve for upgraders and no more detailed knowledge on the value specific individuals place on new or replacement vehicles

Table 5-7: Euro Standard of Non-Compliant Components of Fleet

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Car Petrol	-	11%	89%		
Car Diesel	-	0%	6%	25%	68%
LGV petrol	2%	31%	67%		
LGV diesel	-	1%	6%	25%	67%
Rigid HGV	-	12%	88%		
Artic HGV	-	0%	4%	6%	89%
Buses	-	16%	19%	24%	41%
Taxis Petrol	-	11%	89%		
Taxis Diesel	-	0%	6%	25%	68%
Coaches	-	16%	19%	24%	41%

Source: Jacobs Transport Modelling

NB: some rows may not sum to 100% due to rounding

Three weighted average upgrade cost differentials were derived, reflecting the three types of vehicular upgrades noted in Table 3-4. Following JAQU's Guidance, 25% of vehicle owners upgrading were assumed to upgrade to new vehicles.

For the 75% of vehicle owners upgrading to second-hand vehicles, these individuals were expected to replace their vehicles with the cheapest (i.e. lowest Euro Standard) compliant vehicle that is at least one Euro Standard higher than their current vehicle. Of the 75% of vehicle owners replacing their vehicles with second-hand vehicles, 25% are expected to switch fuel from diesel to petrol with the remaining 75% expected to retain the same fuel.

In light of the above, the weighted average replaces vehicle differential value for vehicle owners upgrading to new and used (same fuel/switch fuel) vehicles are listed in Table 5-8:

Table 5-8: Weighted Replace Vehicle Value Differential (£)

	New	Used (Same Fuel)	Used (Switch Fuel)
CAZ C with Traffic Management Measures			
Car Petrol	-	-	-
Car Diesel	-	-	-
PHV Petrol	-	-	-
PHV Diesel	-	-	-
Taxi Petrol	3,269	134	-
Taxi Diesel	2,689	586	515
LGV petrol	2,894	131	-
LGV diesel	2,583	563	-

Rigid HGV	18,159	4,299	-
Artic HGV	17,044	2,790	-
Buses/Coaches	43,516	9,357	-

Source: Jacobs Economic Modelling

These weighted average upgrade cost differentials were combined with the number of vehicles upgrading in each year in the intervention scenario to generate aggregate consumer welfare loss from upgrading.

5.3.2 Changing Travel Patterns and Behaviours

A loss of consumer welfare resulting from changing travel patterns and behaviours was captured by noting the number of trips in the baseline that would be cancelled, subjected to changing modes or that would avoid the CAZ zone in response to the proposed scheme. Diverted trips were not included in the consumer welfare analysis as any economic impact was captured within the journey time savings/vehicle operating cost analysis below.

Table 3-3 highlights the number of non-compliant vehicle trips in AADT terms in the 2021 baseline and Table 3-9 highlights the reduction in non-compliant vehicles in the baseline. In light of these assumptions, the annualised number of trips cancelled/changed mode/avoiding the zone as a result of the scheme are outlined in Table 5-9.

Table 5-9: Trips with Changed Travel Patterns/Behaviours

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	0	0	0	0	0	0	0	0	0	0
PHV Petrol	0	0	0	0	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0	0	0	0	0
Taxi Petrol	0	0	0	0	0	0	0	0	0	0
Taxi Diesel	0	0	0	0	0	0	0	0	0	0
LGV petrol	2,172	1,829	1,516	1,232	976	806	650	503	363	232
LGV diesel	322,275	292,272	262,239	232,178	202,088	171,913	143,031	114,140	85,242	56,335
Rigid HGV	67,013	64,459	61,891	59,311	56,717	54,110	51,609	49,095	46,568	44,028
Artic HGV	12,358	11,701	11,058	10,428	9,811	9,207	8,637	8,079	7,533	7,001
Buses	5,668	5,088	4,509	3,930	3,351	2,771	2,217	1,663	1,109	554

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total	409,485	375,349	341,214	307,079	272,944	238,808	206,144	173,479	140,815	108,150

Source: Jacobs Economic Modelling

However, it should be noted that not all of these trips are assumed to experience a consumer welfare loss in the intervention scenario relative to the baseline scenario. The traffic modelling outputs demonstrate that only approximately 28% of non-compliant vehicle trips into the CAZ boundary were made by unique non-compliant vehicles. Hence only 28% of non-compliant vehicle trips would be charged for entering the zone.

Changing travel patterns and behaviour in this manner is assumed to occur where the cost of the action is less than the cost of the CAZ charge, otherwise the rational economic choice would be to pay the CAZ charge. Whilst consumers often consider factors beyond financial cost, this qualifying assumption is adopted for simplicity, as per JAQU's option appraisal guidance. As the incurred cost could fall anywhere between zero and the CAZ charge, the average mid-point CAZ charge[10] is adopted as the consumer welfare loss value. Effectively, the overall cost of changing travel patterns and behaviours is equal to the total number of trips that are changed, multiplied by half of the CAZ charge.

