Bristol City Council Clean Air Plan

Economic Assessment Methodology Report E1

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1. Introduction

1.1 Clean Air Zone Context

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

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

The UK Government continue to transpose European Union law into its Environment Bill[2] , to ensure that certain standards of air quality continue to be met, by setting air quality assessment levels (AQALs) on the concentrations of specific air pollutants. It's very unlikely that these AQALs will differ to EU Limit Values prescribed by the European Union's Air Quality Directive and transcribed in the UK's Air Quality Standards Regulation 2010. Therefore, these Limit Values will remain in enforcement post-Brexit. In common with many EU member states, the EU Limit Value for annual mean nitrogen dioxide (NO_2) is breached in the UK and there are on-going breaches of the NO_2 limit value in Bristol. The UK government is taking steps to remedy this breach in as short a time as possible, with the aim of reducing the harmful impacts on public health. Within this objective, the Government has published a UK Air Quality Plan and a Clean Air Zone Framework, both originally published in 2017 (noting there have been subsequent revisions). The latter document provides the expected approach for local authorities when implementing and operating a Clean Air Zone (CAZ). The following business cases have been submitted to JAQU for the Clean Air Plan; Strategic Outline Case (April 2018), an Outline Business Case (November 2019 and updated between April and June 2020) and a Full Business Case (February 2021).

1.2 Purpose of this Report

This Economic Appraisal Methodology Report (EAMR) is written to support the FBC and outlines the overarching framework and detailed analysis that underpins the economic appraisal of the preferred option for the Bristol Clean Air Plan, i.e. Small CAZ D. 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 Full Business Case (FBC).

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

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[1] Public Health England (2014) Estimating local mortality burdens associated with particular air pollution. https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution

[2] Environment Bill 2019-21 https://services.parliament.uk/bills/2019-21/environment.html

Earlier versions of this report were published in January 2019, October 2019, June 2020 and February 2021 in support of the developing economic cases.

This document reflects the updated Bristol Clean Air Zone modelling, including the modelled impacts of the Bristol Street Space Schemes on the Bristol highway network and Small CAZ D.

The Street Space Schemes have been incorporated in an updated Baseline model which has helped refine the Bristol Clean Air Zone scheme presented in the Outline Business Case submission, prior to the Full Business Case submission.

2. Analytical Framework

2.1 Overarching Framework

The overarching framework for assessing the economic impacts of the preferred intervention for Bristol's 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, 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 Bristol, 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;
  - Damage costs, sourced from DEFRA's Air Quality Damage Cost Appraisal Toolkit;
- 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 (based on Transport Economic Efficiency tables);
  - Cost modelling – which provides capital and operational cost 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; and
  - 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) for the intervention, 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), which act 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 2020)
- DfT Transport Analysis Guidance (TAG) framework (updated October 2019)

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)
- Bristol ANPR data (2017)
- Bristol taxi licensing data (2018)
- Bristol 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 (2019)
- Vehicle prices, informed by ANPR data on most common car types in Bristol, www.parkers.co.uk, www.Which.com and discussion with local bus and fleet operators.
- DEFRA's Air Quality Damage Cost Appraisal Toolkit

Other key assumptions adopted within the model include:

- Opening year of 2022 to reflect assumed scheme opening
- Appraisal period of ten years (2022-2031), 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 HM Treasury's GDP Deflator (2020)

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 FBC should be consulted for further details on these key data sources and assumptions:

- Behavioural Responses – FBC-28 'Stated Preference Survey', Appendix F and FBC-26 'Response Rates' within Appendix E of the FBC.
- Air Quality Technical Workstream – FBC-18 'AQ2 Methodology Report' and FBC-19 'AQ3 Modelling Report' within Appendix D of the FBC.
- Traffic Modelling Technical Workstream – FBC-22 'T2 Model Validation Report', FBC-23 'T3 Methodology Report ', FBC-24 'ANPR Summary TN', FBC-25 'LGV and HGV Validation TN', FBC-26 'Response Rates' and FBC-27 'T4 Model Forecast Report' within Appendix E of the FBC.

2.3 Structure of this Report

This report provides a step-by-step guide to the approach adopted to assess 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 intervention scheme.
  - PM/NOx Emissions – an assessment of the change in PM and NO_2 emissions resulting from implementation of the intervention 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 intervention 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 intervention scheme.
  - Scrappage Costs – an assessment of the loss in asset value for vehicles that are scrapped earlier as a result of implementation of the intervention 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 intervention 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 intervention scheme.
  - Walking/Cycling Impacts – an assessment of the change in number of individuals travelling by active modes as a result of implementation of the intervention scheme.
- Costs to Local/Central Government – an analysis of the cost to set-up and operate the intervention scheme.
  - Set-Up (Implementation) Costs – an assessment of the capital expenditure required to deliver the intervention scheme.
  - Running (Operational) Costs – an assessment of the ongoing operational expenditure required to deliver the intervention 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 net present value analysis and are therefore discounted from consideration.

The following sections detail the 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 considers the following scenarios:

- Baseline case – 2022-2031 scenario without a Clean Air Plan
- Preferred intervention scheme – 2022-2031 scenario with the following measures in place:
  - Small Area Class D CAZ charging non-compliant cars, buses, coaches, taxis, HGVs and LGVs;
  - Holding back traffic to the city centre through the use of existing signals; and

  - Changes to the boundary at Cabot Circus so vehicles can enter / exit Cabot Circus car park via Houlton St access without going through the CAZ.

