Bristol City Council Clean Air Plan

Outline Business Case

Economic Appraisal Modelling Report (E1)

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Contents

1. Introduction

1.1 Background

The UK has in place legislation transposing requirements in European Union law, to ensure that certain standards of air quality are met, by setting Limit Values on the concentrations of specific air pollutants. In common with many EU member states, the EU limit value for annual mean nitrogen dioxide (NO_2) is breached in the UK and there are on-going breaches of the NO_2 limit value in Bristol. The UK government is taking steps to remedy this breach in as short a time as possible, with the aim of reducing the harmful impacts on public health. Within this objective, the government has published a UK Air Quality Plan and a Clean Air Zone Framework, both published in 2017. The latter document provides the expected approach for local authorities when implementing and operating a Clean Air Zone (CAZ).

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

Jacobs has been commissioned to support BCC to produce an Outline Business Case (OBC) for the delivery of the CAP; a package of measures which will bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in Bristol. The OBC assesses the shortlist of options set out in the Strategic Outline Case, and proposes a preferred option including details of delivery. The OBC forms a bid to central government for funding to implement the CAP.

1.2 Purpose of this Report

This Economic Appraisal Methodology Report (EAMR) is written to support the OBC and outlines the overarching framework and detailed analysis that underpins the economic appraisal of shortlisted options for the Bristol 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 Outline Business Case (OBC).

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

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

2. Analytical Framework

2.1 Overarching Framework

The overarching framework for assessing the economic impacts of the shortlisted options 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.
  - 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 each of the shortlisted options, 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 each shortlisted option, 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 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)
- Bristol ANPR data (2017)
- DfT WebTAG Databook (2018)
- 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 (2018)
- 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 2021 to reflect assumed 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 should be consulted for further details on these key data sources and assumptions:

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

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 shortlisted options.
  - PM/NOx Emissions – an assessment of the change in PM and NO_2 emissions resulting from implementation of the shortlisted options.
- 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 shortlisted options.
  - 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 shortlisted options.
  - Scrappage Costs – an assessment of the loss in asset value for vehicles that are scrapped earlier as a result of implementation of the shortlisted options.
  - Journey Time/Vehicle Operating Costs – an assessment of the change in travel times and vehicle-use costs as a result of implementation of the shortlisted options. 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 shortlisted options.
  - Walking/Cycling Impacts – an assessment of the change in number of individuals travelling by active modes as a result of implementation of the shortlisted options.
- Costs to Local/Central Government – an analysis of the cost to set-up and operate the shortlisted options.
  - Set-Up (Implementation) Costs – an assessment of the capital expenditure required to deliver the shortlisted options.
  - Running (Operational) Costs – an assessment of the ongoing operational expenditure required to deliver the shortlisted options.
- 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.

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 and intervention) across four shortlisted options:

- Baseline case – 2021-2030 scenario without a clean air plan
- Intervention case – 2021-30 scenario with shortlisted options:
  - Option 1: Medium Area Class C (charging non-compliant buses, coaches, taxis, HGVs and LGVs); plus:
    - Diesel car scrappage scheme;

    - HGV exclusion on links within the city centre with exceedances as follows:
      - Park Row/Upper Maudlin St/Marlborough St, Rupert Street, Lewins Mead, Baldwin Street;
    - Close of Cumberland Road inbound to general traffic;
    - M32 Park and Ride with bus lane inbound;
    - Holding back traffic to the city centre through the use of existing signals; and
    - 8-hour car diesel exclusion on Park Row/Upper Maudlin Street and Marlborough Street.
- Medium CAZ D + Option 1: As Option 1 but includes charging non-compliant cars.
- Option 2: 8-hour small area diesel car exclusion (7am – 3pm)
- Hybrid Option: Option 1 + Option 2.

3. Vehicle Fleet Composition

3.1 Base and Baseline Vehicle Fleet

The compositional split of the 2020 baseline vehicle fleet between compliant and non-compliant vehicles for the shortlisted options, based on AADT crossing the relevant option cordon, is outlined in Table 3.1. The 2020 baseline composition is derived by adjusting 2021 baseline modelled fleet data according to the forecast change in vehicle compliance between 2021 and 2022 under the baseline. For the purposes of the two shortlisted options, vehicle compliance is defined as follows:

- Option 1 Medium CAZ C - petrol vehicle compliance based on Euro 4+ for all non-car vehicles; diesel vehicle compliance (including HGVs, buses/coaches) based on Euro 6+ for all non-car vehicles.
- Medium CAZ D + Option 1 – petrol vehicle compliance based on Euro 4+ for all vehicles; diesel vehicle compliance (including HGVs, buses/coaches) based on Euro 6+.
- Option 2: 8-hour small area diesel car exclusion (7am – 3pm) – all vehicles compliant except for diesel cars.
- Hybrid Option: Option 1 + Option 2 – petrol vehicle compliance based on Euro 4+ for all non-car vehicles; diesel vehicle compliance (including HGVs, buses/coaches) based on Euro 6+ for all non-car vehicles; all diesel cars are non-compliant.

Table 3.1: Base Vehicle Fleet (AADT) in 2020

Euro Standard	Cars/Taxis (Petrol)	Cars/Taxis (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Buses/ Coaches
Option 1 Medium CAZ C							
Compliant	186,895	175,068	157	47,890	20,804	6,677	48,161
Non-Compliant	0	0	154	34,540	8,858	1,172	34,694
Medium CAZ D + Option 1							
Compliant	159,572	60,869	157	47,890	20,804	6,677	48,161
Non-Compliant	27,323	114,199	154	34,540	8,858	1,172	34,694
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)							
Compliant	102,696	0	152	40,720	15,763	4,245	40,931
Non-Compliant	0	97,676	0	0	0	0	0
Hybrid Option: Option 1 + Option 2							
Compliant	186,895	0	157	47,890	20,804	6,677	48,161
Non-Compliant	0	175,068	154	34,540	8,858	1,172	34,694

Source: Jacobs Transport Modelling

The 2020 baseline vehicle fleet composition (pivoting from the 2021 baseline vehicle fleet data) 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 OBC-30 'Stated Preference Survey Report' Appendix L of this OBC 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
Option 1 Medium CAZ C							
Pay Charge/ Excluded	0.0%	15.9%	8.8%	8.8%	0.0%	17.8%	4.1%
Avoid Zone	0.0%	19.2%	4.3%	4.3%	0.0%	0.0%	0.0%
Cancel Journey/ Change Mode	0.0%	2.6%	4.3%	4.3%	6.4%	11.4%	0.0%
Replace Vehicle/ Upgrade	0.0%	62.2%	82.6%	82.6%	93.6%	70.8%	95.9%
Total	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Medium CAZ D + Option 1							
Pay Charge/ Excluded	7.3%	15.9%	8.8%	8.8%	0.0%	17.8%	4.1%
Avoid Zone	14.1%	19.2%	4.3%	4.3%	0.0%	0.0%	0.0%
Cancel Journey/ Change Mode	22.1%	2.6%	4.3%	4.3%	6.4%	11.4%	0.0%
Replace Vehicle/ Upgrade	56.5%	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%
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)							
Pay Charge/ Excluded	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Avoid Zone	17.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cancel Journey/ Change Mode	23.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Replace Vehicle/ Upgrade	58.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hybrid Option: Option 1 + Option 2							
Pay Charge/ Excluded	0.0%	15.9%	8.8%	8.8%	0.0%	17.8%	4.1%
Avoid Zone	17.5%	19.2%	4.3%	4.3%	0.0%	0.0%	0.0%
Cancel Journey/ Change Mode	23.8%	2.6%	4.3%	4.3%	6.4%	11.4%	0.0%
Replace Vehicle/ Upgrade	58.7%	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 various intervention options are 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%	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%

**NB for Option 2 and the hybrid, the proportion of diesel cars switching fuel type and to a used vehicle is 100% as diesel cars become non-compliant. All vehicles that upgrade are assumed to switch to the cheapest possible secondhand petrol 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 in all scenarios.