However, it should be noted that because the CAZ charge can only be incurred once per day, and in light of the fact that only 28% of non-compliant vehicle trips are made by unique non-compliant vehicles, the consumer welfare loss can only be applied to 30% of the foregone non-compliant vehicle trips estimated in Table 5-9. Applying consumer welfare loss to multiple trips by the same vehicle on a single day would overestimate the aggregate welfare loss as the charge is only incurred once.

The approach to analysis of consumer welfare loss is outlined in Figure 5.2 (see end of report).

5.4 Scrappage Costs

Pivoting from JAQU Guidance, the number of vehicles being scrapped is assumed to be equal to the number of new vehicles being purchased through the upgrading process (i.e. 25% of all upgraded vehicles). The intervention case is assumed to bring forward the replacement (and therefore scrappage) of vehicles, meaning that vehicles are scrapped earlier and with higher residual values than they would have been under the baseline scenario. As a result, the intervention case leads to a greater loss of residual asset value.

The value of scrapped vehicles is estimated by identifying the age of scrapped vehicles (inferred from Euro Standards) and estimating their residual value taking into account JAQU's recommended depreciation rates, in line with the vehicle upgrading analysis described above. As the intervention case is assumed to accelerate scrappage, scrapped vehicles in the intervention case have a higher residual value than in the baseline case where vehicles are scrapped later. This is because additional depreciation can occur where scrappage occurs at a later date (i.e. in the baseline).

The methodology for calculating the differential between residual asset value in the baseline and intervention cases was aligned with the approach adopted in the vehicle upgrading analysis described above, i.e.:

- Established the asset value of vehicles to be scrapped based on age and depreciation rates;
- Subtracted the asset value of vehicles to be scrapped in each year of the appraisal period from the 2021 value to establish an asset value differential per vehicle scrapped earlier than intended, across all years
- Used the interpolation rates to determine the proportion of vehicles scrapped each year in the intervention case, and applied the proportion to the asset value differential per vehicle identified above

[10] £4.50 for cars and LGVs (all fuel types), £50 for HGV (all types) and buses/coaches

- Summed the asset value differential across all years and Euro Standards to arrive at a weighted average asset value differential to act as a proxy for scrappage cost change between the baseline and intervention cases (Table 5-10)

Table 5-10: Weighted Average Scrappage Costs (£)

Vehicle Type	CAZ C with Traffic Management Measures
Car Petrol	£0
Car Diesel	£0
PHV Petrol	£0
PHV Diesel	£0
Taxi Petrol	£175
Taxi Diesel	£776
LGV petrol	£140
LGV diesel	£732
Rigid HGV	£531
Artic HGV	£3,990
Buses/Coaches	£5,986

Source: Jacobs Economic Modelling

The values were then applied to the profile of vehicle upgrades in the intervention case. The profile is outlined in Table 5-11, based on Table 5-5 above and pivoting from the relevant behaviour response rates and interpolation data presented above.

Table 5-11: Rate of Vehicle Upgrading to New Vehicles

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	0	0	0	0	0	0	0	0	0	0
PHV Petrol	0	0	0	0	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0	0	0	0	0
Taxi Petrol	121	0	0	0	0	0	0	0	0	0
Taxi Diesel	73	0	0	0	0	0	0	0	0	0
LGV petrol	0	0	0	0	0	0	0	0	0	0
LGV diesel	0	0	0	0	0	0	0	0	0	0
Rigid HGV	0	0	0	0	0	0	0	0	0	0
Artic HGV	0	0	0	0	0	0	0	0	0	0

Buses/Coaches	53	0	0	0	0	0	0	0	0	0
Total	**246**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Source: Jacobs Economic Modelling

The approach to analysis of scrappage costs is outlined in Figure 5.3 (see end of report).

5.5 Journey Time/Vehicle Operating Costs

Transport user benefits were assessed using TUBA 1.9.11. The key assumptions adopted include:

- Model outputs from the transport modelling workstream;
- Modelled years: 2021 and 2031;
- Appraisal period: 10 years;
- Price base year for discounting: 2010;
- Discount rate as per Green book guidance of 3.5% for first 10 years;
- Vehicle Classes: Taxi, Bus/Coach, HGV, LGV and Car;
- Annualisation factors: AM 687, PM 701, Inter-Peak 1518; and
- Value of Time: WebTAG Databook May 2018.

In addition to the key assumptions outlined above, the key TUBA Inputs are:

- a standard economics file which includes the latest transport economics values in accordance with WebTAG guidance (March 2018 parameters were used);
- trip and skim matrices from the GBATH model; and
- scheme file detailing all aspects of the scheme including costs, input matrices and annualisation factors.

Trip matrices, distance and time skims and cost matrices for the opening and design years of the scheme options have been obtained from the SATURN GBATH models for the baseline and intervention scenarios.

The annualisation factors applied to TUBA have been calculated based on the one-hour period as modelled in each defined period, therefore the skims have been multiplied by the standard annual TUBA figure of 253 and the period factor to give the annualisation factors as detailed in Table 5-12 below.

