Economic appraisal methodology report (E1)

Southampton Clean Air Zone feasibility study

Report for Southampton City Council

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Contact:

David Birchby
Ricardo Energy & Environment
Gemini Building, Harwell, Didcot, OX11 0QR, United Kingdom

t: +44 (0) 1235 75 3555
e: david.birchby@ricardo.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Author:

Birchby, David;Hekman, John

Approved By:

Guy Hitchcock

Date:

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1 Introduction

Southampton has been named as one of many cities in the UK that will not be compliant with nitrogen dioxide regulations by 2020 (which have been set in line with EU air quality targets). As a result, DEFRA's air quality action plan named Southampton as having to implement a Clean Air Zone (CAZ).

Each city must develop a Business Case which explores viable options for a CAZ and present the case to support the preferred CAZ option. The Business Cases are being developed in line with guidance issued by JAQU, which in turn is based upon HMT's five case model[1]. Government will assess plans to ensure they deliver the necessary air quality compliance, are fair, are cost effective and where possible deliver wider benefits.

One of the five cases which constitutes the overall Business Case is the Economics Case. At the Outline Business Case (OBC) stage, the Economics Case must meet the following criteria (taken from JAQU's guidance: 'Business Cases for Local Plans'):

- Elements of the existing economic case are revisited, all changes to the underlying assumptions made in the Strategic Outline Case (SOC) should be noted.
- All relevant costs and benefits should be evaluated at this stage. Net Present Value (NPV) for each option should be considered.
- The short list is to be assessed considering the benefits and costs in detail to identify a preferred option; including a distributional analysis of the option.
- Relevant annexes will include the full economic model and associated documentation, and the outputs of the scenario analysis of the air quality and transport modelling in order to assess the key Critical Success Factor on delivering compliance in the shortest possible time.

JAQU have shared with the cities detailed guidance around the methodologies and assumptions to adopt when appraising the CAZ options[2].

Ricardo has supported Southampton City Council (SCC) to develop its CAZ feasibility study, including undertaking the economic analysis around proposed options.

This report sets out the detail of the methodology and data sources applied to appraise the options, and the results. The purpose of this paper is to meet deliverable E1 of JAQU's requirements. The results section of this paper forms the basis of the write up of economic appraisal, which is presented formally in the overarching Economics Case.

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

This represents the third version of the Methodology Report. The first version was submitted alongside the submission of the draft OBC to JAQU in March 2018. The second was an updated version of the first, submitted in July 2018. The first and second versions undertook cost-benefit analysis (CBA) of an initial short-list of four CAZ options. Following submission and update of the underlying air quality modelling, SCC undertook further development and refinement of the options under consideration. This third version detail the assessment of a refined shortlist of two CAZ options. However, given the OBC Economics Case draws on the assessment of both short-lists, the methodology adopted and the results of the assessment of both the initial and refined shortlists are presented in this document.

The economic analysis relies on the modelling work undertaken to support the assessment of CAZ options, specifically the transport modelling undertaken by Systra and air quality modelling undertaken by Ricardo. This paper references where the economic analysis has used the outputs of other modelling and describes how these outputs are used. However, it does not set out a detailed account of how this

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/469317/green_book_guidance_public_sector_business_cases_2015_update.pdf

[2] Latest version issued 27/11/17

supporting modelling work has been undertaken, which has been provided elsewhere (e.g. through the Transport and Air Quality Modelling Needs Assessment / Modelling Methodology Reports).

2 Methodology

2.1 Summary overview

JAQU have provided detailed guidance on the appraisal of CAZ options. This guidance recommended many of the key data inputs and assumptions that were used in the analysis undertaken.

The key guidance documents include:

- Options Appraisal – Guidance (2017)[3] (and preceding versions of this guidance)
- National data inputs for Local Economic Models (2017)[4].

In some steps in the approach, we have sought alternative methods to those contained within the above guidance or we have undertaken additional steps and/or developed assumptions where the study team felt that such approaches were warranted to facilitate or improve the analysis. This is the case where our economic modelling went beyond (in terms of detail) that set out in JAQU's guidance.

The analysis is underpinned by the following overarching assumptions:

- Each impact associated with each CAZ option is assessed relative to a 'do nothing' counterfactual
- All impacts are presented in real terms with a price year of 2018
- A lifetime approach has been adopted (rather than an annualised approach) and all impacts are assessed over a 10-year appraisal period from 2020-30
- All impacts are discounted to 2018 applying the Green Book discount factor of 3.5%.

To support the appraisal, quantification and monetisation of impacts associated with the CAZ, Ricardo have developed a model performing the underlying calculations. The methodology set out in this report describes the approach, data and assumptions applied in the model.

A summary of the key assumptions, data inputs and baseline can be found in Appendix 2 – Summary of data inputs and assumptions.

2.2 Scope of assessment

2.2.1 CAZ options assessed – initial shortlist

The analysis is defined by the CAZ options that are considered in the OBC. Work to develop CAZ options and refine these from a long-list to short-list has been undertaken by SCC.

The initial short-list comprised four CAZ options which were prioritised for detailed analysis as part of the OBC stage. These options range across different geographies and CAZ classes (variation in the coverage of vehicle types included in the scope of the CAZ – classifications are consistent with those set out by JAQU in the National Air Quality Plan). In addition, SCC considered non-charging measures in combination/as an alternative to a charging CAZ. The options assessed as part of the OBC are set out in Table 1.

Each scenario is compared with a 'do nothing' baseline scenario. The construction of which is discussed below.

The Map of the proposed CAZ areas are included in: Appendix 1 – Maps of proposed CAZ areas.

For each vehicle type, 'compliance' with the CAZ is defined in line with JAQU's standard assessment as defined in the national plan: i.e. non-compliant vehicles are petrol Euro 3/III or older and diesel Euro 5/V or older.

[3] Unpublished – provided directly by JAQU to cities
[4] Unpublished – provided directly by JAQU to cities

Table 1 – Initial shortlist option construction

Option	Details
City Wide CAZ B (Option 1)	• Introduced in 2020 • CAZ operating along but excluding the motorways around Southampton city area (M27 and M271 of Southampton) • CAZ applies to Taxis, Private Hire Vehicles (PHV), Buses, HGVs and Coaches.
City wide CAZ B (HGV only) (Option 1a)	• Introduced in 2020 • CAZ operating along but excluding the motorways around Southampton city area (M27 and M271 of Southampton) • Charging CAZ area Applies only to HGVs • Bus condition / funding for retrofit and taxi incentives which lead to vehicle upgrades

City Centre CAZ A (Option 2)	• Introduced in 2020,
	• CAZ operating in the city-centre (within and including A3024 and A33 in the East)
	• CAZ applies to Taxis, PVHs, Buses, and Coaches.
	• Non-charging measures for HGVs:
	  ○ Increasing use of freight delivery service plans (DSP) and consolidation centre (SDC)
	  ○ Greater uptake of fleet recognition scheme, and port booking and 24-hour delivery used to incentivise cleaner vehicles

Non-charging measures (Option 3)	• Introduced in 2020
	• Non-charging measures applied to all vehicle modes
	  ○ Bus traffic condition plus grant
	  ○ Taxi incentives
	  ○ Increasing use of freight delivery service plans and consolidation centre
	  ○ Greater uptake of fleet recognition scheme, and port booking and 24-hour delivery used to incentivise cleaner vehicles

2.2.2 CAZ options assessed – revised shortlist

Following the submission of the draft OBC in spring 2018, several factors contributed to SCC refining the shortlist of measures for assessment from four to two CAZ options:

1. SCC further reflected on the feasibility and analysis of the options included in the initial shortlist.
2. transport and air quality modelling of the baseline and CAZ options was updated to reflect a number of improvements in the underlying evidence base.
3. Due to the confirmation of funding for bus retrofit through the CBTF, this measure was moved from CAZ option to baseline

The revised shortlist retains one charging CAZ option (a city-wide CAZ B, similar to 'Option 1' under the initial shortlist) and a revised non-charging option (similar in principle to 'Option 3' of the initial shortlist, but with different sub-measures).

These options are presented in detail in For each vehicle type, 'compliance' with the CAZ is defined in line with JAQU's standard assessment as defined in the national plan: i.e. non-compliant vehicles are petrol Euro 3/III or older and diesel Euro 5/V or older.

Table 2.

For each vehicle type, 'compliance' with the CAZ is defined in line with JAQU's standard assessment as defined in the national plan: i.e. non-compliant vehicles are petrol Euro 3/III or older and diesel Euro 5/V or older.

Table 2 – Revised shortlist option construction

Option	Details
City Wide Class B Clean Air Zone (CAZ B)	• Introduced in 2020 • CAZ operating along but excluding the motorways around Southampton city area (M27 and M271 of Southampton) • CAZ applies to Taxis, Private Hire Vehicles (PHV), Buses, HGVs and Coaches. ○ However, no scheduled buses operating services in Soton are anticipated to be affected given CBTF funding for retrofit will cover all buses • Also includes taxi-licence in 2023: in 2023, licencing conditions are tightened such that only Euro VI vehicles can operate a licence

Non-charging Clean Air Zone (NCH CAZ)	• Introduced in 2020
	• Option is comprised of four sub-measures:
	  ○ Taxi-licence in 2023: in 2023, licencing conditions are tightened such that only Euro VI vehicles can operate a licence
	  ○ Shore-side power: Facilities installed at 1 berth in Southampton port to allow cruise ships to 'plug-in' and use mains electricity when at berth (rather than using auxiliary engines to provide power)
	  ○ Port booking system: a peak hour £5 charge is implemented at the container port terminal for non-Euro VI HGVs accessing the port
	  ○ Sustainable distribution centre (SDC): Implementation of a Delivery Service Plan (DSP) and channelling of deliveries through the SDC for the General Hospital
	    ▪ This is consistent with the SDC Option 1 as presented in the Finance Case where the programme achieves successful implementation of a DSP at one site by 2020

2.2.3 Scope of impacts assessed

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

JAQU's guidance sets the basis for the scope of impacts to be assessed in CAZ appraisal. In some cases, we have grouped impacts by the methodology adopted and as a result our methodology may use a different terminology than that set out in the JAQU guidance.

The impacts captured by the CBA, and how they correspond to the impact categories described in the JAQU guidance are presented in Table 3.

A quantitative assessment of the impacts associated with the CAZ has been undertaken wherever possible. However, in some cases it has not been possible to complete a full quantitative assessment given limitations in the data available.

Where impacts have not been assessed quantitatively, a qualitative assessment has been performed. The results of the analysis are presented in Section: Appendix 4 – Qualitative assessment of wider impacts.