These behavioural responses were incorporated into the traffic modelling to forecast the scale of vehicle movements across the cordons for the shortlisted options in 2021 (opening year) and 2031 (future year) under the intervention scenarios. 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 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 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 for the Medium area CAZ D option. 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 2021, Baseline

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)
Option 1 Medium CAZ C								
1	0	0	3	0	0	0	0	0
2	2,165	219	43	518	87	4	143	14
3	15,025	7,634	94	1,964	656	108	989	474
4	24,739	20,073	11	7,837	1,427	64	312	1,246
5	64,640	66,406	65	20,963	5,852	886	817	4,122

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Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)
6	84,540	84,684	84	48,970	21,273	6,827	1,068	11,367
Compliant	191,108	179,015	160	48,970	21,273	6,827	2,197	11,367
Non-Compliant	0	0	139	31,282	8,022	1,062	1,132	5,855
Medium CAZ D + Option 1								
1	0	0	3	0	0	0	0	0
2	2,165	219	43	518	87	4	143	14
3	15,025	7,634	94	1,964	656	108	989	474
4	24,739	20,073	11	7,837	1,427	64	312	1,246
5	64,640	66,406	65	20,963	5,852	886	817	4,122
6	84,540	84,684	84	48,970	21,273	6,827	1,068	11,367
Compliant	173,919	84,684	160	48,970	21,273	6,827	2,197	11,367
Non-Compliant	17,190	94,331	139	31,282	8,022	1,062	1,132	5,855
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)								
1	0	0	n/a	n/a	n/a	n/a	n/a	n/a
2	1,178	119	n/a	n/a	n/a	n/a	n/a	n/a
3	8,174	4,153	n/a	n/a	n/a	n/a	n/a	n/a
4	13,459	10,920	n/a	n/a	n/a	n/a	n/a	n/a
5	35,166	36,127	n/a	n/a	n/a	n/a	n/a	n/a
6	45,993	46,071	n/a	n/a	n/a	n/a	n/a	n/a
Compliant	103,970	0	n/a	n/a	n/a	n/a	n/a	n/a
Non-Compliant	0	97,391	n/a	n/a	n/a	n/a	n/a	n/a
Hybrid Option: Option 1 + Option 2								
1	0	0	3	0	0	0	0	0
2	2,165	219	43	518	87	4	143	14
3	15,025	7,634	94	1,964	656	108	989	474
4	24,739	20,073	11	7,837	1,427	64	312	1,246
5	64,640	66,406	65	20,963	5,852	886	817	4,122
6	84,540	84,684	84	48,970	21,273	6,827	1,068	11,367
Compliant	191,108	0	160	48,970	21,273	6,827	2,197	11,367
Non-Compliant	0	179,015	139	31,282	8,022	1,062	1,132	5,855

Source: Jacobs Transport Modelling

Table 3.5: 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)
Option 1 Medium CAZ C								
1	0	0	0	0	0	0	0	0
2	2,251	205	7	81	2	0	7	1
3	15,625	7,148	15	309	18	3	46	20
4	25,728	18,795	16	1,233	38	2	510	52
5	67,224	62,178	91	3,298	156	24	1,333	171
6	87,920	79,292	117	68,446	11,487	3,687	1,743	16,702
Compliant	198,748	167,618	224	68,446	11,487	3,687	3,585	16,702
Non-Compliant	0	0	22	4,922	215	28	52	243
Medium CAZ D + Option 1								
1	0	0	0	0	0	0	0	0
2	213	4	7	84	3	0	30	0
3	1,479	123	15	318	20	3	211	17
4	26,226	324	16	1,271	44	2	1,580	44
5	68,526	1,072	92	3,399	182	28	4,128	144
6	89,623	144,320	119	69,459	11,753	3,772	5,400	9,423
Compliant	184,375	144,320	227	69,459	11,753	3,772	11,108	9,423
Non-Compliant	1,692	1,522	23	5,072	250	33	241	205
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)								
1	0	0	n/a	n/a	n/a	n/a	n/a	n/a
2	1,513	59	n/a	n/a	n/a	n/a	n/a	n/a
3	10,498	2,057	n/a	n/a	n/a	n/a	n/a	n/a
4	17,285	5,408	n/a	n/a	n/a	n/a	n/a	n/a
5	45,164	17,891	n/a	n/a	n/a	n/a	n/a	n/a
6	59,068	22,816	n/a	n/a	n/a	n/a	n/a	n/a
Compliant	133,527	0	n/a	n/a	n/a	n/a	n/a	n/a
Non-Compliant	0	48,230	n/a	n/a	n/a	n/a	n/a	n/a
Hybrid Option: Option 1 + Option 2								
1	0	0	0	0	0	0	0	0
2	2,685	181	7	81	2	0	8	1
3	18,636	6,300	15	307	17	3	58	19
4	30,685	16,565	16	1,225	38	2	650	49
5	80,176	54,802	91	3,276	156	24	1,697	162

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)
6	104,860	69,886	117	68,566	11,501	3,691	2,220	15,722
Compliant	237,043	0	224	68,566	11,501	3,691	4,567	15,722
Non-Compliant	0	147,734	22	4,889	214	28	67	230

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)
Option 1 Medium CAZ C								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	248	214	0	214	27	0	4	0
5	10,051	7,612	3	2,339	353	42	170	0
6	194,579	165,783	155	93,906	30,089	8,136	3,290	17,921
Compliant	204,878	173,609	157	93,906	30,089	8,136	3,464	17,921
Non-Compliant	0	0	0	2,553	380	42	0	0
Medium CAZ D + Option 1								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	248	214	0	214	27	0	4	0
5	10,051	7,612	3	2,339	353	42	170	0
6	194,579	165,783	155	93,906	30,089	8,136	3,290	17,921
Compliant	204,878	165,783	157	93,906	30,089	8,136	3,464	17,921
Non-Compliant	0	7,827	0	2,553	380	42	0	0
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)								
1	0	0	n/a	n/a	n/a	n/a	n/a	n/a
2	0	0	n/a	n/a	n/a	n/a	n/a	n/a
3	0	0	n/a	n/a	n/a	n/a	n/a	n/a
4	135	117	n/a	n/a	n/a	n/a	n/a	n/a
5	5,477	4,148	n/a	n/a	n/a	n/a	n/a	n/a
6	106,034	90,342	n/a	n/a	n/a	n/a	n/a	n/a
Compliant	111,646	0	n/a	n/a	n/a	n/a	n/a	n/a
Non-Compliant	0	94,607	n/a	n/a	n/a	n/a	n/a	n/a