Table 5-12: TUBA Annualisation Factors Applied to Model Outputs

Period	Modelled Duration (minutes)	Annual Factor	Period Factor	Overall Annualisation Factor
Morning peak	60	253	2.7	687
Inter peak	60	253	6	1,518
Evening peak	60	253	2.77	701

Source: Jacobs Economic Modelling

Outputs from the two peak periods and the inter-peak period models have been used for the TUBA assessment. It is considered that these models do not constitute an appropriate base for assessing either the weekend or off-peak periods and their relative level of benefits. Therefore, the benefits for these periods will not be assessed.

The TEE benefits were calculated from changes in travel time and distance for the affected vehicles. Reduced travel time is usually associated with a reduction in congestion leading to increased speeds. The speed of the vehicle affects the vehicle operating costs associated with that journey.

The following adjustments have been applied to the GBATH model output files, to assure compliance with standard TUBA process:

- WebTAG guidance advice that the economic assessment should be performed over ten-year period. Hence, the outputs have been adjusted to apply to 2021 to 2030.
- Do Something OD matrices have been applied to both the Do Minimum and the Do Something scenarios. Since the scheme bans part of the traffic driving into the centre and that results in trips transferred from private vehicles to modes not included in the assessment, using both Do Minimum and Do Something matrices would result in an overestimation of journey time benefits due to banned car trips that shift to other modes.
- GBATH model matrices are split between compliant and non-compliant vehicles and the TUBA assessment has been performed separately and added at a final stage of the assessment.
- Buses were split into two user classes, Bus (driver) and Bus (passenger). TUBA default occupancy levels (12.2 passengers/bus) was applied to the Bus (passenger) user class to capture benefits from coach users.
- GBATH model LGV matrices were split into two user classes in TUBA: LGV personal (12% of total LGV) and LGV freight (88% of total).
- GBATH model non-business car matrices were split into two user classes in TUBA: commuting car trips (41.2% of total non-business car trips) and “other” car trips (58.8% of total non-business car trips).

See Table 5-13 for further detail of the user classes applied.

Table 5-13: User Classes in TUBA

User Class	Description	Vehicle/Sub mode	Purpose	Person type
1	Car business	Car	Business	Default split
2	Car commute	Car	Commuting	Default split
3	Car other	Car	Other	Default split
4	LGV personal	LGV personal	Default split	Default split
5	LGV Freight	LGV Freight	Business	Default split
6	OGV	OGV1	Default split	Default split
7	Bus driver	Bus	Business	Driver
8	Bus passenger	Bus	Default split	Passenger

9	Taxi	Car	Default split	Default split

Source: Jacobs Economic Modelling

5.6 Accident Impacts

An accident analysis was undertaken using DfT's CoBALT software. The analysis estimates the change in accident/casualty frequency and severity attributable to the scheme and can be used to derive a monetary value associated with this change. Over the ten-year appraisal period (2021-30), a reduction of 10 accidents is anticipated through intervention, as outlined in Table 5-14.

Table 5-14: Change in Accidents and Casualties

Accident Summary	CAZ C with Traffic Management Measures
Baseline Accidents	2,357
Intervention Accidents	2,348
Accident Reduction Due to Scheme	10

Source: Jacobs Transport Modelling

5.7 Walking/Cycling Impacts

By inducing mode shift for non-compliant vehicle owners, the proposed scheme could promote a simultaneous uplift in use of active transport modes (i.e. walking and cycling). By switching to active modes, there is a societal economic benefit driven primarily by increased health and reduced absenteeism from work. To assess the scale of the impact attributable to the proposed scheme, DfT's Active Mode Toolkit was utilised.

Key inputs to the toolkit include forecasts of the number of additional walkers/cyclists generated by the scheme. This was estimated by taking the mode share component of the 'Cancel Journey/ Change Mode' behavioural response and applying the proportion to the annual number of baseline non-compliant vehicle trips. A further adjustment was made to forecast the scale of mode shift from non-compliant vehicles to walking and cycling specifically, by applying the relevant weightings for walking (26%) and cycling (2%) trips to all non-vehicular trips (39%) according to the National Travel Survey 2017. The resulting forecast for number of additional walking and cycling trips each year converted from non-compliant vehicle trips in the baseline is outlined in Table 5-15.

Table 5-15: Additional Walking and Cycling Trips Converted from Non-Compliant Vehicle Trips in the Baseline

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CAZ C with Traffic Management Measures										
Walking	2,574	2,358	2,142	1,925	1,709	1,493	1,286	1,079	873	666
Cycling	33,460	30,650	27,840	25,030	22,220	19,411	16,722	14,033	11,344	8,656
Total	36,033	33,008	29,982	26,956	23,930	20,904	18,008	15,113	12,217	9,322

Source: Jacobs Economic Modelling

The annual number of active mode trips were converted to daily trips and inputted into the Active Mode Toolkit. All were assumed to be return journeys. No assumptions were made about the quality or service level of any infrastructure that active mode users would utilise. Default National Travel Survey and DfT WebTAG values were utilised to estimate journey length, speed of travel and other trip characteristic data. An independent assessment was run for each year in the appraisal period.

Note that the analysis ignores mode shift to other, non-active modes (i.e. bus, rail, other). Mode shift to these other modes is not monetised beyond the consumer welfare loss induced by switching mode in response to the intervention.