Table 3 – Impact description and mapping to options

Impact name	Description	Included in option?	
		CAZ B	NCH CAZ

Impact name	Description	Included in option? CAZ B	NCH CAZ
Upgrade costs	The impact on those vehicles owners that respond to CAZ implementation by replacing their vehicle. These are the upfront costs for vehicle owners associated with switching from a non-compliant to a compliant vehicle. This encompasses the vehicle scrappage cost and the consumer welfare impact as described in the JAQU guidance. This also captures the cost of retrofit where this action is taken to ensure vehicles are compliant, rather than switching vehicles.	Yes - Included in quantitative analysis	Yes – taxi licence sub-measures lead to upgrades in 2023 Vehicle upgrades not assumed associated with other sub-measures
Operating cost impacts	Those savings or additional costs that can result from CAZ implementation. This includes both changes in fuel consumption and the associated cost and change in operating and maintenance costs. The options considered for the CAZ will cover a range of different impacts on operating and fuel costs, given the different ways in which the measures will influence behaviour.	Yes - Included in quantitative analysis	Yes – Shore-side power – marine gas oil savings, but increase in electricity cost SDC leads to opex and fuel savings for trips saved Taxi licence sub-measures leads to upgrades in 2023
Implementation costs	Cost of upfront and ongoing activity and assets required to implement, monitor and enforce the CAZ by the administering authority. This category also aims to capture costs related to implementation of the non-charging measures such as port booking, implementation of DSPs and 24-hour delivery.	Yes - Included in quantitative analysis	Yes Shore side power - upfront investment and ongoing maintenance cost Port booking – upfront cost and ongoing operation of ANPR cameras. Does not include potential additional stack management costs SDC – costs included for implementing scheme on behalf of SCC and implementing DSP for hospital; also includes additional stack management cost; assume spare capacity so no additional vehicle or warehouse space costs included No implementation costs included for taxi licence
Air quality emissions	The impact on affected populations by a change in NOx and PM emissions as a result of CAZ implementation	Yes - Included in quantitative analysis	Yes - Included in quantitative analysis
Greenhouse Gas impacts	The impact on affected populations by a change in greenhouse gas emissions that result from CAZ implementation. As with fuel and operating costs, the options considered for the CAZ will cover a range of different impacts on GHG emissions, given the different ways in which the measures will influence behaviour.	Yes - Included in quantitative analysis	Yes – Shore-side power – marine gas oil savings, but increase in electricity cost SDC leads to GHG savings for trips saved Taxi licence sub-measures leads to upgrades in 2023
Congestion / travel time impacts	The impact of the CAZ on traffic flow and the subsequent impact on travel time experienced by those directly affected by the CAZ and indirectly by other road users. Again, the options considered for the CAZ will cover a range of different	Yes - Included in quantitative analysis	Yes - SDC leads to driver time savings There may be some knock-on effect of port booking system and SDC to wider congestion,

Impact name	Description	Included in option?	
		CAZ B	NCH CAZ
	impacts on travel time given the different ways in which the measures will influence behaviour.		but effects are too small to quantify
Welfare loss	Where vehicle users change their travel patterns in response to a charging CAZ, there will be a cost for the user associated with not being able to take their first preference. E.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (e.g. shopping trip to city centre). The vehicle user will miss out on the happiness / value that they would have gained from that trip, which is captured by this impact category.	Yes - Included in quantitative analysis	Yes – port booking system leads some older HGVs to shift time of trip to second-best alternative to avoid charge

2.3 Developing the fleet baseline

A key input into the economic analysis (and in particular for the calculation of upgrade costs) is the number of unique vehicles that will be affected by a CAZ. Although some sources of data are available that hint at what this figure may be, no one source of data offers a complete and robust dataset which can be used. Hence an assumption on the number of vehicles affected is calculated, drawing on the data available and sense checked against other sources. The development of these values is set out in this section.

2.3.1 Number of vehicles in base year (2016)

The baseline fleet is based on a number of data sources depicting the size of the fleet historically.

For HGV and coaches, the analysis used ANPR data gathered by SCC in 2016 across a number of locations throughout Southampton. The ANPR data provided:

- Data from one week (in December 2016)
- 18 sites covering key links entering Southampton and around the periphery of the city
- The ANPR sites were located in the city centre and on key links city wide. The sites were spread across the proposed CAZ areas, and were located on many of the key links which will comprise the city-centre and city-wide boundaries and on sites which will be within the zones. It was therefore assumed that the ANPR data could be assumed to be broadly representative of vehicles travelling within the proposed CAZ areas.

Custom runs of this ANPR data were performed to identify the number of unique vehicles in each area of interest, and to develop a frequency distribution over the week of how often unique vehicles entered the CAZ areas.

For buses, SCC provided data from the operators on their fleet in 2016. This data presented the number of buses, Euro category and the expected new Euro 6 buses by bus operator. This was used to construct the bus fleet data for 2016. This represents the bus fleet that are operating services in and around the Southampton city area, but it did not capture buses using the Southampton depot but serving routes outside Southampton.

The construction of coach fleet data was more challenging. The ANPR data provided information on the total number of scheduled buses and coaches, but it was not possible to differentiate between the two. Therefore, we subtracted the number of buses operating scheduled services within Southampton from the ANPR data to get an estimate for the number of coaches accessing the CAZ areas.

Annual, not weekly data was of interest to the modelling team. Therefore, uplift factors were required to take into account the additional vehicles entering the areas of interest throughout the year. These uplift factors were based on expert judgement, drawing on a range of insights, including:

- analysis of the ANPR data which described the number of times a particular vehicle entered the areas of interest. This allowed the modelling team to identify the proportion of different vehicle types which enter the CAZ on a regular basis and those that enter less frequently.
- the type and typical nature of travel of different vehicle types (e.g. the majority of buses run frequent routes over the course of a week, and hence are more likely captured in the weeks' worth of ANPR data, whereas HGVs operate more national travel patterns, travelling less frequently to the same city areas)
- The amenities located in each proposed CAZ area.

The uplifts applied are presented in Table 4. Applying these uplifts to the weekly data provided the unique vehicles operating in the City Centre and City-Wide CAZ in Southampton on an annual basis in 2016.

Taxi (including private hire, PH vehicles) data was based on 2016 licence data provided by SCC. This data did not require the application of any of the uplift factors to move from weekly to annual data. This licence data is assumed to be representative of the unique vehicles operating in the CAZ zones as it is assumed all the Southampton registered fleet will travel within both the city wide and city centre over the course of a year. The drawback with this data is that it does not capture the total number of vehicles operating in Southampton as some vehicles may come in from outside the Southampton licencing area. To compensate, it is assumed that the full taxi fleet across Southampton, Eastleigh and New Forest will travel to Southampton centre over the course of a year – although this will not be true in practice, this will compensate for taxis which will travel in from other areas. An uplift of 1.5 is applied to calculate the number of taxis which will access the city-wide CAZ area over the course of a year, as this will likely be a greater number than those accessing the city centre (this has been derived from a comparison of the number taxi and PH vehicles accessing the city centre and city-wide zones over the course of a week, as depicted in the ANPR data).

Table 4 – ANPR Uplift Factors – Weekly to Annual

	Uplift factor	Rationale
Bus	1	Baseline fleet based on fleet data so no uplift required
Coach	2	This category will include some vehicles accessing CAZ fairly regularly (e.g. those services taking the same routes for private clients), accessing the CAZ less often but on a regular basis (e.g. operated by national operators such as Stagecoach, or those servicing the port) and those which visit Southampton sporadically or only once (e.g. to supply the football stadium and other amenities). Analysis of the ANPR suggests that the majority of vehicles accessed the CAZ areas only once over the course of the week analysed, so a fairly large uplift could be applied.
HGV	2.5	This category will include some vehicles accessing CAZ fairly regularly (e.g. those based in Soton), accessing the CAZ less often but on a regular basis (e.g. servicing the port) and those which visit Southampton sporadically or only once. Analysis of the ANPR suggests that the majority of vehicles accessed the CAZ areas only once over the course of the week analysed, so a fairly large uplift could be applied.
Taxi / PH	1	Baseline fleet based on fleet data so no uplift required

2.3.2 Number of vehicles in study year (2020)

The CAZ is anticipated to be introduced in 2020 and therefore a growth factor is required to reflect the growth in vehicles between 2016-2020. In this case we utilised the vehicle kilometres (vkm) produced by the Systra transport model.

The growth in the transport model between 2015 and 2020 is calculated and the annual growth rate is applied between 2016 and 2020. These factors were split by vehicle type and showed growth in vkm over time (direct application of these factors assume growth in vehicles matches growth in vkm, hence average vkm per vehicle stays constant over time).

The underlying data from the transport model is presented in Table 5.

Table 5 – Traffic growth in transport model

		AADT	Cars	LGV	HGV	PSV
Base 2015	veh-km	17,202,674	13,822,686	1,355,533	945,2671	133,920
DM 2020	veh-km	18,607,907	15,024,927	1,498,533	975,4431	133,560

		AADT	Cars	LGV	HGV	PSV
%age change over 5 years	veh-km	8.17%	8.7%	10.6%	3.19%	-0.003%

2.3.3 Fleet composition in 2020

The underlying ANPR provided data on the split of different vehicle types between Euro standards. However, as with the overall change in the number of vehicles in the fleet between 2016-20, there will also be some underlying churn in the spread of vehicles across Euro standards.

The fleet composition in 2020 adopted for the economic analysis was the same as that which fed into the preceding air quality modelling. This was calculated taking the ANPR data as a starting point, then using projection factors derived from National Atmospheric Emission Inventory (NAEI) data to project forward and give forecasts annually from 2015 to 2020. The fleet split assumed is shown in Table 6.

Table 6 – Fleet composition in 2020

Euro Standard	Bus/coach	Taxi (petrol)	Taxi (diesel)	HGV[5]
0	0%	0%	0%	0%
1	0%	0%	0%	0%
2	0%	0%	0%	0%
3	2%	3%	1%	1%
4	6%	43%	27%	3%
5	15%	35%	46%	15%
6	77%	18%	26%	80%

Note: this only shows composition of conventional fuelled vehicles. Hybrid and electric vehicles have been excluded from the fleet used in this study given the CAZ options only affect convention fuelled vehicles.

2.3.4 Fleet baseline used for assessment

Presented below are the raw numbers of unique vehicles derived from the ANPR data and other sources for the city centre, city-wide and port areas in 2016.