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)
Hybrid Option: Option 1 + Option 2								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	248	214	0	214	27	0	4	0
5	10,051	7,612	3	2,339	353	42	170	0
6	194,579	165,783	155	93,906	30,089	8,136	3,290	17,921
Compliant	204,878		157	93,906	30,089	8,136	3,464	17,921
Non-Compliant	0	173,609	0	2,553	380	42	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)
Option 1 Medium CAZ C								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	243	210	0	38	1	0	5	0
5	9,852	7,456	3	419	11	1	184	0
6	190,729	162,386	157	95,225	12,750	3,447	3,558	17,451
Compliant	200,824	170,052	160	95,225	12,750	3,447	3,746	17,451
Non-Compliant	0	0	0	457	11	1	0	0
Medium CAZ D + Option 1								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	243	4	0	38	1	0	14	0
5	9,823	129	3	421	11	1	563	0
6	190,165	168,039	157	95,389	12,774	3,454	10,909	9,744
Compliant	200,231	168,039	160	95,389	12,774	3,454	11,487	9,744
Non-Compliant	0	132	0	459	12	1	0	0
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)								
1	0	0	n/a	n/a	n/a	n/a	n/a	n/a
2	0	0	n/a	n/a	n/a	n/a	n/a	n/a

Euro Standard	Cars (Petrol)	Cars (Diesel)	LGV (Petrol)	LGV (Diesel)	HGV Rigid	HGV Artic	Taxis (Petrol)	Taxis (Diesel)
3	0	0	n/a	n/a	n/a	n/a	n/a	n/a
4	175	54	n/a	n/a	n/a	n/a	n/a	n/a
5	7,074	1,930	n/a	n/a	n/a	n/a	n/a	n/a
6	136,945	42,026	n/a	n/a	n/a	n/a	n/a	n/a
Compliant	144,194	0	n/a	n/a	n/a	n/a	n/a	n/a
Non-Compliant	0	44,010	n/a	n/a	n/a	n/a	n/a	n/a
Hybrid Option: Option 1 + Option 2								
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	309	173	0	38	1	0	6	0
5	12,495	6,157	3	417	11	1	234	0
6	241,896	134,092	157	95,433	12,778	3,455	4,532	16,427
Compliant	254,699		160	95,433	12,778	3,455	4,772	16,427
Non-Compliant	0	140,423	0	456	11	1	0	0

Source: Jacobs Transport Modelling

Note that in the tables above, a residual number of ‘non-compliant’ diesel trips are recorded under the intervention options that include a small area car diesel ban. This is due to the AADT format of the traffic data and relates to diesel vehicles travelling outside of the ban period (i.e. 3pm to 7am). Hence, these ‘non-compliant’ diesel trips are not non-compliant in a literal sense.

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 scenarios across both options 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 in all shortlisted options. Note that the vehicle fleet in the intervention options that include a small area diesel car exclusion component appears to become compliant slower than in the CAZ-related intervention options. As noted above, this is because the ‘non-compliant’ trips for the small area diesel car exclusion options include diesel car trips through the exclusion area outside of the ban period and are therefore compliant. This appears to act as a drag on movement to compliant trips for Option 2 and the Hybrid Option; however, any potential skewing effect of compliant ‘non-compliant’ diesel car trips in these options is accounted for in impact analysis.

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

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
Baseline	10%	18%	27%	36%	44%	53%	61%	70%	78%	86%
Intervention	90%	91%	92%	92%	93%	94%	95%	96%	97%	98%
Medium CAZ D + Option 1										
Baseline	18%	32%	44%	54%	62%	70%	77%	83%	88%	92%
Intervention	95%	96%	96%	97%	97%	98%	98%	98%	99%	99%
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Baseline	0%	1%	1%	1%	1%	2%	2%	2%	3%	3%
Intervention	51%	51%	52%	52%	52%	53%	53%	54%	54%	55%
Hybrid Option: Option 1 + Option 2										
Baseline	4%	7%	10%	13%	16%	20%	23%	26%	29%	32%
Intervention	64%	65%	66%	66%	67%	67%	68%	69%	69%	70%

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 under each shortlisted option (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 for each shortlisted option 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)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
Baseline	287,117	288,053	288,988	289,924	290,860	291,796	292,691	293,592	294,486	295,380
Intervention	285,942	286,827	287,711	288,596	289,480	290,365	291,211	292,066	292,910	293,754
Difference	1,175	1,226	1,277	1,328	1,380	1,431	1,480	1,527	1,576	1,626
Medium CAZ D + Option 1										
Baseline	287,117	288,806	290,177	291,374	292,415	293,317	294,137	294,859	295,480	296,004
Intervention	255,244	259,144	263,044	266,943	270,843	274,743	278,475	282,228	288,078	291,113
Difference	31,873	29,662	27,133	24,431	21,572	18,574	15,662	12,631	7,403	4,891
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Baseline	287,117	288,053	288,989	289,925	290,860	291,796	292,692	293,587	294,483	295,378
Intervention	296,857	296,767	296,676	296,586	296,495	296,405	296,318	296,232	296,145	296,059
Difference	-9,740	-8,714	-7,687	-6,661	-5,635	-4,608	-3,626	-2,644	-1,662	-680

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hybrid Option: Option 1 + Option 2										
Baseline	287,117	288,053	288,988	289,924	290,860	291,796	292,691	293,592	294,486	295,380
Intervention	284,542	285,500	286,457	287,415	288,372	289,330	290,246	291,168	292,083	292,998
Difference	2,575	2,553	2,531	2,509	2,487	2,466	2,445	2,425	2,403	2,382

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[1]:

- 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[2].

- 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[3] are also linked to air pollution exposure.
- Exposure can exacerbate lung and heart disease in older people[4].
- Approximately 40,000 deaths can be attributed to NO_2 and fine particulate matter pollution in England every year[5].

[1] Ambient (Outdoor) Air Quality and Health Fact Sheet. World Health Organisation (2016). Accessed February 2018.
[2] 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
[3] 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
[4] 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/)
[5] *Royal College of Physicians (2016) 'Every breath we take: the lifelong impact of air pollution'. 2016*

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 4.3. 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 for each shortlisted option was then calculated to determine the change in PM/NO2 emissions attributable to the interventions 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
Option 1 Medium CAZ C										
Baseline	589.4	558.9	528.4	498.0	467.5	437.0	407.8	378.5	349.3	320.2
Intervention	536.1	511.8	487.5	463.1	438.8	414.5	391.2	367.7	344.5	321.3
Difference	53.3	47.1	41.0	34.8	28.6	22.5	16.6	10.7	4.8	-1.1
Medium CAZ D + Option 1										
Baseline	589.4	534.4	489.7	450.7	416.8	387.4	360.7	337.2	317.0	299.9
Intervention	502.3	481.3	460.4	439.4	418.5	397.5	377.4	357.3	325.8	309.5
Difference	87.1	53.0	29.3	11.3	-1.6	-10.1	-16.7	-20.1	-8.9	-9.6
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Baseline	589.4	558.9	528.4	497.9	467.5	437.0	407.8	378.6	349.4	320.3