  This intervention scheme also includes Fast Track measures, some of which have been included in the revised Baseline (e.g closure of Cumberland Rd inbound and other measures such as additional cycle provision in the zone, additional air quality monitors etc). The M32 P&R and bus lane are not included as it cannot be delivered within the study programme, so do not form part of this option.

Note that the assessment is predicated on a 1st June 2022 switch-on date for the intervention option. As such, the economic analysis presented in the economic case reflects intervention impacts in 2022 accruing for a portion of the year only, rather than the full year. A pro-rata approach was adopted to account for the scheme being partially in place in 2022, based on numbers of days per month from start of June through to end of December compared to total days per year. This resulted in an adjustment factor of c. 59% being applied to 2022 economic analysis. This factor was validated against historic annual count data for BCC and more up to date 2019 count data at M32 (both of which demonstrate June-December traffic also represents 59% of annual traffic), which demonstrates excellent alignment with the pro-rata factor.

Also, in light of the change in opening year, resultant shift in economic appraisal period from 2021-30 to 2022-31 and the availability of traffic and air quality modelling data for 2021, 2023 and 2031 only, the approach to interpolation has been updated. In particular, the following key elements of the interpolation process that are worth noting are:

- 'Pre-CAZ' data for 2020 is no longer required; 2021 modelled baseline data provides the revised 'pre-CAZ' data.
- In the absence of 2022 modelled data, the opening year data for the baseline and intervention scenarios has been estimated via interpolation of 2021 and 2023 modelled data.
- Data for 2023-2031 reliant on same interpolation processes as utilised previously.

3. Vehicle Fleet Composition

3.1 Base and Baseline Vehicle Fleet

Based on 2021 model outputs, the compositional split of the 2021 baseline vehicle fleet between compliant and non-compliant vehicles is outlined in Table 3.1. For the purposes of the Table 3.1, vehicle compliance is defined as follows:

- Petrol vehicle compliance based on Euro 4+ for all vehicles;
- Diesel vehicle compliance (including all HGVs, buses/coaches) based on Euro 6+ for all vehicles.

Table 3.1: Base Vehicle Trips (AADT) in 2021

Euro Standard	Cars/Taxis (Petrol)	Cars/Taxis (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Buses/ Coaches
Compliant	108,456	42,681	107	25,186	5,067	1,626	679
Non-Compliant	12,178	41,923	89	16,100	1,910	253	295

Source: Jacobs Transport Modelling

The 2021 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-28 'Stated Preference Survey Report' Appendix F of this FBC for more detail). The key primary behavioural response rates derived from the survey are replicated in Table 3.2.

Table 3.2: Primary Behavioural Response Rates

Response	Cars	LGV	HGV rigid	HGV artic	Buses	Coaches	Taxis
Pay Charge/ Excluded	10.4%	15.9%	8.8%	8.8%	0.0%	17.8%	4.1%
Avoid Zone	19.0%	19.2%	4.3%	4.3%	0.0%	0.0%	0.0%
Cancel Journey/ Change Mode	20.4%	2.6%	4.3%	4.3%	6.4%	11.4%	0.0%
Replace Vehicle/ Upgrade	50.3%	62.2%	82.6%	82.6%	93.6%	70.8%	95.9%
Total	100.0%	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 3.2 were artificially adjusted within the model to reflect feedback received by local bus operators in Bristol, which demonstrated that all buses would be compliant by 2021 in the baseline. Hence, the intervention scheme is assumed to have no effect on buses.

In relation to the replace vehicle/upgrade behavioural choice, a secondary behavioural response assumption was adopted in line with JAQU guidance. Table 3.3 outlines the standard proportion of people replacing existing vehicles with new vehicles versus people replacing with used (same fuel) and used (switched fuel) vehicles.

Table 3.3: Secondary Behavioural Response Rates (Source JAQU Guidance)

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%	0%	100%
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%

3.3 Upgrade in Vehicle Fleet

Future composition of the vehicle fleet was determined by applying the behavioural responses to the 2021 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 cordons in 2021, 2023 and 2031 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 the years 2022 and 2031 is presented in Tables 3.4 to 3.7. 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 information on buses in the tables below, because bus operators in Bristol have confirmed that the bus fleet will be fully compliant by 2021 in the baseline.

Table 3.4: Vehicle Fleet (AADT) in 2022, Baseline

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Coaches
1	0	0	1	0	0	0	0	0	0
2	698	52	22	162	9	1	52	4	13
3	5,243	1,871	49	683	102	18	389	142	76
4	10,364	5,315	5	2,909	236	11	105	404	38
5	34,282	28,128	46	8,935	1,083	154	346	2,138	100
6	63,135	46,115	85	29,168	5,551	1,697	637	6,622	749
Compliant	107,781	46,115	137	29,168	5,551	1,697	1,087	6,622	749
Non-Compliant	5,941	35,367	71	12,689	1,431	183	441	2,688	226

Source: Jacobs Transport Modelling

Table 3.5: Vehicle Fleet (AADT) in 2022, Intervention Case

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Coaches
1	0	0	1	0	0	0	0	0	0
2	583	41	13	119	9	0	2	0	10
3	4,079	1,189	29	461	68	11	16	8	46
4	10,902	3,089	5	1,869	149	7	145	20	23
5	36,634	13,230	53	5,186	621	93	488	85	62
6	68,616	49,299	100	33,495	6,054	1,846	914	9,387	829
Compliant	116,152	49,299	158	33,495	6,054	1,846	1,547	9,387	829
Non-Compliant	4,662	17,549	42	7,635	847	112	19	112	141