Table 7 – Numbers of vehicles in the model – city centre CAZ

	Input data		Derived 2020 baseline (after applying uplift factors)		Number of non-compliant vehicles
	No. of vehicle; 2016; one-week data	% compliant	No. of vehicles; 2020; per year / total	% compliant (2020)	No. of vehicles; 2020; per year / total
Bus	275	30%	275	77%	64
HGV (ANPR)	6,356	45%	16,192	80%	3,180
Taxi – HC	482	12%	507	30%	354
Tax - PH	1,288	12%	1,354	30%	945
Coaches	1,181	30%	2,407	77%	563

Table 8 – Numbers of vehicles in the model –city wide CAZ

	Input data	Derived 2020 baseline (after applying uplift factors)	Number of non-compliant vehicles

[5] This is the weighted average of the rigid and articulated HGVs

	No. of vehicle; 2016; one-week data	% compliant	No. of vehicles; 2020; per year / total	% compliant (2020)	No. of vehicles; 2020; per year / total
Bus	275	30%	275	77%	64
HGV (ANPR)	14,420	45%	36,736	80%	7,215
Taxi – HC	482	12%	761	30%	531
Tax - PH	1288	12%	2,031	30%	1,417
Coaches	1,982	30%	4,039	77%	944

Table 9 – Numbers of vehicles in the model – port

	Input data		Derived 2020 baseline (after applying uplift factors)		Number of non-compliant vehicles
	No. of vehicle; 2016; one-week data	% compliant	No. of vehicles; 2020; per year / total	% compliant (2020)	No. of vehicles; 2020; per year / total
HGV (ANPR)	3,768	45%	9,660	80%	1,932

For the port, one specific ANPR camera site was analysed (both directions), on First Avenue, which leads towards Dock Gate 20 – the main entrance to the container terminal and the Western Docks. However, there are a number of off-port businesses which are serviced by HGVs (and possibly coaches) leading off from First Avenue prior to dock gate 20, and so the ANPR count at this location will be an upper estimate of the number of vehicles accessing the Western Docks via dock gate 20.

This also presents the resulting numbers of vehicles from application of the uplift factors, fleet growth, and fleet composition adjustments in 2020 as described above.

Note: for buses, this data only considers the number of buses running scheduled routes in and around Southampton. This does not include buses that access the bus depot within Southampton on an annual basis for servicing. Through stakeholder correspondence, a bus company has noted that on average 4 buses access the depot per week for annual servicing (208 buses per annum). Given these buses only enter the CAZ once a year, they are treated separately in the analysis, as detailed in the following sections.

2.3.5 Sense-check of unique vehicles

The number of unique vehicles travelling into the CAZ areas is a critical intermediary output of the analysis and defines a large proportion of the resultant impacts seen in the model. There is no perfect source for the number of unique vehicles. However, as part of the Quality Assurance of the analysis the number of unique vehicles that arise from the modelling work has undergone a detailed sense-check against a number of different sources and the modelling work of Systra.

The unique vehicles that resulted from the ANPR data and application of uplift factors were compared with a number of different sources to ensure that the results were reasonable. The greatest uncertainty relates to the number of HGVs and coaches. We are confident in the taxi and bus fleet data because it was provided by SCC and therefore required little manipulation, and cars and LGVs were not included in the CAZ options. The following sources were consulted:

Expert judgement – The economic model assumes that 36,700 unique HGVs travel into the Southampton city wide CAZ in a year. This is based on 14,420 unique vehicles being captured by ANPR cameras over the course of a single week. The majority of these vehicles are likely to be irregular visitors with the ANPR data suggesting that the majority of the vehicles visited the area only once a week. However, what the ANPR data does not describe is how many of these vehicles are repeat visitors week on week. It is therefore reasonable to assume that a large number of vehicles visiting the Southampton city wide CAZ will not be captured in this single week of ANPR data.

***Licenced vehicles* –** The total number of unique vehicles were compared against the number of licenced vehicles in Southampton and Hampshire.

The number of unique coaches assumed to be affected by the city-wide CAZ is significantly higher (13 times) than those registered in Southampton, but is broadly similar to those registered in Hampshire. Hence the assumption is equivalent to saying all coaches registered in Hampshire will travel into Southampton city region at some point. Some of course will not, but Southampton will attract coach travel from outside Hampshire, in particular to serve the port, amenities such as the football stadium, and for national coach routes.

The picture is similar for HGVs: the vehicles assumed to be impacted by the city-wide CAZ represent 17-times the HGVs registered in Southampton and nearly 300% of HGVs registered in Hampshire. Again, Southampton as a major urban centre will attract HGV traffic from many regions outside Southampton, in particular to serve the port, suggesting that the difference is considered explainable.

Table 10 – Registered vehicles in Southampton and the difference between the model otuptus

	Registered Vehicles	Registered Vehicles	Difference between registered vehicles and those assumed travelling into City wide CAZ	
	DfT Stats for Southampton	DfT Stats for Hampshire	Southampton	Hampshire
Coaches	300 (including buses and coaches)	3,700 (buses and coaches)	1346%	109%
HGV	2,100	13,800	1749%	266%

***Systra transport model* –** The transport model provides trip count data. The model provides 9,500 PCU points through the city-wide CAZ enclosure over the course of a 12-hour period. Scaling this up and converting from PCU to trips, this equates to 2.1m HGV trips into Southampton every year.

Assuming all HGVs make a return trip, this equates to 28.5 days for each unique vehicle spent in CAZ each year, or equivalent to one return trip per month. This is considered within a sensible bound, given some HGVs may travel in fairly frequently (e.g. once per week or more), and many will also be infrequent visitors.

***Traffic master* -** the study team are aware of the Trafficmaster dataset which was used in the modelling of the national plans. It has been suggested that this could be a useful triangulation point for our modelling outputs but it has not been made available in time for the publication of this methodology document.

2.4 Modelling assumptions

In Table 11 below we present the modelling assumptions of each CAZ option and the sub-measures which comprise the option. These are common across the modelling elements and are consistent between the transport, air quality and economic assessment.

Table 11 - Modelling assumptions

Option	Components	Modelling approach
CAZ B	City Wide CAZ B	City Wide CAZ B in transport model, which feeds into AQ model
	Taxi licence	All Euro V and older taxis upgrade to Euro VI in 2023 to comply with licence changes in 2023, following natural upgrade and provision of further taxi upgrade incentives, SCC anticipate there will be around 136 taxis remaining in 2023 that are Euro V or older. It is uncertain whether these will be taxis or private hire (PH) vehicles hence we split them according to the fleet split in current licence data. Given this comes into place in 2023, we assume all remaining taxis are Euro V (a Euro IV will be around 12 years old by 2023 hence there is a lower chance of these older vehicles continuing to operate)
NCH CAZ	Taxi licence	All Euro V and older taxis upgrade to Euro VI in 2023 to comply with licence changes

Option	Components	Modelling approach
	Shore-side power	Shore-side power installed at one berth; used by 20% of cruise terminal calls (discussions with ABP identified around 20% of existing fleet could use shore-side power)
	Port booking system	1% of non-compliant (i.e. Euro V and older) HGV's shift trips to off-peak periods (result of Systra transport modelling)
	Sustainable Distribution Centre	DSP put in place at General Hospital, removes 113 HGV and 640 LGV trips per week (as defined by SCC) No information is available on length of trips taken off the road. Hence, we assume the distance between the SDC and general hospital of 4km as average distance saved, leading to a total vkm saving per annum of 25,300 HGV and 143,000 LGV vkms

Where a charging CAZ has been modelled, the assumed charging levels modelled are consistent with those proposed for the London Ultra-low emission zone (ULEZ). These are presented in Table 12. These are assumed as a placeholder at this stage as the exact final charging levels to implemented in Southampton have yet to be defined.

Table 12 – Charging levels assumed

Vehicle type	Bus	Coach	HGV	Taxi/PH
Daily charge (£/day)	£100	£100	£100	£12.50

The assumption around the number of upgrades in response to these charges is taken from JAQU's overarching guidance. The most recent guidance issued by JAQU ('Inception Package') states that where 'possible local behavioural surveys' should be used if they exist. In the case of Southampton, no such behavioural studies exist with which an alternative charge-response relationship could be defined. That said, no evidence exists to suggest that these charge-response relationships are not appropriate for Southampton. This is recognised as one of the key uncertainties in the analysis and is intended to be explored as part of proposed sensitivity analysis.

The exception to this is for buses: CBTF funding will be available to retrofit all scheduled buses in Southampton. Hence it is assumed that all buses will upgrade to the compliance standard. This only considers buses running scheduled routes in and around Southampton. This applies in baseline and both CAZ options, hence no impacts associated with bus upgrades and retrofit are included in the CAZ options analysis.

However, this does not include buses that access the bus depot within Southampton on an annual basis for servicing. Given these buses only enter the CAZ once a year, they are assumed unlikely to upgrade in response to the CAZ (although some may already be compliant). Instead they are considered likely to either pay the charge or avoid/cancel their journey and use another service depot. For simplicity it is assumed that they 'pay the charge', with no impact on the impacts assessed.

For taxis and PH vehicles, the upgrade assumptions adopted are those for car vkm from JAQU's guidance. Specific assumptions for taxis and PH vehicles were not available from JAQU's guidance. These are adopted on the basis that taxis will enter the zone more frequently than cars and hence have a greater incentive to upgrade (and hence higher upgrade level), but also perhaps have greater opportunity and flexibility in their response relative to say coach or HGV operators.

Once the number of upgrades has been defined, the proportion of vehicles which adopt other behavioural responses to the CAZ are also taken from JAQU's guidance for taxis and PH vehicles and coaches. For HGVs, this alternative response is defined endogenously within the transport modelling – i.e. the number that pay, avoid zone or cancel. The assumptions adopted in the modelling are set out in Table 13.

Table 13 – First-order behavioural responses assumed in the modelling (% of vehicles)

Vehicle type	Coach	HGV	Taxi/PH*
Upgrade	41%	44%	64%
Pay	33%	54%**	7%
Other (E.g. avoid zone, cancel journey, etc)	26%	2%**	29%

*Assumption adopted for upgrade response for car vkms and assumed applicable to taxi vehicles

**Determined endogenously in transport model.

2.5 Approach to assessing the impacts

2.5.1 Upgrade costs

This applies to all vehicle types upgraded under the charging CAZ B measure – all upgrades under this measure are assumed to occur in the year of implementation: 2020. This also applies to taxis which upgrade under the non-charging measure in 2023 in response to tightened licence conditions.