NO_2	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Intervention	582.7	552.5	522.3	492.1	461.9	431.6	402.7	373.8	344.9	316.0
Difference	6.7	6.4	6.1	5.9	5.6	5.3	5.1	4.8	4.5	4.3
Hybrid Option: Option 1 + Option 2										
Baseline	589.4	558.9	528.4	498.0	467.5	437.0	407.8	378.5	349.3	320.2
Intervention	523.3	498.6	473.9	449.2	424.5	399.8	376.2	352.4	328.8	305.2
Difference	66.1	60.3	54.5	48.7	43.0	37.2	31.6	26.1	20.5	15.0
PM	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Option 1 Medium CAZ C										
Baseline	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Intervention	30.20	30.29	30.38	30.48	30.57	30.66	30.75	30.84	30.92	31.01
Difference	1.20	1.11	1.02	0.92	0.83	0.74	0.65	0.56	0.48	0.39
Medium CAZ D + Option 1										
Baseline	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Intervention	27.90	28.21	28.52	28.83	29.14	29.45	29.75	30.05	30.52	30.76
Difference	3.50	3.19	2.88	2.57	2.26	1.95	1.65	1.35	0.88	0.64
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Baseline	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Intervention	32.20	32.09	31.98	31.86	31.75	31.64	31.53	31.42	31.32	31.21
Difference	-0.80	-0.69	-0.58	-0.46	-0.35	-0.24	-0.13	-0.02	0.08	0.19
Hybrid Option: Option 1 + Option 2										
Baseline	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Intervention	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00
Difference	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

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)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
NO_2	£17,594	£17,946	£18,305	£18,671	£19,045	£19,426	£19,814	£20,210	£20,615	£21,027
PM	£335,598	£342,310	£349,156	£356,139	£363,262	£370,527	£377,938	£385,496	£393,206	£401,070

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 cases 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

All shortlisted options 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 options:

- 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 options lead 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 options:

- 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 scenario for both shortlisted options, as vehicle owners upgrade sooner than in the bassline.

Under the CAZ-related intervention options, 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 diesel exclusion-related intervention options, the total number of diesel car owners who replace their vehicle in response to intervention is a function of the number of owners who want to continue to use their vehicle to access or pass through the exclusion zone. Again, those diesel car owners that make more regular trips into the exclusion zone are more likely to replace their vehicle than those who rarely enter the zone, in order to minimise disruption to their day-to-day activities. Those diesel car owners who enter the exclusion zone less frequently are more likely to avoid the zone, cancel their journey or switch mode rather than upgrade their vehicle.

For both shortlisted options, 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 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-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 5.4.

Table 5.4: Vehicle Upgrade Response Rate Estimates

Vehicle Type	Option 1 Medium CAZ C		Medium CAZ D + Option 1		Option 2: 8-hour small area diesel car exclusion (7am – 3pm)		Hybrid Option: Option 1 + Option 2	
	Trips	Vehicles	Trips	Vehicles	Trips	Vehicles	Trips	Vehicles
Car	0%	0%	57%	11%	59%	12%	59%	12%
LGV	62%	15%	62%	15%	0%	0%	62%	15%
Rigid HGV	83%	32%	83%	32%	0%	0%	83%	32%
Artic HGV	83%	47%	83%	47%	0%	0%	83%	47%
Taxi	96%	74%	96%	74%	0%	0%	96%	74%

Source: Jacobs Economic Modelling

Based on the response rates outlined in Table 3.2 and the interpolation approach described in Section 3.33, the number and timing of vehicles upgrades that are directly attributable to the intervention scenario of the shortlisted options is outlined in Table 5.5.

Table 5.5: Rate of Vehicle Upgrading

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
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	1,154	12	9	7	5	3	2	1	1	0
Taxi Diesel	4,475	11	13	16	17	20	20	20	21	21
LGV petrol	20	1	0	0	0	0	0	1	0	0
LGV diesel	4,386	67	67	67	67	68	65	65	65	65
Rigid HGV	2,748	6	7	7	7	7	6	6	6	6
Artic HGV	540	1	1	1	1	1	1	1	1	1
Buses	0	0	0	0	0	0	0	0	0	0
Total	13,323	98	98	98	98	98	94	95	94	94
Medium CAZ D + Option 1										
Car Petrol	2,878	18	18	18	18	18	17	17	69	0
Car Diesel	12,652	16	16	16	16	16	15	15	15	15
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	1,014	19	19	19	18	18	17	17	52	0
Taxi Diesel	4,503	15	15	15	16	16	15	15	-19	32
LGV petrol	19	1	1	0	0	0	0	1	0	0
LGV diesel	4,364	70	70	70	70	70	67	67	67	67
Rigid HGV	2,737	8	8	8	8	8	7	7	7	8
Artic HGV	538	2	2	2	2	2	1	1	1	1
Buses										
Total	28,704	147	147	147	147	147	141	141	192	123
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	5,977	52	52	52	52	52	50	50	50	50
PHV Petrol	0	0	0	0	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0	0	0	0	0

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
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	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	0									
Total	5,977	52	52	52	52	52	50	50	50	50
Hybrid Option: Option 1 + Option 2										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	5,977	52	52	52	52	52	50	50	50	50
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	1,143	14	12	8	7	4	2	2	1	0
Taxi Diesel	4,485	9	11	14	16	19	19	20	20	22
LGV petrol	20	1	0	0	0	0	0	1	0	0
LGV diesel	4,391	67	67	67	67	67	64	64	64	64
Rigid HGV	2,749	6	6	7	7	7	6	6	6	6
Artic HGV	540	1	1	1	1	1	1	1	1	1
Buses	0									
Total	19,304	150	150	150	150	150	143	144	143	143

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 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 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	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	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%[6] 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).

Table 5.7: Euro Standard of Non-Compliant Components of Fleet

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Option 1 Medium CAZ C						
Car Petrol						
Car Diesel						
LGV petrol	2%	31%	67%			
LGV diesel	0%	2%	6%	25%	67%	
Rigid HGV	0%	12%	88%			
Artic HGV	0%	0%	10%	6%	83%	
Buses	0%	8%	32%	16%	43%	
Taxis Petrol	0%	13%	87%			
Taxis Diesel	0%	0%	8%	21%	70%	
Medium CAZ D + Option 1						
Car Petrol	0%	13%	87%			
Car Diesel	0%	0%	8%	21%	70%	
LGV petrol	2%	31%	67%			

[6] 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
LGV diesel	0%	2%	6%	25%	67%	
Rigid HGV	0%	12%	88%			
Artic HGV	0%	0%	10%	6%	83%	
Buses	0%	8%	32%	16%	43%	
Taxis Petrol	0%	13%	87%			
Taxis Diesel	0%	0%	8%	21%	70%	
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)						
Car Petrol						
Car Diesel	0%	0%	4%	11%	37%	47%
LGV petrol						
LGV diesel						
Rigid HGV						
Artic HGV						
Buses						
Taxis Petrol						
Taxis Diesel						
Hybrid Option: Option 1 + Option 2						
Car Petrol						
Car Diesel	0%	0%	4%	11%	37%	47%
LGV petrol	2%	31%	67%			
LGV diesel	0%	2%	6%	25%	67%	
Rigid HGV	0%	12%	88%			
Artic HGV	0%	0%	10%	6%	83%	
Buses	0%	8%	32%	16%	43%	
Taxis Petrol	0%	13%	87%			
Taxis Diesel	0%	0%	8%	21%	70%	

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. For the CAZ-related intervention options, 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. For the diesel exclusion-related intervention option, all upgrading vehicles were assumed to switch to secondhand petrol vehicles.