6. Costs to Local/Central Government

The capital and operational costs incurred by local and central government are considered in detail as part of FBC-33 ‘Finance Report’ Appendix W of this FBC. Within this document, it is worth noting that unlike in the financial analysis, optimism bias has been applied to costs in line with the HM Treasury Green Book benchmark values. These are summarised in Table 6-1. For comparative purposes, the optimism bias value applied at OBC stage is also presented

Table 6-1: Optimism Bias Adjustments to Costs

Activity	OB Value		Use
	FBC	OBC	
Equipment/Development	10% (lower bound)	200% (upper bound)	For CAPEX related to: • Enforcement System: ANPR cameras (including installation), , control room set up, system integration • Street Works: expanded Wi-Fi system • Non-Charging Measures: variable message signs • Mitigation Measures: bus upgrade retrofitting and repowering, last mile delivery cargo bikes and supporting infrastructure, telematics devices
Standard Civil Engineering	3% (Upper bound CAPEX)	44% (Upper bound CAPEX)	For CAPEX related to: • Street Works: signage, lighting • Traffic management and public realm improvements at Queens Square For OPEX relating the scheme decommissioning.
Equipment/Development	10% (Lower bound)	54% (Upper bound)	For OPEX related to ANPR camera replacement, monitoring equipment, communication systems.
Standard Buildings	2% (Lower bound)	24% (Upper bound)	For CAPEX related to storage units provided as part of the last mile delivery mitigation measure and control room fit out. For OPEX related to building maintenance.

Source: Jacobs Economic Modelling

7. Sensitivity Analysis

7.1 Transport Modelling and Air Quality Sensitivity Analysis

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

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

The base year modelling, both traffic and air quality, has been verified against recent and reliable observed/monitored data, providing reasonable confidence in the 2017 model. Predicting pollutant concentrations in a future year will always be subject to greater uncertainty. For obvious reasons, the model cannot be verified in the future, and it is necessary to rely on a series of projections provided by DfT and Defra as to what will happen to traffic volumes, background pollutant concentrations and vehicle emissions.

To assess the uncertainty further, a series of sensitivity tests have been undertaken on both the baseline and preferred option models as set out in Table 7-1. Full details of this assessment are provided in FBC-31 ‘Sensitivity Test Report’ Appendix N of this FBC but a summary of the tests undertaken and the implications is provided below.

Table 7-1: Summary of sensitivity

Traffic Modelling	Air Quality Modelling
• Uncertainties in the Transport Model at the National Level • Fleet splits by fuel type: ANPR vs. WebTAG • Fleet splits by European emissions standards: EFT option 1 vs option 2 • Fleet splits by Euro Standards: high and low fleet renewal • Behavioural response to charging • Impact of Severn crossings toll removal	• Differential bias • Euro 6 vehicles • Inappropriate emissions groupings • Vehicle size and weight • Average speed emissions factors • Emissions at low speeds • Background concentrations • Model verification • Receptor locations • Road widths and geometries • Gradients • Meteorological Data • Meteorological Parameters • Primary NO_2 Fraction • Regional Ozone • Non-Road Sources

7.2 Economic Modelling Sensitivity Analysis

The economic model is intrinsically linked to the transport modelling and air quality processes, which provide key inputs driving the economic model. As such, any sensitivity analysis that alters the outputs of the transport and air quality modelling will have consequential impacts on the economic modelling process. Similarly, changes to key assumptions in the economic modelling are likely to also impact on assumptions driving the transport and air quality modelling. Essentially, the various modelling processes required to assess the impact of the Bath CAP are interdependent and reliant on common key assumptions and drivers.

Nevertheless, in line with the FBC-31 ‘Sensitivity Test Technical Note’ Appendix N of this FBC, a series of sensitivity tests were developed to test changes to the following key assumptions on the economic impacts of the Bath CAP:

- Implementation Costs: in line with sensitivity tests adopted within the Financial Case, assessing the impact of an 10% increase and 10% decrease in CAPEX
- Damage Costs: to assess the impact of changing the value of NO_2 and PM_{10} emissions, adjusting the DfT recommended geographical definition for Bath from ‘Urban Medium’ to ‘transport average’ (representing a lowest-case estimate of damage costs) and ‘Inner London’ (representing a highest case estimate of damage costs).
- Carbon prices: to assess upside and downside fluctuations in carbon prices and their impact on the value of greenhouse gas emissions, adjusting BEIS’ central carbon price to BEIS high and low estimates.
- Vehicle non-compliance: in line with transport modelling scenario testing, assessing the impact of changes to behavioural response rates and their impact on dependent economic impacts (e.g. consumer welfare, transaction costs, scrappage costs, active mode) using pessimistic and optimistic response rates.
- Upgrading rate: assessing relaxation to the assumption that those vehicles who travel into the CAZ most frequently are the first to upgrade, by considering all unique vehicles have the same propensity to upgrade irrespective of frequency of entry into the CAZ.
- Charge Rate: assessing an increase and decrease to the core charge rate to understand the scale of downstream economic impacts (e.g. consumer welfare).