Calculation steps: Calculation of the vehicle replacement costs for CAZ scenarios follows the following calculation steps:

1. Calculation of the number of non-compliant vehicles for all vehicle types based on 'fleet baseline' and CAZ specifications.
2. Calculation of the number of non-compliant vehicles that will be upgraded for all vehicle types according to 'first order' JAQU assumptions (i.e. as opposed to those avoiding/cancelling/paying the charge).
3. Calculation of the vehicles to be scrapped, bought new, sold and replaced with vehicles of the same fuel, and sold and replaced with vehicles of a different fuel based on 'second order' JAQU assumptions.
4. Calculation of upgrade costs for CAZ scenarios:
    a. Lost residual value from scrapped vehicles based on depreciated value of non-compliant vehicle
    b. New compliant vehicle purchase costs are cost of new vehicle
    c. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles with same fuel
    d. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles of different fuel
    e. Aggregate the relevant costs for different CAZ scenarios (e.g. CAZ B aggregates HGVs, Taxis, Coaches and Private Hire Vehicles)
5. Calculation of baseline upgrade costs (this assumes the same activity as the CAZ scenario, however this activity simply occurs at a later date, either where the non-compliant vehicle reaches the end of useful life or end of the ownership profile):
    a. Each vehicle replaced under CAZ scenario will be replaced under the baseline at a later date.
        i. Those vehicles that are scrapped under CAZ are assumed to run until end of useful life
        ii. Hence no lost residual value in baseline.
    b. New vehicle purchase costs – assume new vehicles would have been purchased anyway to replace scrapped vehicles, just at a later date
        i. Associated with scrappage – so assume timing of new vehicle purchase is associated with remaining lifetime of vehicles scrapped
        ii. Discount costs to 2018
    c. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles with same fuel
        i. The non-compliant used vehicles would have been replaced anyway, just at a later date
        ii. Some vehicles assumed to run to end useful life and scrapped – hence net cost in baseline is just cost of compliant used

iii. Some vehicles assumed to be replaced anyway. Assume delay until replacement is 2 years (as midpoint of 4-year ownership cycle). After two years, cost is as under CAZ scenario: Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles but two years later

1. A four-year ownership cycle was assumed on the basis of evidence collected as part of a feasibility study for a Zero-Emissions Zone in Oxford[6]. JAQU also provided data on typical ownership lengths. A comparison of the two sources suggests differences between them are small, in particular for HGVs which are the only category for which JAQU provide data and that are included in Southampton's CAZ proposals. Any difference will be even smaller given the model halves remaining ownership lifetime as part of the analysis.

iv. Split between those non-compliant used vehicles which are scrapped at end of useful life, and those which are sold as used at end of ownership profile is determined by age of non-compliant vehicle: older vehicles are more likely to be scrapped

1. Proportion of different Euro standards scrapped at end useful life / old at end of ownership profile is based on expert judgement

v. Used compliant vehicle purchased is same age as under baseline – i.e. whether bought in 2020 or 2022, person buys a 5-year-old car

vi. Discount costs to 2018

d. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles with different fuel (same points i. – vi. apply as under c. above).

e. Aggregate the relevant baseline costs

6. Calculating the marginal impact of each CAZ scenario compared to the baseline. Given the same activity is assumed under CAZ scenario and baseline, just at a different time, the key difference driving the net effect is discounting of the impacts under the baseline.

The critical step in the above calculation steps is the application of the 'second order' behavioural response which defines how those owners of non-compliant vehicles undertake the replacement of their vehicle – scrap, buy new, sell and buy the same fuel, and sell and buy a vehicle of a different fuel. JAQU provides high level guidance regarding the proportions of vehicle owners adopting each response, but it was necessary for the economic modelling team to construct more detailed assumptions regarding behaviour in order to facilitate the analysis. A summary of these assumptions is presented in Table 14.

Table 14 – Upgrade cost assumptions

	Scenario	Scrap	Buy new	Sell & Buy Same Fuel	Sell & Buy Different Fuel
Numbers of vehicles	**CAZ**	25% of all vehicles upgraded JAQU behavioural response applied. Oldest vehicles scrapped first in 2020	25% of all vehicles upgraded JAQU behavioural response applied. Every vehicle scrapped is replaced with new vehicle in 2020	75% * 25% (for diesel) 75% for petrol JAQU behavioural response applied. Vehicles to be sold (those not scrapped) * behavioural response	75% * 75% (for diesel) 0% for petrol JAQU behavioural response applied. Vehicles to be sold (those not scrapped) * behavioural response
	Baseline	Vehicles scrapped under CAZ are scrapped in baseline post 2020 when end useful life reached	Every vehicle scrapped replaced with new in year after 2020 at end of useful life of scrapped non-compliant vehicle	Same activity as CAZ scenario But some resell at end of ownership profile Some scrap when reach end useful life	Same activity as CAZ scenario But some resell at end of ownership profile Some scrap when reach end useful life

[6] Ricardo (2017); 'Oxford Zero Emission Zone Feasibility and Implementation Study'; https://www.oxford.gov.uk/downloads/file/4019/zero_emission_zone_feasibility_study_october_2017

	Scenario	Scrap	Buy new	Sell & Buy Same Fuel	Sell & Buy Different Fuel
Costs	**CAZ**	Loss of residual value determined by remaining life of vehicle	Purchase cost of new compliant vehicle in 2020	Cost of compliant used vehicle less resale value of used non-compliant vehicle	Cost of compliant used vehicle less resale value of used non-compliant vehicle
	Baseline	No residual value of vehicles as they reach end useful life	Purchase cost of the same new vehicle in year post 2020 (real cost is same as CAZ scenario, but purchase delayed by remaining life of existing vehicle hence cost discounted to 2020)	Discounted cost of used compliant vehicle less resale value of existing vehicle (for those reaching end ownership profile) Discounted cost of used compliant vehicle (for those reaching end useful life) Resale/scrappage profile applied to vehicle depending on age of non-compliant vehicle	Discounted cost of used compliant vehicle less resale value of existing vehicle (for those reaching end ownership profile) Discounted cost of used compliant vehicle (for those reaching end useful life) Resale/scrappage profile applied to vehicle depending on age of non-compliant vehicle

2.5.2 Air quality emissions

2.5.2.1 NOx and PM emissions (except coaches)

The key objective of the CAZ is to reduce the emission (and subsequently concentration) of air pollutant emissions from road transport sources. Reducing air pollutant emissions will have a range of subsequent benefits, on human and environmental health, productivity and amenity.

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

1. Take quantities (tonnes) of NOx emissions from underlying air quality modelling undertaken by Ricardo for all scenarios and the baseline
    a. Modelling of all scenarios was provided for 2015 (base year) and 2020 (CAZ implementation year)
    b. The modelling domain is the network output covered by the underlying Systra transport model: this includes all AQMAs in Southampton and the wider transport network out to and including the M27 and M271 which will cover all the likely key diversion routes should the vehicles seek to avoid the AQMA. In addition, the domain was extended to cover the expected exceedance area in New Forest and surrounding roads.
    c. Emissions related to the port activities have also been considered
    d. The chosen modelling domain is likely to capture the majority of emissions impacts associated with the CAZ, but there may still be some emissions impacts outside of this area (i.e. outside the modelling domain) – see qualitative analysis for further discussion.
2. Aggregate quantities of emissions for each CAZ scenario and for the baseline
    a. Modelling was provided split by road, period of the day and for compliant (C) and non-compliant (NC) vehicles
3. Calculate total emissions impact of CAZ scenarios on emissions relative to baseline
4. Value impact of CAZ applying damage costs provided by JAQU
    a. The damage cost 'Urban big' is applied to all emissions reductions under the CAZ scenarios.

The results of the analysis for 2020 are presented in Table 15.

Table 15 – NO_x and PM impacts of CAZ scenarios in 2020 (Soton modelling domain only)

Scenario	NOx Difference from Baseline (tonnes)	PM Difference from Baseline (tonnes)
NCH CAZ	-7.3	0.45
CAZ B	270	1.12

2.5.2.2 Emissions savings from non-charging measure

As can be seen from Table 15, in the air quality modelling the non-charging measure is seen to increase emissions in total over the modelling domain. This seems non-sensical, given all sub-measures in the non-charging measure should lead to emissions savings. Through further interrogation, we believe this result is likely due to noise around the underlying transport modelling, hence given the impact of the sub-measures is small we cannot see a significant impact in the aggregate modelling.

However, the measures are still likely to deliver an emission saving. As an alternative, the economic analysis estimated the air quality impacts of each of the individual sub-measures in turn to provide an alternative estimate of the impacts:

- Shore-side power: these results were taken directly from the separate modelling of the port emissions which modelled this change directly
- Sustainable distribution centre: and illustrative run of RapidEms was undertaken to estimate the emission impacts of the vkm saved from HGV and LGV trips removed under the scenario assumed
- Taxi licencing: An illustrative run of the EfT was undertaken to assess the emissions impacts of shifting 136 taxis from Euro V to Euro VI in 2023.

No bespoke modelling was undertaken for the port booking measure. Given the size of the proposed charge, we do not anticipate many if any vehicles to upgrade in response to the measure, instead this will shift some trips off peak. Hence the measure will influence time of day of emissions, more than emissions in aggregate. Although this will likely have some impact on exposure (and therefore health), these benefits will not appear in the economic analysis given the way in which damage costs are simply combined with total changes in emissions.

The results of these analyses are presented in Table 16. These impacts form the basis of the assessment of the NCH CAZ option, rather than the impacts from the AQ modelling, from which a significant impact could not be observed.

Table 16 – Emissions impacts of NCH CAZ sub-measures

Sub-measure	NOx emission savings (2020, tonnes)	PM emission savings (2020, tonnes)	Method
Shore-side power	-8.34	-0.31	Direct modelling of port emissions
SDC	-0.68	-0.18	RapidEms
Taxi licence 2023	-1.24	-0.01	EfT

2.5.2.3 Emissions from coaches

The Systra transport model does not split out coaches as a separate vehicle category. Hence, the impacts of the CAZ options on coaches are not captured in the core NOx and PM modelling undertaken by Ricardo. However, given the large amount of coaches entering Southampton, the impact of coaches was identified as a potentially important impact of the Southampton CAZ. Hence, Ricardo undertook supplementary modelling to illustrate the potential size of such effects. This modelling deployed Defra's Emission Factor Toolkit (EfT v8.0) in a relatively simple way. The estimated emissions from coaches under each scenario were then included in the scenario impacts illustrated above.

The following appraisal steps were followed:

1. Take ANPR data on the combined number of coaches and buses; subtract the number of buses to get an estimate on the number of unique coaches entering each CAZ boundary per week.
2. Apply an uplift factor of 2 to estimate the annual number of coaches affected by the CAZ
3. Use the bus baseline fleet to split coaches by Euro standard
4. Combine with data on average data on vkm per annum travelled by coaches
    a. In doing so, again the illustrative modelling will capture all impacts of upgrading coaches, i.e. covering both travel within and outside the city, hence covering a different scope to the core air quality modelling undertaken
5. Input vkm change by vehicle type and Euro standard into the EfT to calculate changes in emissions (PM and NOx)
6. Combine changes with damage cost from JAQU guidance ('Urban big')

The results of the modelling are presented in **Error! Not a valid bookmark self-reference.**.