In light of the above, the weighted average replace 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)
Option 1 Medium CAZ C			
Car Petrol	£0	£0	£0
Car Diesel	£0	£0	£0
PHV Petrol	£0	£0	£0
PHV Diesel	£0	£0	£0
Taxi Petrol	£3,302	£146	£0
Taxi Diesel	£2,653	£591	£524
LGV petrol	£3,409	£159	£0
LGV diesel	£3,068	£671	£0
Rigid HGV	£12,591	£3,416	£0
Artic HGV	£13,915	£2,707	£0
Medium CAZ D + Option 1			
Car Petrol	£2,948	£132	£0
Car Diesel	£3,246	£709	£629
PHV Petrol	£0	£0	£0
PHV Diesel	£0	£0	£0
Taxi Petrol	£2,857	£127	£0
Taxi Diesel	£2,669	£595	£527
LGV petrol	£3,390	£158	£0
LGV diesel	£3,052	£667	£0
Rigid HGV	£12,537	£3,401	£0
Artic HGV	£13,855	£2,696	£0
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)			
Car Petrol	£0	£0	£0
Car Diesel	£3,712	£364	£391
PHV Petrol	£0	£0	£0
PHV Diesel	£0	£0	£0
Taxi Petrol	£0	£0	£0
Taxi Diesel	£0	£0	£0
LGV petrol	£0	£0	£0

	New	Used (Same Fuel)	Used (Switch Fuel)
LGV diesel	£0	£0	£0
Rigid HGV	£0	£0	£0
Artic HGV	£0	£0	£0
Hybrid Option: Option 1 + Option 2			
Car Petrol	£0	£0	£0
Car Diesel	£3,712	£364	£391
PHV Petrol	£0	£0	£0
PHV Diesel	£0	£0	£0
Taxi Petrol	£3,259	£144	£0
Taxi Diesel	£2,661	£593	£526
LGV petrol	£3,414	£159	£0
LGV diesel	£3,072	£671	£0
Rigid HGV	£12,592	£3,417	£0
Artic HGV	£13,917	£2,708	£0

Source: Jacobs Economic Modelling

These weighted average upgrade cost differentials vary across the intervention options because the pattern and timing of upgrading varies. Further, under diesel exclusion-related intervention options, some Euro 6 diesels are induced to upgrade. As Euro 6 diesels are newer vehicles, the impact of upgrading is greater due to the larger change in depreciation rates for newer vehicles. The weighted average upgrade cost differentials were combined with the number of vehicles upgrading in each year in the intervention scenarios 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 captured within the journey time savings/vehicle operating cost analysis below.

Table 3.2 highlights the number of non-compliant vehicle trips in AADT terms in the 2021 baseline and Table 3.8 highlights the reduction in non-compliant vehicles in the baseline. Meanwhile Table 3.2 demonstrates quantum 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 5.9.

Table 5.9: Trips with Changed Travel Patterns/Behaviours

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	0	0	0	0	0	0	0	0	0	0

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
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	11,105	9,216	7,504	5,969	4,610	3,770	3,009	0	0	0
LGV diesel	2,493,040	2,259,844	2,026,470	1,792,919	1,559,192	1,324,947	1,100,750	876,503	652,206	427,860
Rigid HGV	251,815	227,703	203,498	179,201	154,813	130,332	106,828	83,237	59,557	35,789
Artic HGV	33,327	29,653	26,071	22,581	19,184	15,878	12,792	9,795	6,885	4,064
Buses	0	0	0	0	0	0	0	0	0	0
Total	2,789,287	2,526,415	2,263,543	2,000,671	1,737,799	1,474,926	1,223,380	969,534	718,648	467,713
Medium CAZ D + Option 1										
Car Petrol	2,273,775	1,430,499	858,302	499,748	258,864	136,775	65,143	25,129	0	0
Car Diesel	12,477,763	10,306,958	8,545,484	6,942,618	5,557,576	4,349,501	3,241,538	2,314,775	1,584,600	1,038,423
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	11,105	9,216	7,504	5,969	4,610	3,770	3,009	0	0	0
LGV diesel	2,493,040	2,259,844	2,026,470	1,792,919	1,559,192	1,324,947	1,100,750	876,503	652,206	427,860
Rigid HGV	251,815	227,703	203,498	179,201	154,813	130,332	106,828	83,237	59,557	35,789
Artic HGV	33,327	29,653	26,071	22,581	19,184	15,878	12,792	9,795	6,885	4,064
Buses	0	0	0	0	0	0	0	0	0	0
Total	17,540,825	14,263,872	11,667,329	9,443,036	7,554,239	5,961,202	4,530,061	3,309,438	2,303,248	1,506,136
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	7,404,254	7,426,363	7,448,472	7,470,582	7,492,691	7,514,800	7,535,957	7,557,114	7,578,271	7,599,427
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	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	0	0	0	0	0	0	0	0	0	0
Total	14,668,420	14,625,564	14,582,707	14,539,851	14,496,994	14,454,138	14,413,128	14,372,118	14,331,108	14,290,098
<u>Hybrid Option: Option 1 + Option 2</u>										
Car Petrol	0	0	0	0	0	0	0	0	0	0
Car Diesel	7,404,254	7,426,363	7,448,472	7,470,582	7,492,691	7,514,800	7,535,957	7,557,114	7,578,271	7,599,427
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	11,105	9,216	7,504	5,969	4,610	3,770	3,009	0	0	0
LGV diesel	2,493,040	2,259,844	2,026,470	1,792,919	1,559,192	1,324,947	1,100,750	876,503	652,206	427,860
Rigid HGV	251,815	227,703	203,498	179,201	154,813	130,332	106,828	83,237	59,557	35,789
Artic HGV	33,327	29,653	26,071	22,581	19,184	15,878	12,792	9,795	6,885	4,064

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Buses	0	0	0	0	0	0	0	0	0	0
Total	17,457,708	17,151,979	16,846,250	16,540,522	16,234,793	15,929,064	15,636,507	15,341,652	15,049,756	14,757,810

Source: Jacobs Economic Modelling

The approach to monetising consumer welfare loss relating to changing travel patterns and behaviours varies depending on the key mechanism inducing these changes. For CAZ-related intervention options, 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 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[7] 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.

For the diesel exclusion-related intervention options, the transport modelling assumes that all non-compliant vehicles adhere to the exclusion zone. There is no specific charge level against which consumer welfare loss (via the standard rule of half approach) can be applied. Within this context, it is not possible to use a charging value to proxy consumer welfare loss. Instead, consumer welfare loss for changed travel patterns and behaviours for excluded trips was estimated by making the following assumptions:

- Individuals cancelling/avoiding trips (i.e. not upgrading) assign a total discounted value of all trips over the lifetime of the diesel ban between zero and the vehicle upgrade cost because any value above this would result in them upgrading their vehicle.
- As per the standard approach, for a given individual, the average discounted lifetime trips value is half of the upgrade cost.