Source: Jacobs Transport Modelling

Table 3.6: Vehicle Fleet (AADT) in 2031 Baseline

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Coaches
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	149	81	0	107	6	0	3	0	0
5	6,028	3,585	2	1,170	83	10	119	0	0
6	116,705	54,759	119	46,010	7,094	1,918	2,310	8,602	1,009
Compliant	122,883	54,759	121	46,010	7,094	1,918	2,432	8,602	1,009
Non-Compliant	0	3,666	0	1,277	90	10	0	0	0

Source: Jacobs Transport Modelling

Table 3.7: 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)	Coaches
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	152	6	0	16	1	0	3	0	0
5	6,153	266	2	175	7	1	120	0	0
6	119,122	55,873	114	44,027	6,999	1,892	2,328	8,671	985
Compliant	125,427	55,873	116	44,027	6,999	1,892	2,452	8,671	985

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)	Coaches
Non-Compliant	0	272	0	191	8	1	0	0	0

Source: Jacobs Transport Modelling

For the intervening years between 2023 and 2031, interpolation was undertaken to estimate the annual change in the vehicle fleet. Traffic flows for years between 2023 and 2031 were calculated using interpolation factors derived from traffic growth forecasts from TemPRO. To calculate the required vehicle and 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 2023 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 2023 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 2023 to 2031.

Prior to 2022, 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 scenarios is outlined in Table 3.8. The table clearly demonstrates that the number of non-compliant trips reduces at much quicker rate in the intervention case relative to the baseline.

Table 3.8: Percentage Reduction in Non-Compliant Trips in the Baseline (Relative to 2020)

Scenario	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Baseline	18%	31%	39%	47%	55%	63%	70%	78%	86%	93%
Intervention	92%	94%	94%	95%	96%	97%	97%	98%	99%	99%

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 interpolated between modelled outputs for 2021 and 2023 for the opening year (2022). Explicit modelled data was utilised for the interim/compliance year (2023) and future year (2031). Linear interpolation was undertaken for intervening years between 2023 and 2031, for 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 interventions across the appraisal period.

Table 4.1: Temporal Change in CO_2 Emissions (tonnes)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Baseline	167,702	285,193	284,683	284,172	283,662	283,151	282,641	282,130	281,620	281,109
Intervention	165,457	282,149	282,496	282,843	283,190	283,537	283,884	284,231	284,578	284,925
Difference	2,245	3,044	2,187	1,329	472	-386	-1,243	-2,101	-2,958	-3,816

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)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
£/tCO2e	£71.59	£72.74	£73.90	£75.05	£76.21	£77.36	£78.52	£79.67	£80.83	£88.33

Source: BEIS Carbon Tables (2018 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[3]:

- High concentrations can lead to inflammation of the airways.

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

- 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 as older people, children and people with pre-existing respiratory and cardiovascular conditions[4].

- 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[5] are also linked to air pollution exposure.
- Exposure can exacerbate lung and heart disease in older people[6].
- Approximately 40,000 deaths can be attributed to NO_2 and fine particulate matter pollution in England every year[7].

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; and
- 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 Bristol) through a reduction in emissions of NO_2;
- Reduced impact on climate change through a reduction in NOx; and
- Reduced damage to townscape and the built environment, 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:

- 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/NO_2 emissions across the appraisal period for both the baseline and intervention scenarios as shown in Table

[4] 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
[5] 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
[6] 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/)
[7] *Royal College of Physicians (2016) 'Every breath we take: the lifelong impact of air pollution'. 2016*

4.3. Model data was interpolated between modelled outputs for 2021 and 2023 for the opening year (2022). Explicit modelled data was utilised for the interim/compliance year (2023) and future year (2031). Linear interpolation was undertaken for intervening years between 2023 and 2031, for both the baseline and intervention scenarios.

The difference in emissions under the two scenarios was then calculated to determine the change in PM/NO_2 emissions attributable to the interventions across the appraisal period

Table 4.3: Temporal Change in PM/NO_2 Emissions (tonnes)

NO_2	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Baseline	302.4	476.4	448.9	421.4	393.8	366.3	338.8	311.3	283.7	256.2
Intervention	271.7	432.5	411.2	389.9	368.6	347.3	326.0	304.7	283.4	262.1
Difference	30.7	43.9	37.7	31.5	25.2	19.0	12.8	6.6	0.3	-5.9
PM	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Baseline	18.42	31.00	30.99	30.98	30.96	30.95	30.94	30.93	30.91	30.90
Intervention	17.89	30.30	30.38	30.45	30.53	30.60	30.68	30.75	30.83	30.90
Difference	0.53	0.70	0.61	0.53	0.44	0.35	0.26	0.18	0.09	0.00

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 DEFRA's Air Quality Damage Cost Appraisal Toolkit). Bristol falls within the 'Urban Big' area type according to DfT's classification system, therefore the damage cost relevant to 'Urban Big' setting was utilised.

Table 4.4: Damage Costs (£ per Tonne)

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
NO_2	£17,353	£17,700	£18,054	£18,415	£18,783	£19,159	£19,542	£19,933	£20,332	£20,738
PM	£324,500	£330,990	£337,610	£344,362	£351,249	£358,274	£365,440	£372,749	£380,204	£387,808

Source: DEFRA's Air Quality Damage Cost Appraisal Toolkit

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 5.4. No additional or separate analysis is provided here.