The specification of the sensitivity test analyses are considered in more detail below; the results of the analyses are presented in the Economic Case of the main FBC document. At this stage, it should be noted that the economic modelling sensitivity tests are run independently of transport and air quality modelling. The economic analysis is isolated from the inputs and outputs of these other processes. Therefore, even though it is acknowledged that the economic, transport and air quality modelling processes are interdependent with shared assumptions, any changes to key assumptions for the economic modelling are not reflected in transport and air quality modelling runs and outputs. In reality, changes to some of the key assumptions outlined above could fundamentally change transport and air quality modelling, which could alter key inputs to the economic modelling process. This is not reflected in the sensitivity analysis below.

7.2.1 Implementation Costs

As noted above, the sensitivity tests on implementation costs comprise a 10% increase and decrease on CAPEX assumed under both intervention options.

7.2.2 Damage Costs

Both intervention options assume that the appropriate damage cost to monetise changes in NO_2 and PM_{10} emissions is ‘Urban Medium’ (as per DfT guidance). A range of damage costs are provided for other geographical areas, as outlined in Table 7-2 and Table 7-3. To estimate the maximum and minimum impact of changes in NO_2 and PM_{10} emissions, the ‘Inner London’ and ‘Transport Average’ damage costs were adopted as sensitivity tests respectively.

Table 7-2: Damage Costs by Geographical Area for NO_2

Geography	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Inner London	£27,329	£27,876	£28,433	£29,002	£29,582	£30,173	£30,777	£31,392	£32,020	£32,661
Central London	£26,654	£27,187	£27,731	£28,285	£28,851	£29,428	£30,017	£30,617	£31,229	£31,854
Outer London	£14,461	£14,751	£15,046	£15,347	£15,654	£15,967	£16,286	£16,612	£16,944	£17,283
Inner conurbation	£10,122	£10,325	£10,531	£10,742	£10,957	£11,176	£11,399	£11,627	£11,860	£12,097
Urban big	£7,332	£7,478	£7,628	£7,781	£7,936	£8,095	£8,257	£8,422	£8,590	£8,762
Urban large	£5,927	£6,046	£6,167	£6,290	£6,416	£6,544	£6,675	£6,809	£6,945	£7,084
Urban Medium	£4,927	£5,025	£5,126	£5,228	£5,333	£5,439	£5,548	£5,659	£5,772	£5,888
Transport average	£4,859	£4,957	£5,056	£5,157	£5,260	£5,365	£5,472	£5,582	£5,693	£5,807

Table 7-3: Damage Costs by Geographical Area for PM_{10}

Geography	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Inner London	£486,192	£495,916	£505,834	£515,951	£526,270	£536,795	£547,531	£558,481	£569,651	£581,044
Central London	£477,212	£486,756	£496,492	£506,421	£516,550	£526,881	£537,418	£548,167	£559,130	£570,313
Outer London	£258,722	£263,896	£269,174	£274,558	£280,049	£285,650	£291,363	£297,190	£303,134	£309,197
Inner conurbation	£180,833	£184,449	£188,138	£191,901	£195,739	£199,654	£203,647	£207,720	£211,874	£216,112
Urban big	£131,467	£134,096	£136,778	£139,514	£142,304	£145,150	£148,053	£151,014	£154,034	£157,115
Urban large	£106,458	£108,588	£110,759	£112,975	£115,234	£117,539	£119,889	£122,287	£124,733	£127,228
Urban Medium	£87,729	£89,484	£91,274	£93,099	£94,961	£96,860	£98,798	£100,773	£102,789	£104,845
Transport average	£87,717	£89,472	£91,261	£93,086	£94,948	£96,847	£98,784	£100,760	£102,775	£104,830

7.2.3 Carbon Prices

Both intervention options assume that the appropriate carbon prices to monetise changes in greenhouse gas emissions are the central values specified in BEIS carbon tables. The carbon tables also provide low and high carbon prices estimates, as outlined in Table 7-4. To estimate the maximum and minimum impact of changes in greenhouse gas emissions, both the low and high carbon prices were applied as sensitivity tests within the analysis.

Table 7-4: Carbon Prices for Valuing Greenhouse Gas Emissions

Geography	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low	£34.61	£35.18	£35.74	£36.31	£36.88	£37.45	£38.01	£38.58	£39.15	£39.72
Central	£69.22	£70.35	£71.49	£72.62	£73.76	£74.89	£76.03	£77.16	£78.30	£79.43
High	£103.83	£105.53	£107.23	£108.93	£110.64	£112.34	£114.04	£115.74	£117.44	£119.15

7.2.4 Vehicle Non-Compliance

The sensitivity tests for transport modelling included changes to behavioural responses which fundamentally alters the profile and scale of vehicle non-compliance in the intervention case. The economic modelling sensitivity testing assumed an arbitrary 10% increase and decrease in non-compliant flows to provide an indicative optimistic and pessimistic scenario for CAZ C. Table 7-5 outlines the impact of changing these behavioural response rates on the proportion of non-compliant vehicle trips on the network, relative to the core scenario for both intervention options.