Table 17 – Illustrative impacts of emission related to coaches

Pollutant	Baseline emissions in 2020	Difference to the baseline in 2020, Option 1
	City-wide	City-wide
NOx	474.9	-147.4
PM	19.5	-1.76

2.5.2.4 Extrapolation of air pollutant impacts

Emissions under each scenario from the air quality modelling were only available for 2020. To assess the impacts over the course of the appraisal period, the impacts in 2020 were extrapolated to 2030 using an extrapolation factor.

Two options for the extrapolation factor were considered (see Information Box #1 below). The extrapolation factor selected for the analysis was based on the analysis underpinning the National Air Quality plans. Specifically, the factor considers the convergence of concentrations between baseline and CAZ scenarios analysed by JAQU.

Information Box #1: Impact extrapolation factors

For air pollutant (and other) impacts, detailed modelling of the effects was only available for 2020. Hence a methodology was developed to extrapolate these impacts over the whole appraisal period. Two key sources were considered from which an extrapolation factor could be derived.

National AQ plans scenarios[7]*:* The supporting evidence for the national plans included scenarios run by JAQU presenting resulting concentrations in cities for the baseline and illustrative CAZ scenarios. This information could be analysed to produce a factor with which impacts can be extrapolated over the appraisal period to simulate the erosion of the impacts of the CAZ, as the vehicle fleet naturally catches up with the upgrades brought forward as part of the CAZ. The extrapolation factor is the difference in concentrations between baseline and CAZ scenario, expressed as a ratio relative to the impact in 2020.

Fleet projection model: turnover in fleet can be modelled directly depicting changes in numbers of vehicles using assumptions provided by JAQU to facilitate modelling around the CAZ. Hence, they can be used to compare natural expected turnover in the fleet against the resulting fleet in 2020 following the application of the CAZ, and the convergence between the two going forward from that point. A basic fleet projection model was developed and used as an input to the 2020 air quality modelling to define the fleet Euro Standard split in 2020. This offers the advantage that trends in fleet can be explored directly.

[7] See 'Baseline and with Measures projections' available: https://uk-air.defra.gov.uk/library/no2ten/2017-no2-projections-from-2015-data

Factor used in analysis: The analysis applies an extrapolation factor derived on the basis of the evidence developed as part of the national plans. This approach was adopted as it was deemed most proportionate, and also given limitations in the availability of local information make it doubtful that a significantly different trend to that observed nationally can be confidently assumed for Southampton.

As noted, a simple fleet turnover model was developed to support the air quality modelling. However, this has a number of limitations which prevent its application for the economic analysis:

1. Further effort would be required to extend this past 2020 (this has not yet been undertaken for the air quality modelling)
2. Some method would be required to combine convergence for different vehicle types which converge at different rates. The impact on overall emissions will depend both on the convergence profile of the fleet itself, and the relative emissions factors across different vehicle types. Hence ideally this would be combined in terms of emissions. But this would require collation of a number of additional inputs (e.g. speed, traffic count, etc) which would then need to be combined to calculate emissions, essentially re-creating the functionality of the air quality model (hence not an insignificant task)
3. The model does not cover all vehicle types, hence any model of this type would still not present a fully representative picture unless additional expansion work is undertaken.

It is questionable how different the result would be between the output of a local model and the trend depicted by the national plans. Many of the inputs into any ‘local fleet model’ would draw on national data and parameters given limitations around data available at local level. The starting point of the fleet model noted above is reflective of local Euro splits historically (based on 1-week of ANPR from 2016). But then national parameters are used to depict growth in overall fleet and underlying churn in Euro standards forward (the tool we developed adopts national trends from the NAEI). No data exists to adopt local assumptions for these critical parameters, in particular when projecting out past 2020 to 2025, 2030. Using national assumptions therefore inherently reduces the potential for any outputs from local modelling to vary from outputs produced from a national model.

Further it is questionable whether one could have confidence in any difference produced from a local relative to national modelling. There is always inherent uncertainty associated with projecting parameters forward, including to 2020 – there is uncertainty around the national growth of fleet and turnover, and uncertainty around more localised projection factors would be even greater. There is also uncertainty around the starting point, given only 1 weeks’ worth of ANPR data was collected. Hence the results attained from such a local fleet projection model, and those represented by the extrapolation factors derived from the national plans, are deemed likely to fall within the range of uncertainty around this exercise.

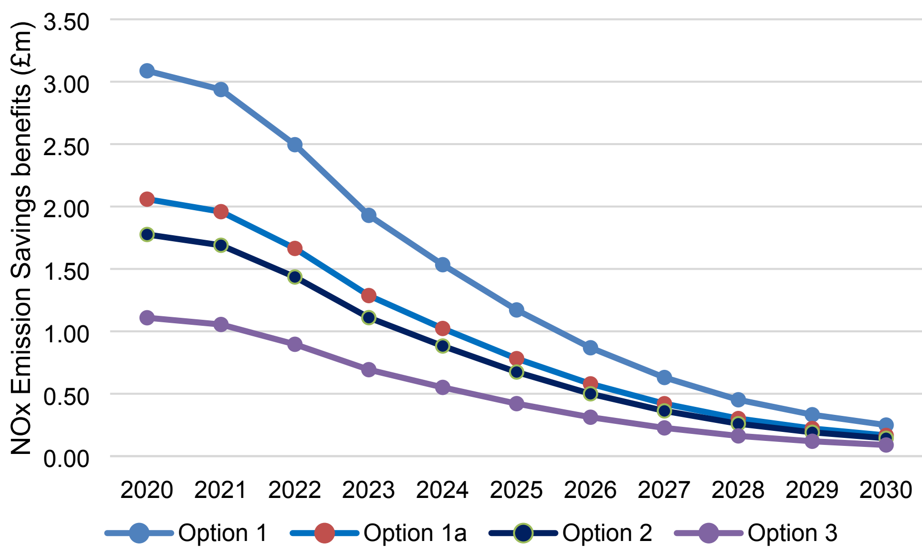
For the non-charging measures, applying this extrapolation factor may lead to a slight underestimation of the air quality benefits. The impacts of some of the measures included will not tail off in the same way as the baseline fleet catches up. This is because some measures do not simply bring forward fleet upgrade, but influence emissions in a different way. Some tailing off will happen as the baseline fleet improves, but not to the same extent as under a charging scheme. Specifically:

1. The emission benefits from use of the SDC and DSP would have a flatter profile over the appraisal period, as the savings in theory will be maintained associated with removing freight vkm from the roads.
2. Emissions saved through shore-side power will not tail off as it is assumed vessels will continue to use these facilities when in port into the future

The air quality modelling does not split emissions impacts by sub-measure. However, given these measures have been modelled individually at sub-measure level, it has been possible to apply the extrapolation factor to the savings from taxi licence changes, and apply no extrapolation factor to savings from the SDC and shore-side power.

To illustrate the shape of the extrapolation factor, the trend in NOx emissions impacts of the initial shortlist options over the appraisal period are illustrated in Figure 1 .

Figure 1 – Trend of NOx emissions impacts of CAZ over appraisal period (undiscounted)



2.5.3 Operating costs and GHG emissions

Different vehicles have different running costs in terms of fuel and operating costs (e.g. maintenance). Where the CAZ incentivises switching between vehicles or changing the use of existing vehicles, there will be an associated impact on fuel consumption, operating costs and GHG emission. Any change in GHG emissions will influence the ability of the UK to meet its climate change targets.

Given the variety in measures which have been combined to form the CAZ options, there is the potential for a range of effects impacting operating costs. Due to limitations in modelling and approach, only the two key impacts have been captured in the quantitative analysis (for further discussion and analysis of the impacts not captured, see Appendix 4 – Qualitative assessment of wider impacts):

1. The impact of upgraded vehicles in response to charging/non-charging measures
2. Direct savings to freight operators (and cost to SDC) associated with greater routing of freight through the SDC.
3. Direct savings to vessel operators from installation of shore-side power – vessels consume grid electricity rather than marine gas oil through their auxiliary engines to provide power when at berth.

In addition, the fuel/opex cost savings associated with alternative responses to a charging CAZ will be captured by welfare loss impacts described below. However, the impact of alternative responses to a charging CAZ on GHG emissions will not be captured as part of the welfare loss as these impacts to not accrue directly to the private individual.

To estimate the effect of upgrading vehicles, the following approach was taken:

1. Take numbers of vehicles upgraded from fleet upgrade calculations
2. Depict change in vehicles over appraisal period using lifetime / ownership profiles to extrapolate differences in the fleet between the baseline and scenario
3. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with the average annual fuel consumption and average annual operating costs per vehicle type and age[8]
    a. By applying average opex and fuel consumption over the full year and average vkm travelled per year, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the AQ modelling domain

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

4. Changes in fuel consumption are combined with emissions factors from BEIS' Green Book Supplementary Guidance to calculate changes in GHG emissions (tCO_2e)
5. Changes in fuel consumption are combined with Long-run variable costs (LRVC) and changes in GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary guidance
    a. Prices for marine gas oil are taken for 'Rotterdam' price point[9] for 2018. These are forecast forward using the trend in diesel price change from BEIS' Green Book Supplementary guidance

To estimate the effect of the DSP/SDC, the following approach was taken:

1. Extract total change in vkm from air quality modelling
2. Apply Euro split in 2020 to get chance in HGV vkm by standard
3. Follow steps above from 3 onwards.

To estimate the effect of the shore-side power, the following approach was taken:

1. Estimate total electricity consumption of cruise ships whilst at berth for those able to use shore-side power facilities
    a. it is assumed that only 20% of cruise vessels are currently equipped to do so
    b. Vessels are assumed to be at berth for 12 hours, with an average power draw of 12MWA[10]
2. Convert this into tonnes of marine as oil saved using average efficiency factor for relevant engine[11]
3. Follow steps above from 3 onwards relating to calculating fuel and GHG cost savings.

The different categories of impacts are then combined for the overall CAZ options, and discounted to 2020.

2.5.4 Congestion impacts / Travel time

The measures which are combined to comprise the CAZ options have a variety of impacts on travel time and congestion. For example, where vehicle owners cancel journeys, shift mode or avoid the zone in response to a charging CAZ, this can lead to changes in traffic and congestion within the zone. Note: other behavioural responses 'upgrade vehicles' and 'pay the charge' are assumed to lead to no change in trips, only change to the vehicle type with which the trip is made. Hence these behavioural responses are assumed to have no impact on congestion.

Only one impact on congestion and travel time have been captured as part of the quantitative analysis (with wider, less significant impacts captured as part of the qualitative analysis):

a) The direct benefit of reduction in driver time for freight re-routing through the SDC
b) The indirect impact of changes associated with the alternative behavioural responses to the charging CAZ on other road users

Furthermore, the change in travel time for non-compliant vehicles avoiding/cancelling in response to a charging CAZ will be captured in the 'welfare loss' impact discussed below.