5.2 Consumer Welfare Loss

The intervention option 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 individuals upgrading or replacing their vehicles earlier; and
- Welfare loss associated with changing travel patterns or behaviours (i.e. mode shift, cancelled journeys, diverted journeys).

5.2.1 Replacing Vehicles

As noted above, the intervention case leads to accelerated reduction in non-compliant trips which is indicative of an acceleration of vehicle replacement (see Table 3.8). 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; and
- 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 5.1.

Table 5.1: 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 scenario, as vehicle owners upgrade sooner than in the bassline.

The total number of vehicle owners who replace their vehicle in response to intervention 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.

For the intervention case, in order to determine the number of vehicles that upgrade, the daily frequency of non-compliant vehicle entries into the CAZ or exclusion zone in 2022 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-month period, was assumed to be representative of annual trip patterns.

Based on the response rates noted in Table 3.2, the number of trips upgrading was converted to a number of vehicles that upgrade by assuming that those vehicles that enter the CAZ or exclusion zone with the highest frequency (i.e. those vehicles that make the most trips on separate days over the two month period) are the first to upgrade. The first vehicles to upgrade are those entering the CAZ or exclusion zone with the highest frequency because these vehicles would incur the CAZ charge most regularly or most disruption to day-to-day activities. As such, from a financial and utilitarian 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 5.2.

Table 5.2: Vehicle Upgrade Response Rate Estimates

Vehicle Type	Small CAZ D	
	Trips	Vehicles
Car	50%	9%
LGV	62%	15%
Rigid HGV	83%	32%
Artic HGV	83%	47%
Taxi	96%	74%
Coach	71%	18%

Source: Jacobs Economic Modelling

Based on the 'vehicles' response rates outlined in Table 5.2 and the interpolation approach described in Section 3.3, the number and timing of vehicle upgrades that are directly attributable to the intervention scenario is outlined in Table 5.3.

Table 5.3: Rate of Vehicle Upgrading

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Car Petrol	966	24	4	3	3	2	2	3	0	0
Car Diesel	3,318	18	23	24	24	24	25	25	25	25
Taxi Petrol	584	8	1	1	1	1	1	1	0	0
Taxi Diesel	2,032	4	10	10	10	10	10	10	10	10

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
LGV petrol	11	0	0	0	0	0	2	0	0	0
LGV diesel	2,080	58	28	28	28	27	27	27	26	26
Rigid HGV	567	10	4	4	4	3	3	4	4	4
Artic HGV	112	2	1	1	1	1	1	1	1	1
Coaches	46	2	1	1	1	1	1	1	1	1
Total	9,717	126	71	71	71	69	70	69	67	67

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 2022 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). Values for the replacement and replaced vehicles reflect 2018 market prices sourced at that time from industry databases, weighted by:

- The popularity of certain brands/models in Bristol (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 2022, with all residual values for older cars pivoting from the value of the new vehicles listed in Table 5.4 and the appropriate depreciation rate.

Table 5.4: 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	Taxi and PHV costs in line with car prices
PHV Diesel	£17,588	Taxi and PHV costs in line with car prices
Taxi Petrol	£19,818	Taxi and PHV costs in line with car prices
Taxi Diesel	£17,588	Taxi and PHV costs in line with car prices
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/Coaches	186,667	Cost for new bus vehicle averaged across single-deck, double deck and midi types (source: Table 4 – Rudimentary funding costs (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 3.8). A factor of 50%[8] 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 5.5).

Table 5.5: Euro Standard of Non-Compliant Components of Fleet

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Car Petrol	0%	12%	88%			
Car Diesel	0%	0%	5%	15%	80%	
LGV petrol	1%	31%	68%			
LGV diesel	0%	1%	5%	23%	70%	
Rigid HGV	0%	8%	92%			
Artic HGV	0%	0%	10%	6%	84%	
Buses	0%	6%	34%	17%	44%	
Taxis Petrol	0%	12%	88%			
Taxis Diesel	0%	0%	5%	15%	80%	

[8] 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

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Coaches	0%	6%	34%	17%	44%	

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 3.3. 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 replacement vehicle differential value for vehicle owners upgrading to new and used (same fuel/switch fuel) vehicles are listed in Table 5.6:

Table 5.6: Weighted Replace Vehicle Value Differential (£)

	New	Used (Same Fuel)	Used (Switch Fuel)
Car Petrol	£2,543	£95	£0
Car Diesel	£2,585	£456	£450
Taxi Petrol	£2,661	£100	£0
Taxi Diesel	£2,183	£419	£414
LGV petrol	£1,691	£68	£0
LGV diesel	£2,606	£480	£0
Rigid HGV	£9,664	£2,228	£0
Artic HGV	£10,550	£1,712	£0
Coaches	£27,377	£5,461	£0

Source: Jacobs Economic Modelling

The 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.

5.2.2 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 or exclusion zone in response to the proposed scheme. Diverted trips were not included in the consumer welfare analysis as any economic impact was assumed to be captured within the journey time savings/vehicle operating cost analysis below.

Table 3.4 highlights the number of non-compliant vehicle trips in AADT terms in the 2022 baseline and Table 3.8 highlights the reduction in non-compliant vehicles in the baseline. Meanwhile Table 3.2 demonstrates the proportion of trips that would be cancelled, change mode or avoid the zone. 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 5.7.