Table 7-5: Non-compliant Traffic Flow Variation

Scenario	CAZ C with Traffic Management Measures
Core	100%
Optimistic	90%
Pessimistic	110%

A change in behavioural responses and the volume non-compliant vehicle trips has implications a range of downstream economic impacts:

- Consumer welfare: as the number of vehicles upgrading and the number of unique vehicle trips changing mode, avoiding the zone or cancelling journeys will change.
- Transaction costs: as the number of vehicles upgrading changes
- Vehicle scrappage costs: as the number of vehicles scrapped changes as vehicles upgrade (and upgrading to new vehicles varies)
- Active mode impacts: as the number of unique vehicle trips switching mode changes, the scale of cycling and walking uplift will change

7.2.5 Upgrading Rate

Both intervention options assume that the non-compliant vehicles that enter the CAZ most frequently will upgrade to compliant vehicles first. As a result, the actual number of unique vehicles upgrading is lower than the proportion of vehicle trips assumed to upgrade (as a number of vehicle trips are assumed to be made by vehicles that enter the CAZ with higher frequency, including repeatedly on the same day). This assumption has been relaxed within the sensitivity analysis, on the basis that all non-compliant vehicles have an equal likelihood of upgrading irrespective of the number or frequency of trips entering the CAZ. Table 7-6 outlines the vehicle upgrade response rates based on frequency and the response rates assuming each upgrading trip equates to a unique upgrading vehicle.

Table 7-6: Vehicle Upgrade Response Rate Estimates

Vehicle Type	CAZ C with Traffic Management Measures	
	Each Trip	Vehicle Frequency
Car	0%	0%
LGV	66%	28%
Rigid HGV	80%	59%
Artic HGV	80%	69%
Taxi	96%	82%
Bus	100%	100%

A change in upgrade rates will influence the volume non-compliant vehicle trips, which has implications a range of downstream economic impacts:

- Consumer welfare: as the number of vehicles upgrading will change.
- Transaction costs: as the number of vehicles upgrading changes

Vehicle scrappage costs: as the number of vehicles scrapped changes as vehicles upgrade (and upgrading to new vehicles varies)

7.2.6 Charge Rates

Changes in charge rates will influence behaviour response rates. For the purpose of the economic modelling, only the direct impact of charge rates on downstream impacts have been considered (specifically around the change in consumer welfare loss for unique vehicles trips changing mode, avoiding the zone or cancelling journeys as a result of the change in charge rates). Table 7-7 outlines the charge rates considered for this assessment.

Table 7-7: Bath CAZ proposed charges

Charge Class	Core Charge	Lower Charge	Higher Charge
Cars	n/a	n/a	n/a
Taxis	£9.00	£4.50	£13.50
Light Goods Vehicles (LGV)s	£9.00	£4.50	£13.50
HGVs	£100.00	£50.00	£150.00
Buses	£100.00	£50.00	£150.00
Coaches	£100.00	£50.00	£150.00