Within this context, the specific stages undertaken to monetise consumer welfare loss in the context of changing travel patterns and behaviours for diesel exclusion-related intervention options are as follows:

- Identify total change in number of trips based on difference in AADT for diesel cars in the baseline vs. intervention case
- Calculate the total number of daily trips that upgrade based on response rates
- Establish the total number of daily trips that do not upgrade (i.e. that cancel journey, change mode or avoid zone), by subtracting the number of upgrading trips per day from the total change in number of trips
- Convert from trips to unique vehicles/individuals based on ANPR trip frequency data and annualise (accounting for ANPR duration of 2 months)
- Derive 50% of the upgrade cost for diesel vehicles converting to petrol (i.e. £195)
- Apply the weighted upgrade cost to the unique vehicles/individuals that cancel/change mode/avoid zone in 2021
- For future years, assume that only trips with a frequency of 1 entry every 2 months from ANPR data would create additional consumer welfare less (i.e. these are assumed to represent 'new' unique

[7] £4.50 for cars and LGVs (all fuel types), £50 for HGV (all types) and buses/coaches

vehicles/individuals not captured in 2021); consumer welfare loss with all more frequent journeys is assumed to be captured by the 2021 estimate.

These steps are demonstrated in the table below, which applies equally across the Option 2: 8-hour small area diesel car exclusion (7am – 3pm) and Hybrid Option: Option 1 and 2 interventions.

Table 5.10: Consumer Welfare Loss from Changing Travel Patterns and Behaviours for Diesel Ban Vehicles

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total Change in Trips	49,161	49,307	49,454	49,601	49,748	49,895	50,035	50,175	50,316	50,456
Trips Upgrading	28,875	28,961	29,047	29,134	29,220	29,306	29,389	29,471	29,554	29,636
Trips Not Upgrading	20,286	20,346	20,407	20,467	20,528	20,588	20,646	20,704	20,762	20,820
Individuals Not Upgrading	17,834	17,887	17,940	17,993	18,047	18,100	18,151	18,202	18,253	18,304
Annualised	107,001	45,221	45,356	45,490	45,625	45,759	45,888	46,017	46,146	46,275

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 for most options 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 cases for both options 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 options are 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 for relevant options 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 cases, 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 cases (Table 5.11)

Table 5.11: Weighted Average Scrappage Costs (£)

Vehicle Type	Option 1 Medium CAZ C	Medium CAZ D + Option 1	Option 2: 8-hour small area diesel car exclusion (7am – 3pm)	Hybrid Option: Option 1 + Option 2
Car Petrol	£0	£170	£0	£0
Car Diesel	£0	£953	£1,581	£1,581
PHV Petrol	£0	£0	£0	£0
PHV Diesel	£0	£0	£0	£0
Taxi Petrol	£188	£164	£0	£186
Taxi Diesel	£795	£799	£0	£797
LGV petrol	£170	£169	£0	£170
LGV diesel	£865	£860	£0	£866
Rigid HGV	£422	£420	£0	£422
Artic HGV	£3,515	£3,500	£0	£3,515

Source: Jacobs Economic Modelling

The values above were then applied to the profile of vehicle upgrades in the intervention cases. The profile is outlined in Table 5.12, based on Table 5.5 above and pivoting from the relevant behaviour response rates and interpolation data presented above.

Table 5.12: Rate of Vehicle Upgrading to New Vehicles

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
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	289	3	2	2	1	1	0	0	0	0
Taxi Diesel	1,119	3	3	4	4	5	5	5	5	5
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
Total	1,407	6	6	6	6	6	5	5	5	5
Medium CAZ D + Option 1										
Car Petrol	719	4	4	4	4	4	4	4	17	0
Car Diesel	3,163	4	4	4	4	4	4	4	4	4
PHV Petrol	0	0	0	0	0	0	0	0	0	0

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PHV Diesel	0	0	0	0	0	0	0	0	0	0
Taxi Petrol	253	5	5	5	5	5	4	4	13	0
Taxi Diesel	1,126	4	4	4	4	4	4	4	-5	8
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
Total	5,262	17	17	17	17	17	16	16	29	12
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
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	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
Total	0	0	0	0	0	0	0	0	0	0
Hybrid Option: Option 1 + Option 2										
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	286	3	3	2	2	1	1	0	0	0
Taxi Diesel	1,121	2	3	4	4	5	5	5	5	5
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
Total	1,407	6	6	6	6	6	5	5	5	5

Source: Jacobs Economic Modelling

It should be noted that no vehicles are assumed to be scrapped for diesel exclusion components of various options. This is because all diesel vehicles induced to upgrade do so to a secondhand petrol vehicle.

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 1.9.11. 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: Bus/Coach, HGV, LGV and Car;
- Annualisation factors: AM 682, 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 GBATS 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 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 5.13 below.

Table 5.13: 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:

- 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 origin-destination matrices have been applied to both the Do Minimum and the Do Something scenarios. This is because, in the small area diesel car exclusion option, using both Do Minimum and Do Something matrices would result in an overestimation of journey time benefits due to diesel car drivers that shift to other modes, as this is something that the GBATS model does not account for.
- 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.

See table 5.14 for further detail of the user classes applied.

Table 5.14 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
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 shortlisted options 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 5.1 outlines the number of vehicles induced to upgrade earlier than they otherwise planned to, as a result of intervention in each shortlisted option.

Table 5.1: Upgraded Fleet by Vehicle Type and Euro Standard

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Option 1 Medium CAZ C						
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	150	1,043	0	0	0
Taxi Diesel	0	11	375	986	3,262	0
LGV petrol	0	7	15	0	0	0
LGV diesel	0	82	313	1,248	3,339	0
Rigid HGV	0	328	2,478	0	0	0
Artic HGV	0	2	56	33	460	0
Buses	0	0	0	0	0	0
Medium CAZ D + Option 1						
Car Petrol	0	386	2,682	0	0	0
Car Diesel	0	30	1,035	2,722	9,005	0
PHV Petrol	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0
Taxi Petrol	0	150	1,043	0	0	0
Taxi Diesel	0	11	374	984	3,255	0
LGV petrol	0	7	15	0	0	0
LGV diesel	0	82	313	1,248	3,337	0
Rigid HGV	0	328	2,477	0	0	0
Artic HGV	0	2	56	33	460	0
Buses	0	0	0	0	0	0
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)						
Car Petrol	0	0	0	0	0	0
Car Diesel	0	8	274	722	2,388	3,045
PHV Petrol	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0
Taxi Petrol	0	0	0	0	0	0
Taxi Diesel	0	0	0	0	0	0
LGV petrol	0	0	0	0	0	0
LGV diesel	0	0	0	0	0	0
Rigid HGV	0	0	0	0	0	0

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Artic HGV	0	0	0	0	0	0
Buses	0	0	0	0	0	0
Hybrid Option: Option 1 + Option 2						
Car Petrol	0	0	0	0	0	0
Car Diesel	0	8	274	722	2,388	3,045
PHV Petrol	0	0	0	0	0	0
PHV Diesel	0	0	0	0	0	0
Taxi Petrol	0	150	1,043	0	0	0
Taxi Diesel	0	11	375	986	3,262	0
LGV petrol	0	7	15	0	0	0
LGV diesel	0	82	313	1,248	3,339	0
Rigid HGV	0	328	2,478	0	0	0
Artic HGV	0	2	56	33	460	0
Buses	0	0	0	0	0	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. Note that no Euro 6 weighted transaction cost is recommended by JAQU. Therefore, for the purpose of the current appraisal (given that under the small diesel exclusion option some Euro 6 diesel cars will be induced to upgrade), Euro 5 weighted transaction costs are adopted as a proxy for Euro 6 too.

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).