Table 5.7: Trips with Changed Travel Patterns/Behaviours

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Car Petrol	500,519	338,448	261,105	193,746	136,370	90,813	54,398	0	0	0
Car Diesel	2,979,700	4,715,458	4,215,799	3,702,064	3,185,633	2,664,360	2,137,907	1,605,967	1,069,322	526,751
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	3,340	4,721	5,719	6,330	6,555	6,409	0	0	0	0
LGV diesel	592,918	819,457	725,958	632,845	540,119	451,749	363,733	276,071	188,762	101,807
Rigid HGV	26,328	34,296	30,286	26,266	22,237	18,371	14,496	10,612	6,719	2,816
Artic HGV	3,366	4,196	3,663	3,140	2,627	2,146	1,674	1,211	758	314
Coaches	5,534	7,419	6,466	5,513	4,560	3,648	2,736	1,824	912	0
Total	4,111,706	5,923,993	5,248,996	4,569,904	3,898,100	3,237,496	2,574,943	1,895,684	1,266,472	631,687

Source: Jacobs Economic Modelling

The approach to monetising consumer welfare loss relating to changing travel patterns and behaviours assumes that a change is made where the cost of the action is less than the cost of the respective charge for entering the boundary, otherwise the rational economic choice would be to pay the 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 consumer welfare loss 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 not all trips are assumed to experience a consumer welfare loss in the intervention scenario relative to the baseline scenario. The ANPR survey in 2017 revealed that only approximately 31% of daily non-compliant vehicle trips into the CAZ were made by unique non-compliant vehicles. Hence only 31% of non-compliant vehicle trips would be charged for entering the boundary as all other trips would be repeat trips by vehicles that had already entered the boundary. 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).

5.3 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.

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

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 case 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 2022 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
- 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 case (Table 5.8)

Table 5.8: Weighted Average Scrappage Costs (£)

Vehicle Type	Small CAZ D
Car Petrol	£193
Car Diesel	£903
Taxi Petrol	£201
Taxi Diesel	£829
LGV petrol	£124
LGV diesel	£887
Rigid HGV	£415
Artic HGV	£3,383
Coach	£5,502

Source: Jacobs Economic Modelling

The values above were then applied to the profile of vehicle upgrades in the intervention case. The profile is outlined in Table 5.9, based on Table 5.3 above and pivoting from the relevant behaviour response rates and interpolation data presented above.

Table 5.9: Rate of Vehicle Upgrading to New Vehicles

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Car Petrol	241	6	1	1	1	1	0	1	0	0
Car Diesel	830	4	6	6	6	6	6	6	6	6
Taxi Petrol	146	2	0	0	0	0	0	0	0	0
Taxi Diesel	508	1	2	2	2	2	2	2	3	3
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
Coach	0	0	0	0	0	0	0	0	0	0
Total	1,725	14	10	10	9	9	9	9	9	9

Source: Jacobs Economic Modelling

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

5.4 Journey Time/Vehicle Operating Costs

The proposed scheme could also have an impact on transport economic efficiency (TEE), measured in terms of changes to journey time savings and vehicle operating costs. Transport user benefits were assessed using TUBA 1.9.14.4. The key assumptions adopted include:

- Model outputs from the transport modelling workstream;
- Modelled years: 2021, 2023 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: Bus/Coach, HGV, LGV and Car;
- Annualisation factors: AM 682, PM 701, Inter-Peak 1518;
- Value of Time: TAG Databook v1.13.1 July 2020; and
- A TUBA v1.9.14.4 sensitivity test with *Economics_TAG_db1_14_0* as economics file was undertaken.

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 TAG guidance (July 2020 parameters were used);
- trip and skim matrices from the GBATS4 model; and
- scheme file detailing all aspects of the scheme including 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 GBATS4 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 5.10 below.

Table 5.10: TUBA Annualisation Factors Applied to Model Outputs

Period	Modelled Duration (minutes)	Annual Factor	Period Factor	Overall Annualisation Factor
Morning peak	60	253	2.7	682
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 GBATS model output files, to assure compliance with standard TUBA process:

- TAG advice that the economic assessment should be performed over ten-year period. Hence, the outputs have been adjusted to apply to 2022 to 2031.
- Do Something origin-destination matrices have been applied to both the Do Minimum and the Do Something scenarios.
- GBATS 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.
- HGV and Buses are coded as PCUs in the GBATS model. Hence, the relevant factors (1/2.3 and 1/2.5) have been applied to HGV and Bus matrices to convert to vehicles.
- The Clifton Suspension Bridge Toll is modelled as 50 p in GBATS. Since the current toll on the bridge is £1, the cost has been factored by 2.
- 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.
- The GBATS model does not have purpose defined user classes, so a default factor of typical purpose distribution has been applied to the user classes in TUBA.
- As the opening date for BCC CAZ is planned for June 2022, a seasonality factor of 585 was applied to 2022 benefits in order to exclude the first five months of 2022 (as per discussion in Section 2.4).

See table 5.11 for further detail of the user classes applied.

Table 5.11 User Classes in TUBA

User Class	Description	Vehicle/Sub mode	Purpose	Person type
1	Cars Low Income	Car	Default split	Default split
2	Cars Medium Income	Car	Default split	Default split
3	Cars High Income	Car	Default split	Default split
4	Cars EMP	Car	Default split	Default split
5	Taxis	Car	Default split	Default split

User Class	Description	Vehicle/Sub mode	Purpose	Person type
6	LGV	LGV freight	Business	Default split
7	HGV	OGV1	Business	Default split
8	Coach	Bus	Business	Driver
9	Coach	Bus	Default split	Passenger

5.5 Transaction Costs

The intervention case 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 5.3), 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 5.12 outlines the number of vehicles induced to upgrade earlier than they otherwise planned to, as a result of intervention.