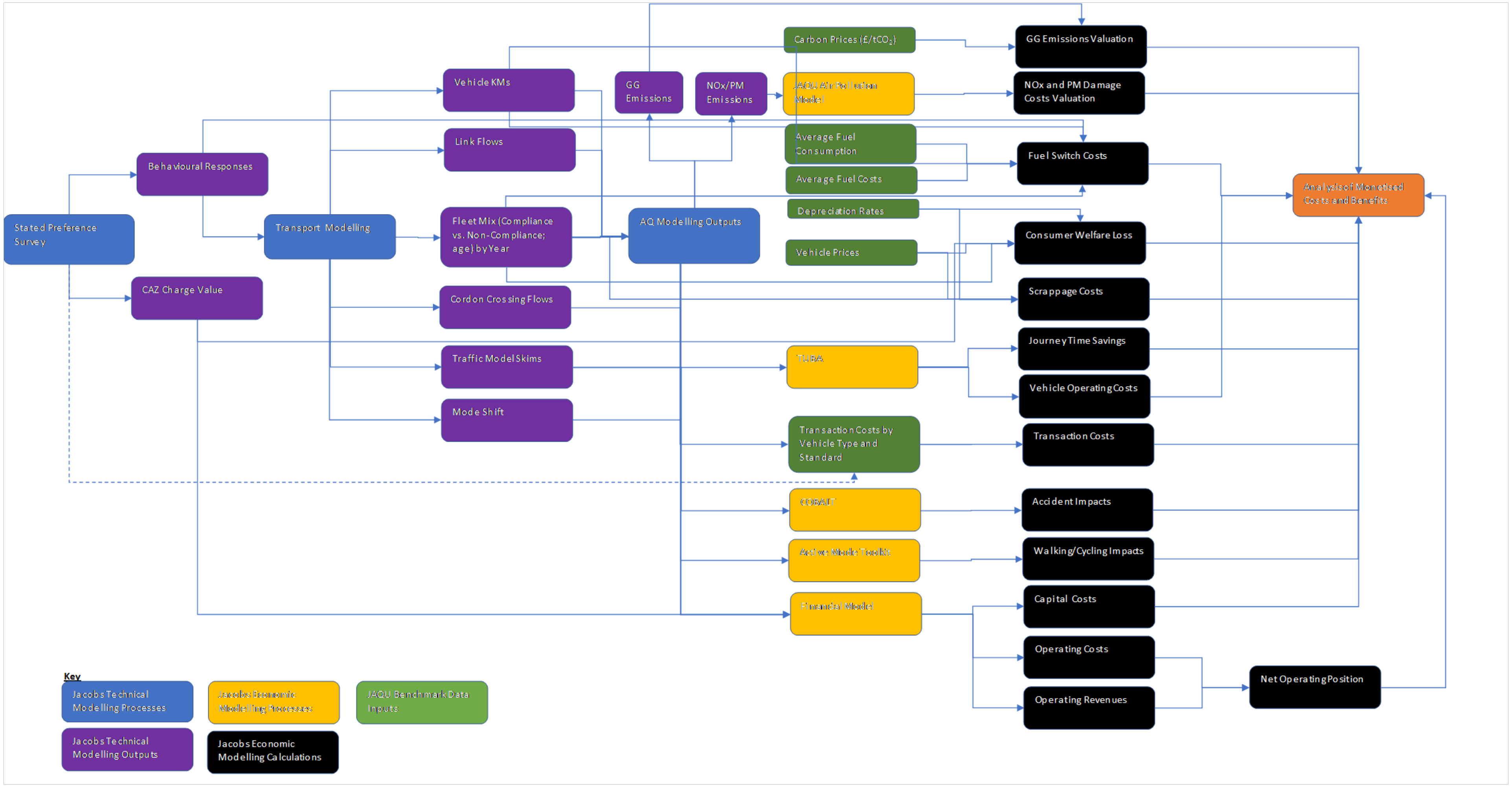

Figure 2.1: Overarching Methodological Framework for Economic Analysis

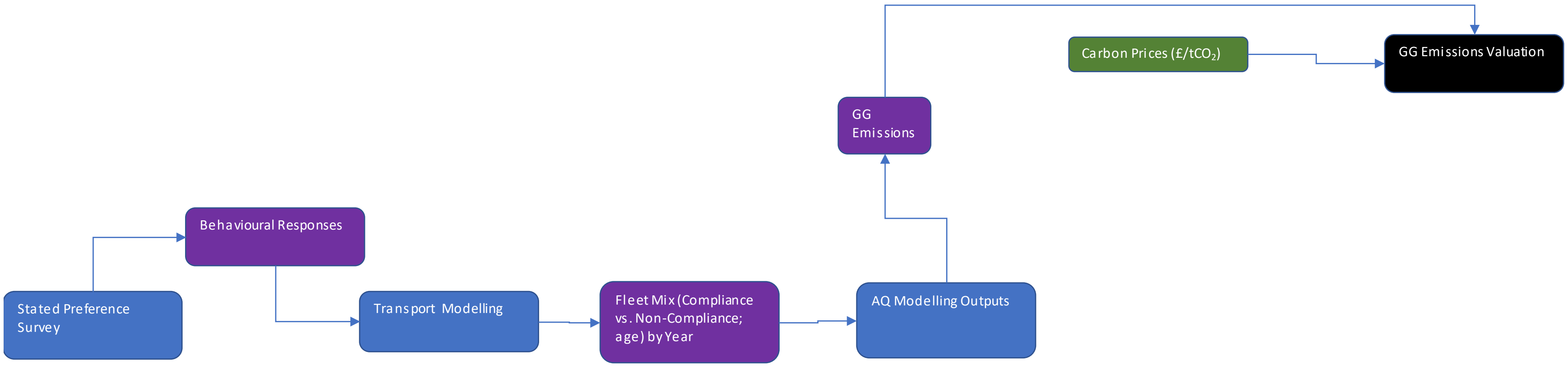

Figure 4.1: Approach to Assessing Economic Impacts of Greenhouse Gas Emissions

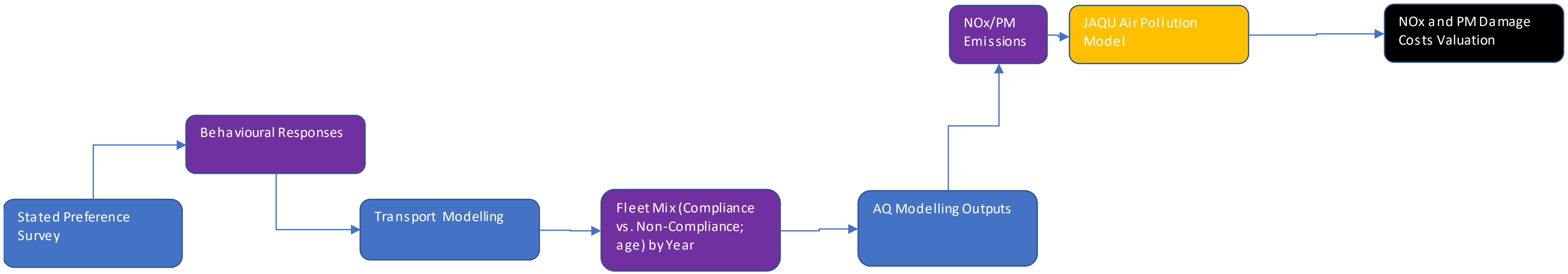

Figure 4.2: Approach to Assessing Economic Impacts of PM/NO_2 Emissions