The direct impacts of the SDC on driver time were calculated as follows:

1. Take data from the transport modelling regarding changes in HGV and LGV trips saved
2. Combine trips saved with an average trip length saved. We have no data on the trip lengths saved, hence for illustration we use the distance between the SDC and General Hospital as the distance saved – which would correspond to the saving for a vehicle accessing the hospital from an area outside the city centre
3. Multiply trip length saved by two to represent savings over a return trip

[9] https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam#MGO
[10] Conversations with ABP
[11] https://www.wartsila.com/sustainability/innovating-for-sustainable-societies/improving-efficiency

4. Combine the result with an assumption on the average speed of those journeys based on transport model outputs (assumed to be 40kmh given most mileage will be removed from city-centre links, plus this should include time savings from stoppages)
5. Combine this result with WebTAG data on value of time for HGV drivers.

2.5.5 Welfare loss

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

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

1. Take frequency distribution of unique vehicles accessing CAZ across week from ANPR data
2. Spread number of non-compliant vehicles in 2020 over this distribution
3. Combine number of vehicles, with days spent in CAZ over the week, to calculate total days in CAZ over all vehicles over the week
4. Remove proportion associated with upgraded vehicles or those paying the charge, leaving CAZ days associated with those adopting alternative behavioural responses.
5. Scale up affected CAZ days per week to affected per year
6. Combine number of affected CAZ days with ½ CAZ charge
7. Extrapolate the impact in the first year over the appraisal period using the extrapolation factor.

This analysis therefore implicitly carries forward the proportion of HGVs taking each alternative response modelled endogenously within the transport model. For other vehicle modes (i.e. taxis and coaches – all non-compliant buses are assumed to retrofit in response to the CAZ), the proportion that adopt behavioural responses (other than upgrade) are taken from JAQU's standard assumptions.

There are a number of different impacts that the user will face associated with switching transport behaviour. Not just the utility of making the trip, but the time required to travel, the fuel, operating cost, comfort of the mode, etc. In theory, the user will take into account all of these impacts when considering the best way to make a trip, and contrast them across alternatives. Under the CAZ scenario, users now face the additional cost of the CAZ charge and will therefore compare the net effect of all these supporting impacts, against the cost of the charge, and decide the appropriate course of action. This approach therefore should not only capture the utility change, but also the other associated impacts associated with changing behaviour and which are privately faced by the user. This wider range of impacts has the potential to overlap with other impacts assessed: where this risk is present, this has been considered and discussed in the assessment of other effects presented in this report. This is predominantly addressed in the qualitative analysis where the impacts which have potential to overlap are considered.

This does not include buses that access the bus depot within Southampton on an annual basis for servicing. Given these buses only enter the CAZ once a year, they are assumed unlikely to upgrade in response to the CAZ (although some may already be compliant). Instead they are considered likely to either pay the charge or avoid/cancel their journey and use another service depot. For simplicity it is assumed that they 'pay the charge', with no impact on the impacts assessed. Even if these buses are assumed to cancel, this would only have a marginal impact on the welfare effects assessed: 4 buses per week results in 208 cancelled CAZ days per year, which equates to an additional cost of £10,400 (assuming half the charge). This impact is small compared to the wider welfare losses estimated.

2.5.6 Implementation costs

Alongside costs to vehicle owners, there will also be costs associated with design, delivery and ongoing monitoring and enforcement of the CAZ options for the implementing authority.

There will be costs associated with both the non-charging and charging CAZ measures. For the charging zones, these costs include items such as cameras, signage, and activities required to set-up and run the CAZ.

Costs for a charging zone are based on those developed by SCC for the Finance Case.

Following Webtag guidance[12], an adjustment for Optimism Bias has been applied to the implementation costs assumed in the central case. Costs are uplifted by 36% to reflect optimism bias.

There will also be costs associated with the non-charging measures under consideration. In the quantitative analysis, costs have been captured representing:

- design and delivery of the port booking incentive scheme, based on costings provided through discussion with DP World
- Costs of designing, negotiating and implementing DSPs to achieve the targeted level of vkm reduction. These are taken from SCC's estimated cost for this measure under 'Option 1' as set out in the Financial Case
    - However, this does not include any additional costs associated with stack management which may occur due to changes in timing of HGV trips to the port
- Cost of additional freight flowing through the SDC
    - Our analysis assumes that the SDC is already established and there is spare capacity to take up additional freight. Hence there will not be any upfront costs associated with setting up an SDC, and some of the variable costs which scale with volume of freight handled will not accrue (e.g. requirement to expand delivery fleet). This assumption has been checked and confirmed as appropriate with the Transport team at SCC.
    - Hence the only additional costs (not captured) will be additional administrative, labour and handling costs within the warehouse. The economic case for use of SDC commonly falls down due to the 'double-handling' costs, suggesting some of these costs could be quite substantial. Indeed, a study by Transport Catapult into the benefits of the University Hospital suggested that the administrative, management and labour costs of operating a DSP are much greater than running the fleet of delivery vehicles, in the range of 3.6:1.
    - The cost included is based on a study by TRL undertaken for SCC[13] which provided a cost of storage per pallet. The costs included are those incurred by space related to the temporary storage of items within the warehouse – i.e. this relates to the physical space on floor which the goods occupy. This cost does not include costs incurred for handling, receipting, picking, generation of proof of delivery notifications (POD), and goods management
    - As noted by the study, SDC costs can vary depending on type of freight (e.g. standard or 'difficult'), delivery model (e.g. transhipment or threshold consolidation) and storage time. It can also depend on existing empty running capacity of freight and the type and size of freight vehicles replaced. Simplifying assumptions have been made for all these parameters to produce an illustrative cost.
- Cost of implementing and maintaining the shore-side power installation at one berth – costs provided through discussion with ABP

Again, an adjustment for Optimism Bias has been applied to the implementation costs assumed in the central case. Costs are uplifted by 36% to reflect optimism bias. The exception is this uplift has not been applied to the shore-side power costs. Based on discussion with ABP, these costings are based on an average of several detailed quotations that ABP have received for the work and are hence assumed to be at a more advanced stage than other implementation costs included in the assessment.

12 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/625380/TAG_unit_a1.2_cost_estimation_jul17.pdf

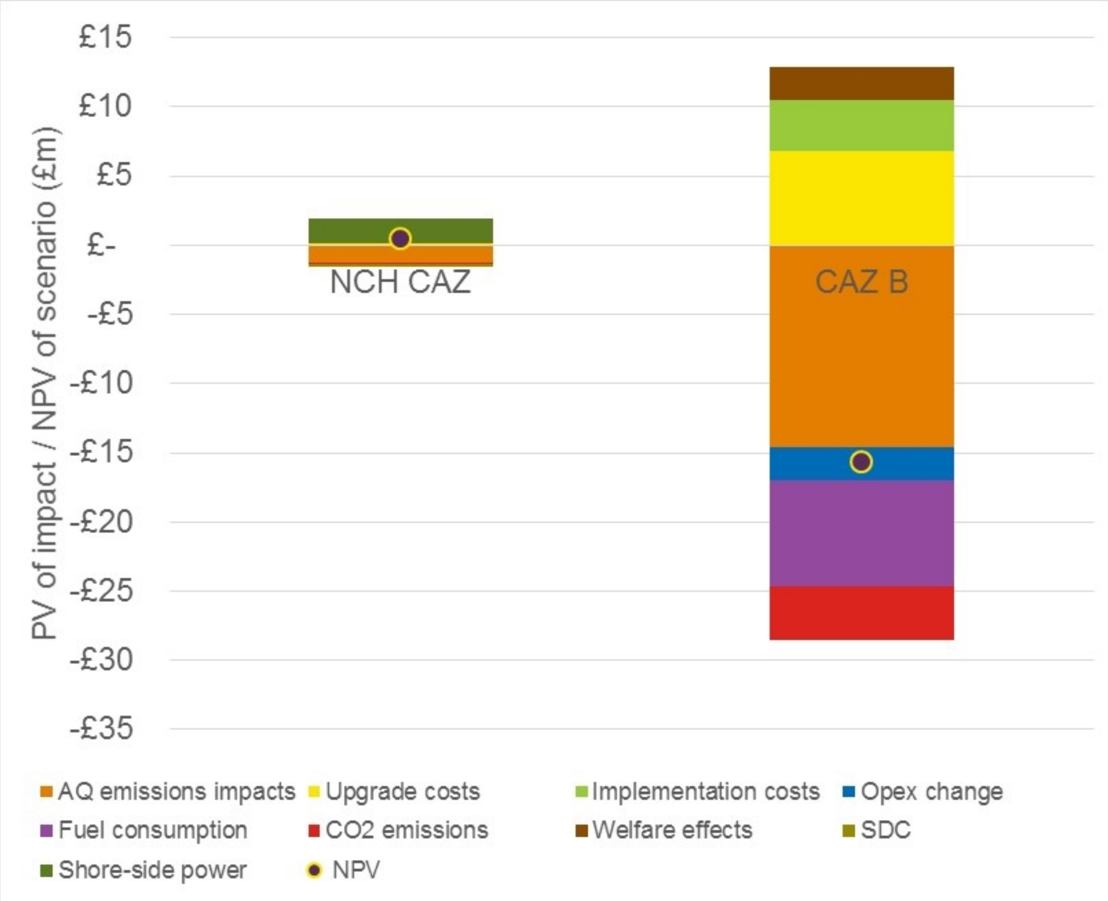
13 TRL (2018); 'Business Case Support for the Implementation of a Clean Air Zone in Southampton' (unpublished)

3 Results

3.1 Quantification and valuation of impacts

The results of the economic analysis are presented in Figure 2, Table 18 and Table 19.

Figure 2 – PV of impacts and NPV of CAZ and NCH option



Note: Bars represent present value (PV) of impacts; dots represent aggregate net present value (NPV) of all impacts associated with CAZ option; all impacts are assessed relative to 'do nothing' baseline; -ve values denote benefit / +ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2018

Table 18 - Monetised impacts associated with CAZ options (cumulative discounted impact (PV) from 2020-30 (£m 2018 prices))

	AQ emissions impacts	Upgrade costs	Implementation costs	Opex change	Fuel consumption	CO2 emissions	Welfare effects	SDC	Shore-side power	**NPV**
NCH CAZ	-1.26	0.15	0.00	0.00	-0.05	-0.03	0.01	-0.19	1.79	**0.43**
CAZ B	-14.57	6.82	3.66	-2.41	-7.71	-3.87	2.40	0.00	0.00	**-15.67**

Notes: -ve values denote benefit / +ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2018;

(*) Air quality impacts represent reductions in emissions valued using the damage costs. These results are distinct from those presented in the air quality modelling report, which focus on concentrations and comparison to the legal limits, although a key input into this economic work is the underlying air quality modelling used to form compliance assessment.