Table 5.12: Upgraded Fleet by Vehicle Type and Euro Standard

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Car Petrol	0	118	888	0	0	0
Car Diesel	0	5	187	531	2,810	0
Taxi Petrol	0	70	528	0	0	0
Taxi Diesel	0	3	112	318	1,683	0
LGV petrol	0	4	9	0	0	0
LGV diesel	0	30	127	540	1,659	0
Rigid HGV	0	47	558	0	0	0
Artic HGV	0	0	12	7	100	0
Coaches	0	3	18	9	23	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 5.13.

Table 5.13: 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).

5.6 Accident Impacts

An accident analysis was undertaken using DfT's CoBALT software. See FBC-30 'COBALT – accident impact assessment' Appendix Giii of this FBC for further details.

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 appraisal period 2022-31, a reduction of 72 accidents is anticipated through intervention, as outlined in Table 5.14.

Table 5.14: Change in Accidents and Casualties

Accident Summary	Small CAZ D
Baseline Accidents	7,607
Intervention Accidents	7,536
Accident Reduction Due to Scheme	71

Source: Jacobs Transport Modelling

5.7 Walking/Cycling Impacts

By inducing mode shift for non-compliant vehicle owners, the intervention case 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 Appraisal Toolkit (AMAT) 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 change mode component of the 'Cancel Journey/ Change Mode' behavioural response and applying that proportion to the number of non-compliant vehicle trips forecast to change travel patterns or behaviour.

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 abstraction rates from car trips to walking (13.75%) and cycling (7.5%) according to Dunkerley et al's (2018) 'Bus fare and journey time elasticities and diversion factors for all modes'[12]. The resulting forecast for number of additional walking and cycling trips each year converted from non-compliant vehicle trips is outlined in Table 5.15.

Table 5.15: Additional Walking and Cycling Trips Converted from Non-Compliant Vehicle Trips in the Baseline

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Walking	70,771	102,749	91,019	79,206	67,541	56,019	44,574	32,658	21,748	10,718
Cycling	129,746	188,373	166,868	145,211	123,825	102,702	81,719	59,873	39,871	19,649
Total	200,517	291,121	257,887	224,417	191,366	158,721	126,294	92,531	61,619	30,367

Source: Jacobs Economic Modelling

The annual number of active mode trips were converted to daily trips and inputted into the Active Mode Toolkit. 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 proportion of return

[12] Derived from Table 27 'Recommended diversion factor values of an intervention on car' in Dunkerley et al (2018) 'Bus fare and journey time elasticities and diversion factors for all modes'. Based on 6% (cycling) and 11% (walking) of 80% of trips that switch to another mode, pro-rated up to 100% (i.e. ignoring the proportion who do not travel according to the research – already captured via 'cancel' journey response in the current analysis).)

journeys, 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 (where relevant).

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-41 'Finance Report' Appendix Q of this FBC. Unlike in the financial analysis, optimism bias has been applied to intervention option costs adopted in the economic case in line with the HM Treasury Green Book benchmark values. These are summarised in Table 6.1.

Where tender prices were available or BCC framework unit rate-based cost estimates were derived, the lower bound optimism bias value was adopted. The upper bound value, which represents the average historic optimism bias found at the outline business case stage for traditionally procured projects, was applied where tender prices or detailed, evidenced-backed cost estimates[14] do not currently exist and there is therefore more uncertainty in costs.

The costs used in the economic assessment are based on an earlier estimate to the final costs presented in FBC-33, the Scheme Costs Report. Detail of the development of the scheme cost is presented in FBC-33.

Table 6.1: Optimism Bias (OB) Adjustments to Costs

Activity	Upper Bound OB	Lower Bound OB	Use
Standard Civil Engineering	44%	3%	For OPEX/CAPEX relating to Highway Works, Decommissioning, Monitoring and Evaluation Activities and Installations, Utilities and all non-charging measures (lower bound, as either tender prices or detailed cost estimates)
Equipment/Development	200%	10%	For OPEX/CAPEX relating to IT/Systems (lower bound, as based on tender responses), Revenue Payments, PCN Production, CAZ publicity and advertising (lower bound, as either tender prices or detailed cost estimates)
Outsourcing	41%	0%	For any OPEX/CAPEX requiring external support e.g. Delivery Phase Management, Additional permit contractors, back office support, monitoring and evaluation staff (lower bound, as either tender prices or detailed cost estimates for nearly all items, except Programme Director staff role, to which the upper bound was applied).
N/A	0%	0%	For most BCC staff costs during delivery and operational phase, as costs based on fixed salary rates.