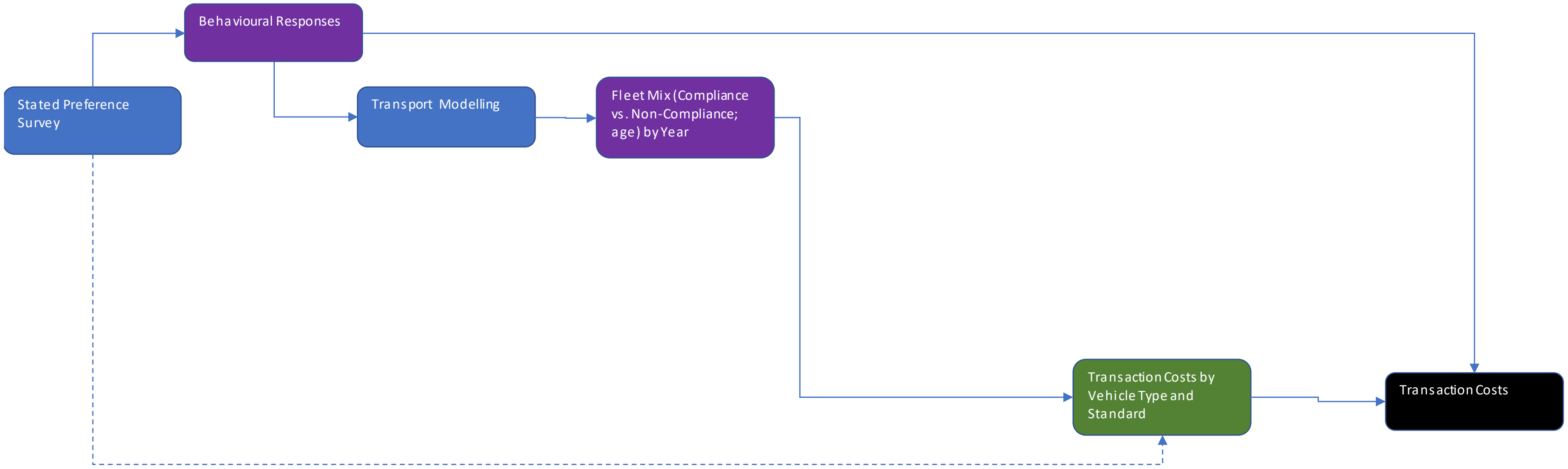

Figure 5.1: Approach to Assessing Economic Impacts of Transaction Costs

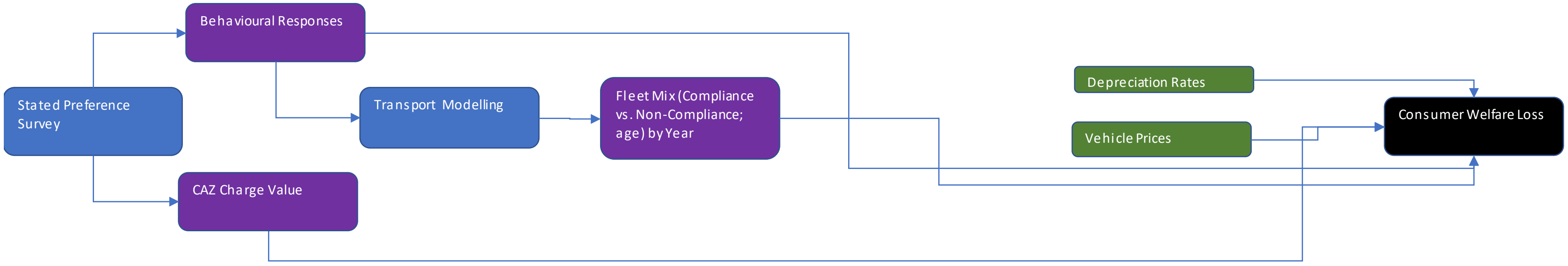

Figure 5.2: Approach to Assessing Economic Impacts of Consumer Welfare Loss

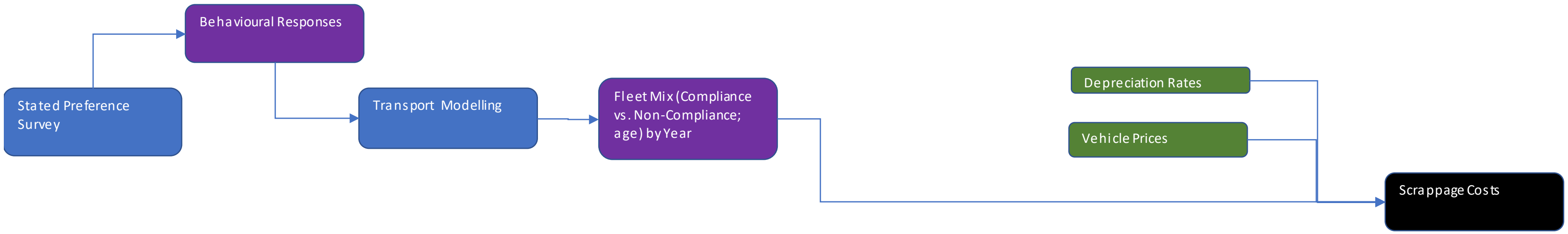

Figure 5.3: Approach to Assessing Economic Impacts of Vehicle Scrappage