Table 19 – Monetised impacts of NCH CAZ at sub-measure level

	AQ emissions impacts	Upgrade costs	Implementation costs	Opex change	Fuel consumption	CO2 emissions	Welfare effects	**NPV**
Taxi licence	-£37,459	£149,912		£1,998	-£46,868	-£25,607		**£41,976**
SDC	-£268,115		£1,084,813	-£1,546,278				**-£729,580**
Port booking			£268,874				£9,749	**£278,623**
Shore-side power	-£950,056		£6,331,518		-£1,549,647	-£2,993,109		**£838,707**

Notes: - ve values denote benefit / +ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2018

Where cells blank, impacts not estimated or are not associated with measure

3.1.1 Detailed analysis

Air quality emissions impacts: Both the CAZ B and NCH CAZ are seen to deliver positive improvements in air quality through reduction in emissions, which in turn carry with them a range of benefits for human and environmental health.

The CAZ B impact on NOx and PM emissions has been modelled in detail using Ricardo's air quality models, which capture impacts within a defined domain. However, this modelling did not capture the impacts of the additional Taxi measure in 2023. For the NCH CAZ, no significant impact could be discerned from the aggregate AQ modelling. Instead, the impacts of each measure were analysed individually and aggregated. The results have been included as part of the NPV and demonstrate that the impacts of the Shoreside power measure can be significant. The impacts of the 2023 Taxi measure, as well as the SDC are less pronounced. This is because these two measures only affect a small proportion (136 Taxis and less than 1% of HGV + LDV travel) of total travel within the modelled domain.

Taken together, the air pollutant impacts represent the largest net effect across the CBA (with the exception of shore-side power investment cost). Each option delivers a large benefit through reduction in emissions, which scales with the size of the CAZ and vehicle types included, and hence the number of vehicles affected. The options deliver larger emissions reduction in NOx.

The CAZ B delivers the greatest reduction in emissions, followed by the NCH CAZ. CAZ B represents a charging scheme with the largest geographical boundary and variety of vehicles covered – hence this will affect the greatest number of vehicles delivering greater emissions savings.

Vehicle upgrade costs: A key impact in the CBA is cost of upgrading non-compliant vehicles. This covers a number of impacts: the scrappage cost of non-compliant vehicles, cost of purchasing new compliant vehicles, retro-fit of non-compliant vehicles and the cost of swapping a non-compliant used for a compliant used vehicle.

There is a significant cost associated with the CAZ option as here, the majority of non-compliant vehicle owners are assumed to choose to upgrade their vehicle in response to the CAZ.

This impact is a net effect associated with the CAZ scenario: there are also costs in the baseline scenario as the predominant impact of the CAZ is simply assumed to be to bring forward activity (in this case upgrading vehicles) which otherwise would have happened anyway, just at a later date. Hence the costs of the baseline activity are removed from those of the CAZ scenario to present the net cost of the CAZ. In fact, the absolute costs for the CAZ and baseline scenario are around £90+ million with the net impact therefore being the difference between two large numbers. Hence the overall NPV is particularly sensitive to assumptions made in modelling the upgrade costs.

Costs increase with the size of the CAZ size and classification as more vehicles are affected: e.g. the costs of a Class A option will be lower than a Class B. Given the CAZ B option affects many more vehicles, the upgrade costs are much higher for this option relative to the NCH CAZ option.

Implementation costs: The cost of implementing a charging CAZ have been captured based cost estimates derived by SCC for the Financial Case.

For non-charging measures, several different implementation costs have been included across the sub-measures, namely:

- design and delivery of the port booking incentive scheme, based on costings provided through discussion with DP World
- Costs of designing, negotiating and implementing DSPs to achieve the targeted level of vkm reduction. These are taken from SCC's estimated cost for this measure under 'Option 1' as set out in the Financial Case
    - However, this does not include any additional costs associated with stack management which may occur due to changes in timing of HGV trips to the port
- Cost of additional freight flowing through the SDC
- Cost of implementing and maintaining the shore-side power installation at one berth – costs provided through discussion with ABP.

Over the ten-year appraisal period, implementation costs are not an insignificant impact in comparison to other impacts.

These costs are higher for the NCH CAZ relative to the CAZ B, namely due to the costs of implementing and maintaining shore-side power.

Operating, fuel consumption and CO_2 emission savings benefits: By affecting the types and patterns of road transport in different ways, the CAZ options could have a range of different impacts on operating costs of vehicles, fuel consumption and CO_2 emissions. Given limitations in data and methodology, only the two most significant impacts have been captured as part of the quantitative analysis (with the rest explored through the qualitative analysis):

1. Newer, compliant vehicles are likely to be much more efficient and less costly to maintain (e.g. they are likely to require fewer repairs), hence upgrading to these vehicles will deliver additional benefits to the vehicle owner through operating and fuel cost savings.
2. An increasing flow of freight through the SDC as a consequence of updating DSPs will lead to a reduction of freight vkm on Southampton's roads. This will lead to a direct reduction in operating and fuel costs, and CO2 emissions which move in line with distance travelled.

In addition, fuel and GHG emissions savings have been estimated for the shore-side power installation.

Comparing this to the other impacts captured, these impacts form a significant secondary benefit (after air pollutant emission reductions). In particular, fuel savings and CO_2 emission reductions.

As with upgrade costs, the impacts scale with the CAZ area and number of vehicles affected. Hence, they are greatest for CAZ B.

Welfare effects: this captures a range of impacts associated with the alternative behavioural responses (i.e. other than upgrade vehicle or pay the charge[14]) to a charging CAZ.

The quantitative analysis shows that this impact is an important element of the CBA.

The size of the impact increases with the range of vehicles covered by and the geographical size of the CAZ. Hence the welfare costs are highest for CAZ B which affects the greatest number of vehicles, and hence also has the greatest number of HGVs, taxis and coaches which may either avoid the zone or cancel their journey in response to the CAZ charge.

This does not include buses that access the bus depot within Southampton on an annual basis for servicing. However illustrative estimates suggest even if all journeys are cancelled the welfare impact would be small compared to the wider welfare losses estimated.

The NCH CAZ will not have the same welfare impact as it does not propose to implement a charging zone. However, there will be a small welfare impact associated with the port-booking measure, which will lead some HGV operators to switch trips off-peak to a second-best alternative.

Travel time effects of SDC: As with changes in fuel and operating costs, the NCH options could have an impact on congestion on Southampton's roads and hence on travel time (which carries an economic value). Again, given limitations in data and methodology, only one of the key impacts have been captured: Impact of DSP/SDC on freight driver time (i.e. reduction associated with freight journeys re-routing and consolidating through the SDC.

The results suggest that travel time savings could be a significant benefit associated with the NCH CAZ (i.e. DSP/SDC). This mirrors the results of the study undertaken by Transport Catapult looking at the impacts of greater uptake of the SDC in Southampton, finding that driver time savings are the most important amongst a range of potential benefits associated with increasing uptake[15].

The analysis has not captured:

[14] No impacts associated with 'pay the charge' are captured as part of the societal CBA. There is no change in behaviour, so no impact on emissions or other impacts associated with this response. There is a cost to vehicle owners paying the charge, although this is wholly offset by the benefit to the authority to which the charge is paid. Hence this impact is a 'transfer' and hence does not need to be captured as part of societal CBA.

[15] Transport Systems Catapult (2017); 'Quantifying the benefits from consolidation centres' (unpublished, provided by SCC)

1. Change in travel time associated with alternative behavioural responses to charging CAZ - this is not included again as part of the travel time effects given it will already be captured by the welfare effects estimated above[16].
2. Wider changes in travel time due to trips removed through use of the SDC
3. Any impact of port booking changes on travel time of HGVs accessing the port, or wider traffic due the removal of these peak-time journeys

Regarding 1, analysis of the initial shortlist suggested the wider congestion impact of non-compliant vehicles responding to the CAZ charge (included as a sensitivity around Option 1a) are very small. This is because only few HGVs have the opportunity and choose to 'avoid' the zone in response to the CAZ charge. Further, the transport modelling observes a small 'rebound' effect as car drivers take advantage of fewer HGVs on the road, potentially eroding further any improvement in travel time for other road users.

3.1.2 Comparing the options

The CBA results present an assessment of the key monetised costs and benefits associated with the CAZ options and a partial NPV (it has not been possible to quantitatively assess some of the impacts – see Qualitative Assessment below).

Based on the analysis conducted, it appears that the CAZ B would deliver a positive NPV on central assumptions: (i.e. the benefits of implementing these options would be greater than the costs), but the NCH CAZ would deliver a net cost.

CAZ B delivers much greater number of vehicles upgraded, which also carries with it greater upgrade and welfare costs. However, this also delivers much larger air quality and GHG emission savings, together with fuel and operating cost savings. These benefits outweigh the costs associated with the measure.

The NCH CAZ delivers emissions reductions in a different way and hence affects many fewer vehicles. In fact, it is useful to look at the impacts of the NCH CAZ at sub-measure level. In summary:

- Taxi licence uplift in 2023: this measure will instigate a small number of taxis to upgrade in 2023 (136 taxis anticipated to remain non-compliant). As with the CAZ measure, there are associated upgrade costs, balanced against air pollutant and GHG emissions savings, and fuel savings. In the central assessment, the result is a slight net cost. However, its benefit-cost ratio of 0.72 is fairly close to one hence the assessment could change under different sensitivities around the central analysis.
- Sustainable distribution centre: as under the assessment of the initial shortlist, the NPV is again positive. There are implementation costs to the 'Option 1' as described in the Financial Case which targets developing 6 DSPs. However, even where only one DSP is implemented as assumed in this economic analysis (albeit for a fairly large site), the benefits outweigh these upfront costs. Further, the benefits will be scalable – where further DSPs are successfully implemented, the benefits will increase in line.
- Port booking system: the quantitative analysis only captures costs for this measure – an implementation cost, and a welfare cost from HGVs needing to use their second-best booking slot. Hence the NPV of this measure is negative. An air quality impact could not be valued given the damage cost methodology does not account for time of day of emission
- Shore-side power: overall the NPV is negative, predominantly due to large upfront investment cost. However, we assume only 20% of cruise vessels visiting the port of Southampton can take advantage of this measure and cut-off benefits at the end of the 10-year appraisal period. If the number of vessels using the shore-side power facility scales up over time and/or the installations lasts longer than 10 years, the NPV may be close to/at NPV neutral.

[16] The 'welfare impact in theory will also capture changes in travel time for those adopting the avoid zone, cancel journey or mode-shift behavioural responses. However, what this will not capture is the wider impacts that these responses will have on general congestion around the network, and hence on the time spent travelling by other vehicle users. Both impacts would be captured by assessing the aggregate travel time however (as described above) a significant effect could not be identified for all options.