Source: Jacobs Economic Modelling

[14] At this stage, these circumstances only apply to one cost item, namely the Programme Director staff role

Figure 2.1: Overarching Methodological Framework for Economic Analysis

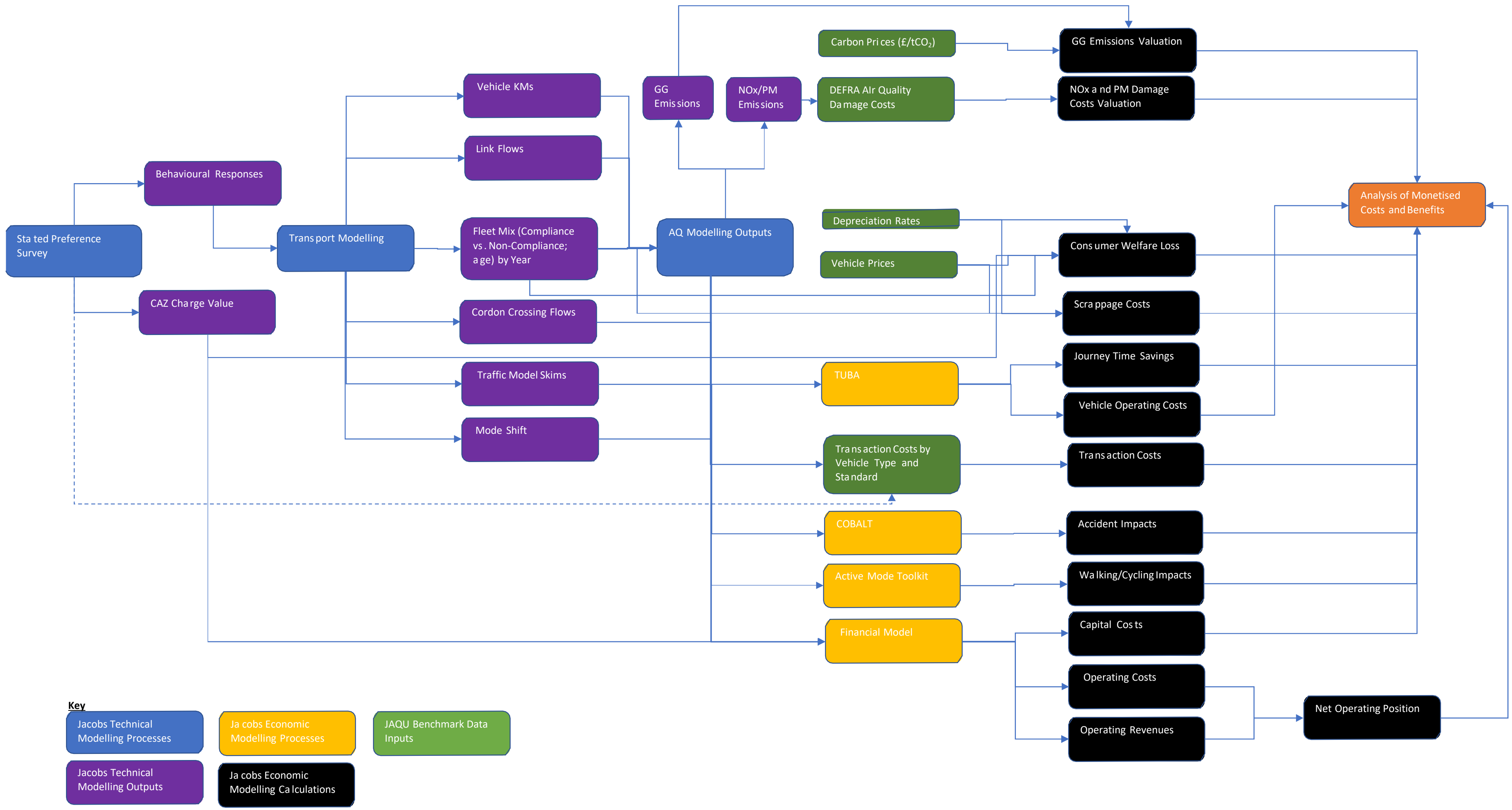

Figure 4.1: Approach to Assessing Economic Impacts of Greenhouse Gas Emissions

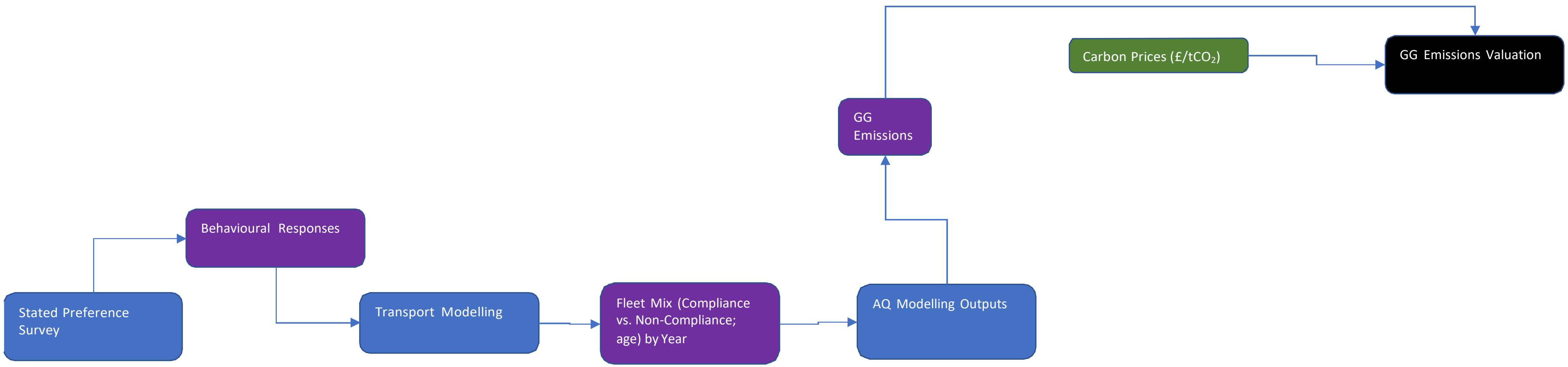