5.6 Accident Impacts

An accident analysis was undertaken using DfT's CoBALT software. See OBC-30 'COBALT – accident impact assessment' Appendix Giii of this OBC 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 sixty-year appraisal period (standard in CoBALT software), a reduction of between 500 and 1,000 accidents is anticipated through intervention, as outlined in Table 5.15.

Table 5.15: Change in Accidents and Casualties

Accident Summary	Option 1 Medium CAZ C	Medium CAZ D + Option 1	Option 2: 8-hour small area diesel car exclusion (7am – 3pm)	Hybrid Option: Option 1 + Option 2
Baseline Accidents	73,096	73,096	73,096	73,096
Intervention Accidents	72,595	72,471	72,204	72,170
Accident Reduction Due to Scheme	501	625	892	926

Source: Jacobs Transport Modelling

5.7 Walking/Cycling Impacts

By inducing mode shift for non-compliant vehicle owners, the intervention case options 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 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'[8]. The resulting forecast for number of additional walking and cycling trips each year converted from non-compliant vehicle trips is outlined in Table 5.16.

Table 5.16: Additional Walking and Cycling Trips Converted from Non-Compliant Vehicle Trips in the Baseline

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 1 Medium CAZ C										
Walking	0	0	0	0	0	0	0	0	0	0
Cycling	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0
Medium CAZ D + Option 1										
Walking	264,074	211,460	170,460	135,814	106,894	83,023	61,771	44,145	30,138	19,700
Cycling	484,135	387,677	312,510	248,992	195,973	152,208	113,247	80,932	55,252	36,116
Total	748,209	599,137	482,971	384,806	302,867	235,231	175,019	125,077	85,390	55,816

[8] 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).)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Option 2: 8-hour small area diesel car exclusion (7am – 3pm)										
Walking	161,389	161,871	162,353	162,834	163,316	163,798	164,259	164,721	165,182	165,643
Cycling	295,879	296,763	297,646	298,530	299,413	300,297	301,142	301,988	302,833	303,679
Total	457,268	458,634	459,999	461,364	462,730	464,095	465,402	466,708	468,015	469,322
Hybrid Option: Option 1 + Option 2										
Walking	161,389	161,871	162,353	162,834	163,316	163,798	164,259	164,721	165,182	165,643
Cycling	295,879	296,763	297,646	298,530	299,413	300,297	301,142	301,988	302,833	303,679
Total	457,268	458,634	459,999	461,364	462,730	464,095	465,402	466,708	468,015	469,322

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 (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 OBC-41 'Finance Report' Appendix R of this OBC. Within this document, it is worth noting that unlike in the financial analysis, optimism bias has been applied to intervention option costs in line with the HM Treasury Green Book benchmark values. These are summarised in Table 6.1.

Table 6.1: Optimism Bias (OB) Adjustments to Costs

Activity	OB Value	Use
Equipment/Development	200%	For IT Expenditure (upper bound)
Outsourcing	41%	For any OPEX/CAPEX requiring external support (upper bound)
Standard Civil Engineering	44%	For most street works OPEX/CAPEX (upper bound)