Figure 4.2: Approach to Assessing Economic Impacts of PM/NO_2 Emissions

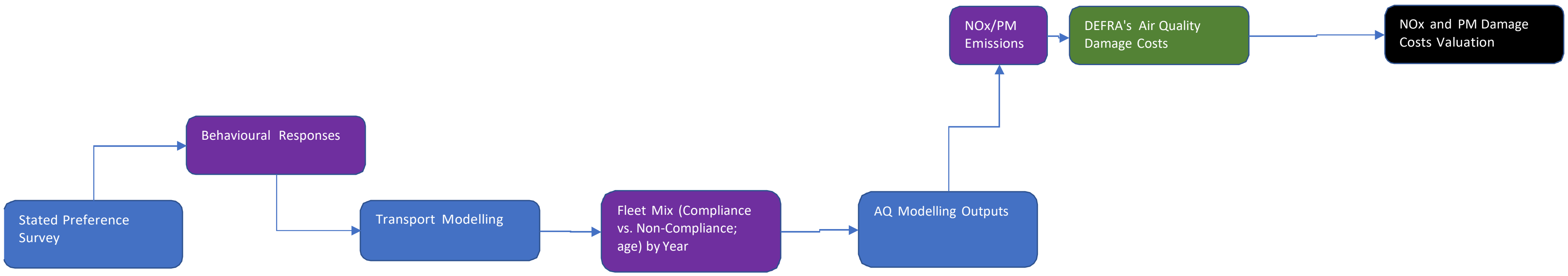

Figure 5.1: Approach to Assessing Economic Impacts of Transaction Costs

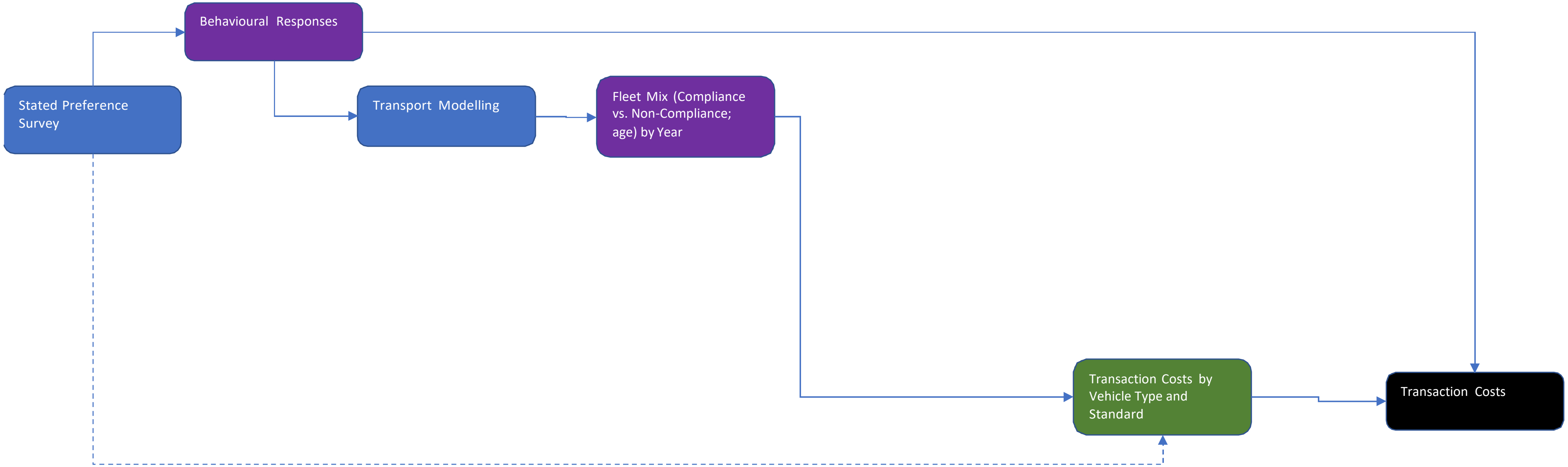

Figure 5.2: Approach to Assessing Economic Impacts of Consumer Welfare Loss

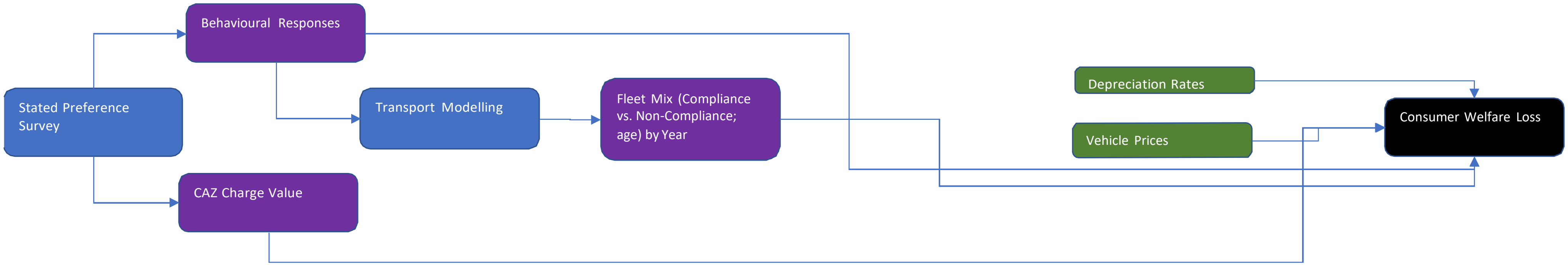

Figure 5.3: Approach to Assessing Economic Impacts of Vehicle Scrappage