Source: Jacobs Economic Modelling

Figure 2.1: Overarching Methodological Framework for Economic Analysis

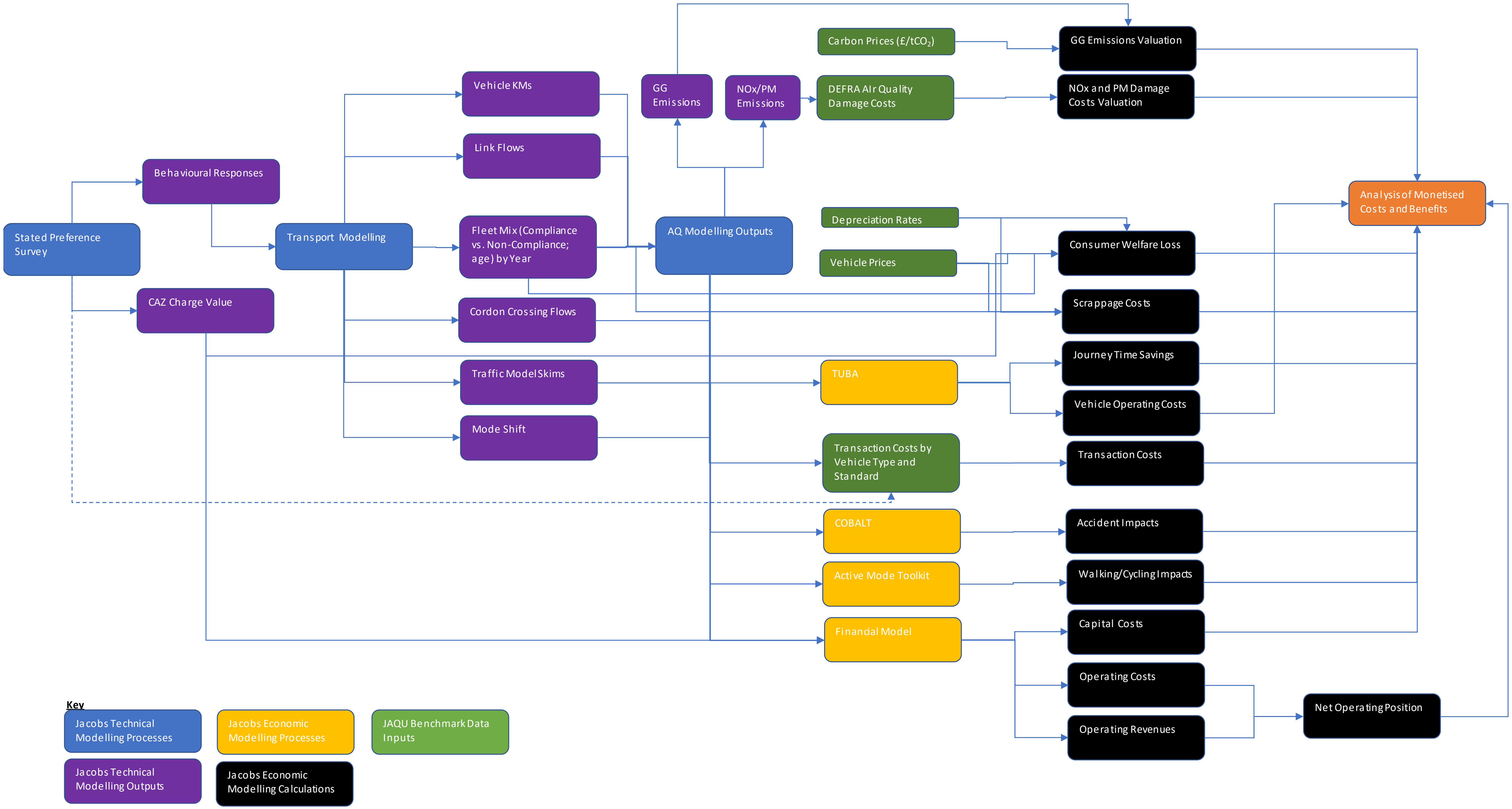

Figure 4.1: Approach to Assessing Economic Impacts of Greenhouse Gas Emissions

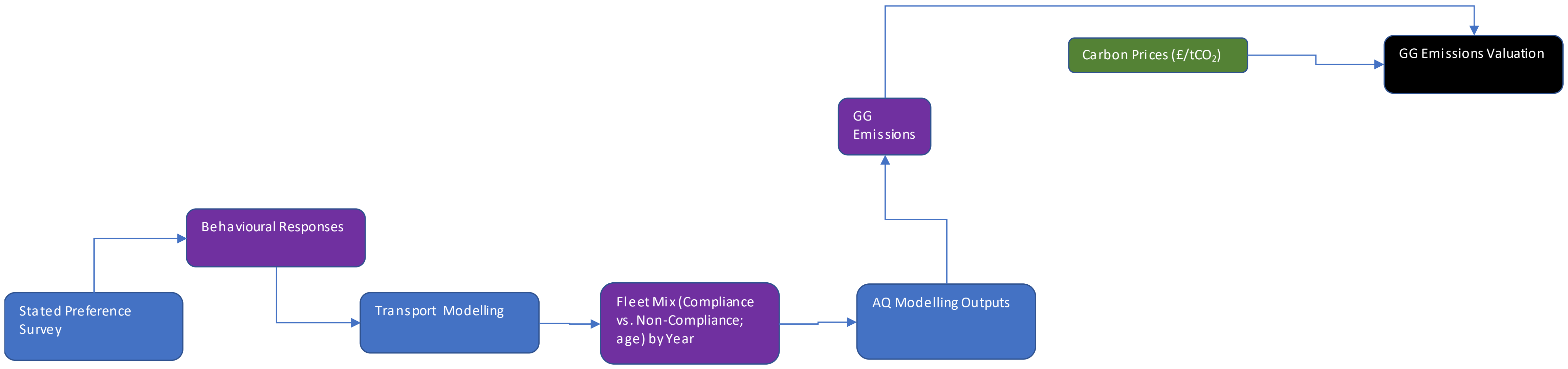

Figure 4.2: Approach to Assessing Economic Impacts of PM/NO_2 Emissions

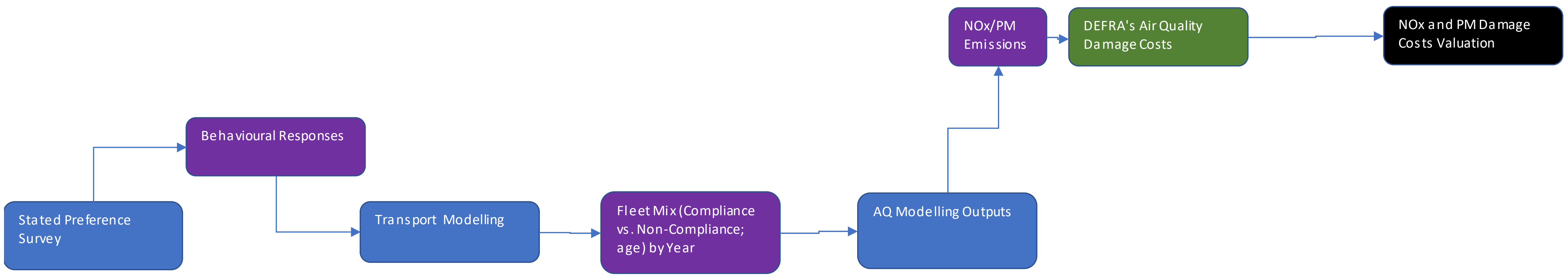

Figure 5.1: Approach to Assessing Economic Impacts of Transaction Costs

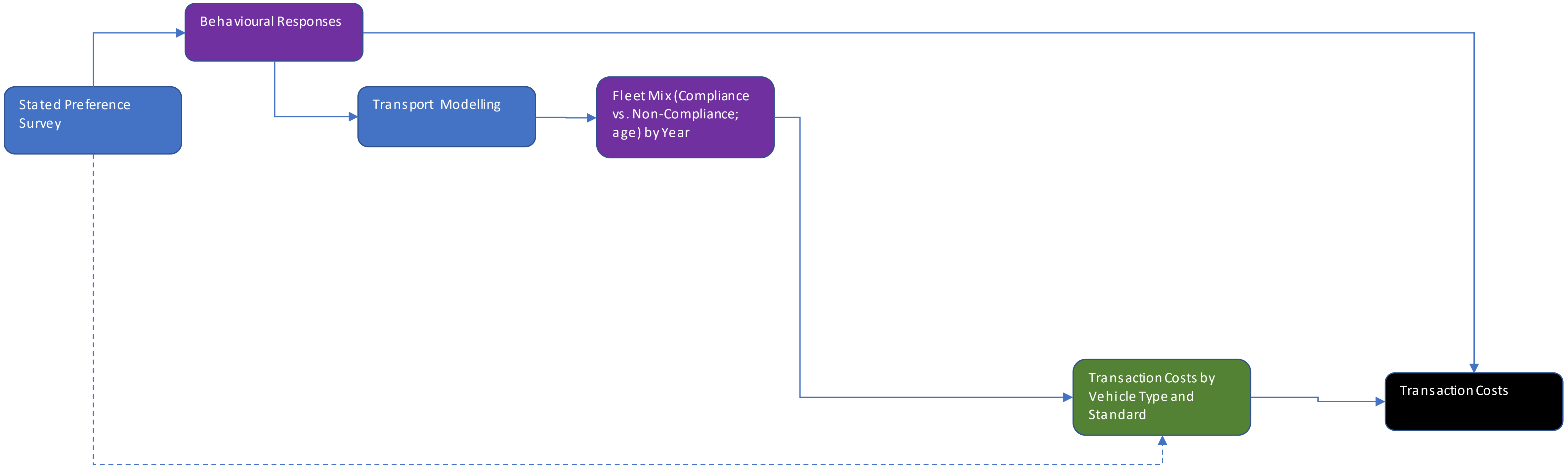

Figure 5.2: Approach to Assessing Economic Impacts of Consumer Welfare Loss

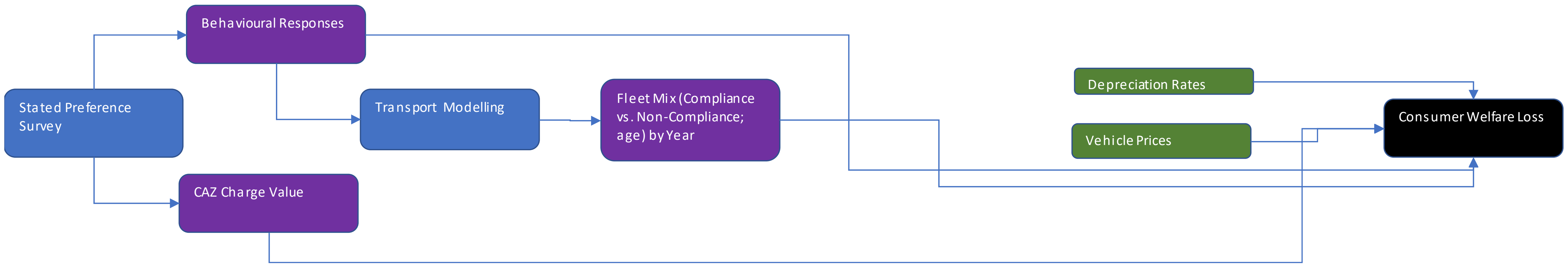

Figure 5.3: Approach to Assessing Economic Impacts of Vehicle Scrappage