3.2 Uncertainty - Delivery risk

The impact of the CAZ options will critically depend of the behavioural response of the transport users. The assumptions used in this analysis to appraise the CAZ B option are derived from two sources:

1. Response of HGVs (which do not upgrade) to the charging CAZ is produced endogenously in the demand module of the transport model
2. Other vehicle responses to the charging CAZ are from a Transport for London (TfL) study on behavioural responses in London and elaborated in the JAQU guidance CAZ implementation.

Therefore, the impact of the CAZ measures in Southampton are affected by the extent to which the behavioural assumptions are applicable in Southampton context. No attempt has been made to adjust the assumptions to differences in economic, business and social environment or transport infrastructure in which the CAZ will be introduced and implemented.

In addition, there are several other areas of uncertainty around many assumptions made to simplify the economic analysis which may affect the ability of the CAZ options to achieve their intended objectives:

- A CAZ is not a binary policy instrument (it is there or it is not). Responses and resultant impact will be determined by the stakeholder engagement, communication, public transport, signs, cameras and enforcement, and complementing policies that go with/alongside CAZ implementation.
  - There is also a wider link to national policy and communications around air quality and CAZ agenda
- The response will also depend on the charge levels set. This analysis is based on the national recommended charges, which are assumed consistent with the JAQU behavioural responses in the Soton context
- The modelling assumes all responses will occur immediately upon implementation in 2020. However, in practice it may take vehicle owners time to realise the additional costs and select their behavioural response
  - Responses will start when the scheme announced to try and achieve compliance when scheme opens (e.g. London LEZ) so some may react before 2020, but some may do so afterwards
  - Also, vehicle owners may switch between behavioural responses over time, and potentially multiple times.

Furthermore, there may also be challenges around the implementation of the options which could affect the feasibility of some of the CAZ options. In particular, the availability of a national database in order to identify taxis entering the CAZ area will critically affect the effectiveness of the CAZ to charge and ultimately instigate behavioural response from these vehicles. Where such a database is not available, there is substantial risk that taxis will simply register outside Southampton were registration data used for the basis of charging, undermining the ability to capture these vehicles entering the zone.

There are also specific risks related to the implementation and effectiveness of the non-charging measures. The impact of these measures also critically relies on behavioural change from vehicle owners, but in this case in response to incentives rather than a CAZ charge.

a) Firstly, vehicle owners often do not hold complete information on the trade-offs between different strategy - i.e. some measures rely on users recognising and capturing benefits such as those associated with the SDC.
b) Second, even where users may know an alternative would be more beneficial they may still not act rationally. This can be the case for several reasons, but one may be down to the design of the incentive given in general economic agents are more averse to loss than attracted to benefits of equal amount.
c) Finally, there may be other barriers related to contractual arrangements, procurement, financial information/commercial sensitivity and feasibility among others that may delay the uptake of these measures.

The specific risks and barriers to implementing these measures are set out in more detail in Table 20 below.

Table 20: Delivery risks related to non-charging measures

Measure	Barriers
DSP/SDC	• **Existing delivery contracts** / procurement arrangements could last several years and be difficult to change/alter in the short term • Majority of benefits accrue to delivery company, not recipient – but recipient has decision making power (and may need to bear additional cost of consolidation)[17] • Companies do not have perfect information on the **potential costs and benefits** to inform a decision – identification of true costs is not always easy as common practice to use standard cost per mile • Fear of loss of control of stock • Limitations around **feasibility** given type of product • Perception that consolidation is expensive • Delivery costs can be centralised in large organisations, hence savings accrued against central (not store specific) bottom line • Reluctance to take 'non-standard' approach to distribution to one store as opposed to the other stores in a chain • Increasing complexity and costs of operation • Loss of contact between suppliers and customers • Difficulties in co-ordinating a DSP across multiple businesses on single site with differing wants and needs.
Shore-side power	• A private company is in charge of the port → delivery impact / timing of port charging relies on will / effectiveness of port companies • Where external funding is not received, installation will rely on private financial assessment of measure which will not include key environmental benefits which help improve the case for installation
Port booking	• A private company is in charge of the port → delivery impact / timing of port charging relies on will / effectiveness of port companies

Given these factors, it could be considered that there is greater uncertainty and risk around the ability of NCH CAZ to deliver anticipated air pollution emissions reductions than around the CAZ B.

3.3 Qualitative Assessment

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

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

a) AQ impacts:
   - outside modelling domain (NOx and PM, not coaches)
   - associated with alternative responses of coaches and taxis
   - associated with port booking measure

b) Implementation costs of non-charging measures
c) Wider fuel/opex/GHG impacts associated with charging and non-charging measures
d) Wider congestion/travel time effects associated with charging and non-charging measures
e) Noise / accidents / infrastructure effects associated with charging and non-charging measures

Further several impacts were identified as associated with the CAZ but were deprioritised for assessment as less significant effects. Specifically:

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

A qualitative analysis of these impacts across the scenarios is undertaken in Appendix 4 – Qualitative assessment of wider impacts, and a summary of the assessment is included in Table 21.

[17] TRL (2018); 'Business Case Support for the Implementation of a Clean Air Zone in Southampton' (unpublished)

Table 21 – Qualitative analysis of CAZ options against impacts not covered by core CBA

Impact category	Option 1 (City-wide CAZ B)	Option 3 (Non-charging measures)
AQ impacts: a) outside modelling domain, b) associated with alternative responses, c) associated with port booking measure	✓✓	✓
Transaction costs	×	×
Welfare loss associated with upgrading vehicles	✓/×	✓/×
Implementation costs of non-charging measures	-	×
Wider fuel/opex/GHG impacts	✓/×	✓
Wider congestion/travel time effects	✓/×	✓
Noise / accidents / infrastructure	✓/×	✓(/×)

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

The impacts not captured by the quantitative analysis could represent both costs and benefits for the CAZ options, and an impact may switch between being a cost or benefit, depending on the option in question. In summary:

- CAZ B could deliver additional air quality emissions reductions outside the modelling domain, but the port booking measure under NCH CAZ could deliver some reduction in exposure which is not captured through the damage cost approach
- Upgrading of vehicles under all options will carry transaction costs, which scale with the number of vehicles upgraded. Hence these will be greatest for CAZ B
- There will be additional implementation costs not captured by the core analysis to design and deliver the non-charging measures, in particular stack handling costs under the port booking measure
- The NCH CAZ will deliver additional fuel, operating cost, GHG savings, congestion/travel time and accident benefits not captured under the core analysis. Some will also reduce noise exposure (e.g. SDC)

To demonstrate the potential emissions impacts which fall outside of the zone further, an illustrative run of the EfT has been undertaken for Option 1 of the initial shortlist. The results are presented in Table 22. This analysis has only been undertaken for one option as:

1. A comprehensive illustration of emissions impacts cannot be produced for all options. For Options 2 and 3, not all non-charging measures can be modelled in this simple way (and a breakdown of savings by sub-measure is not available from the core AQ modelling to be able to clearly see where the estimates from the core AQ modelling could overlap with the results of an illustrative EfT run)
2. This modelling is illustrative and does not go into the same level of detail as the core AQ modelling. These results will not therefore displace the core AQ modelling as part of the core results given there is a greater confidence in the outcomes of this modelling, and hence results for all options are not needed for this purpose
3. Assessing this option will also serve to illustrate the maximum possible impact given this option is assumed to have the largest impact on air quality.

Table 22 – Illustrative run of EfT for Option 1

	Change in NOx emissions (2020, tonnes)	Change in $PM_{2.5}$ emissions (2020, tonnes)	£ impact in 2020	PV impact over appraisal period
Core AQ modelling	-431	-13.2	£4.78m	£22.1m
Illustrative EfT run	-1,476	-14.94	£8.28m	£38.3m

As can be seen from the results in Table 22, the value of emissions impacts outside the modelled zone could be significant, almost doubling the emissions benefits under Option 1. This would push the NPV of this option further positive. But what is more interesting is perhaps what this means for the relative NPV of options.

These additional impacts are driven predominantly by HGV mileage outside of the AQ domain – these are the largest vehicle category affected and also one of the highest annual mileage. Further, an illustration of the coach impacts is already included in the 'core' modelling, further underlining the difference will predominantly be associated with HGVs. Hence this additional £16m or so of benefits will be associated with the CAZ B option.

3.4 Summary assessment

The economic analysis conducted on the CAZ options has taken two forms: the focus has been on undertaking CBA of the options and monetisation of impacts. This has been complemented with exploration of some of the delivery risks around the CAZ options.

A summary of the results is presented in Table 23.

The key focus of the CAZ options is to reduce emissions and help meet legal limits for **air pollutant** concentrations. From the CBA, CAZ B has the greatest impact on emissions. This is driven a charging CAZ instigating greater improvements in HGVs which are a key source of emissions for Southampton. This result includes the emissions impact of the options on coaches, considering the total mileage driven by the coaches, which is not included in the core air quality modelling. However, it does not capture further emissions reductions for other vehicle types which will occur outside the modelling domain – as shown in the sensitivity analysis these impacts could be significant for the CAZ B option.

Alongside greater reductions in air pollutant emissions, the higher level of vehicle upgrades under CAZ B also delivers a higher level of **secondary benefits** – i.e. fuel and operating cost savings, and GHG emission reductions as newer and more efficient vehicles come into the fleet at an earlier stage. NCH CAZ does deliver fuel and GHG savings, in particular through energy-switching under the shore-side power measure and through trips removed by the SDC, but these savings are smaller.

However, CAZ B also carries a higher **cost of upgrading vehicles.** Costs will move in proportion with number of vehicles affected: hence the costs are smaller for the NCH CAZ than the CAZ B. Likewise **welfare costs** from avoided trips will be associated with the options containing a charging area and are higher the larger the area and greater number of vehicles affected.

Given that the CAZ options predominantly target commercial vehicles, these costs (and others associated with CAZ compliance – such as charge payments) will be borne by businesses, raising questions around the **affordability** of such effects in particular for smaller firms. Who will be affected and to what extent will differ by option and scale with the size and class of CAZ. The greatest effects are likely to be those direct felt by affected vehicle owners – taxi drivers, coach firms and HGV businesses.

Many of the potential negative effects for scheduled bus operators have been mitigated through the confirmation of funding for retrofit of buses operating routes within the city. However other buses using the regional depot would still be captured by CAZ B. Owners of vehicles in the other categories affected by a charging CAZ (i.e. taxis, HGVs and coaches) will likely capture to some extent smaller firms and operators, in particular taxi drivers, which may find it more difficult to meet any upfront costs of CAZ compliance.

CAZ B could also have a more prominent indirect impact on **household affordability** through costs being passed on by taxi operators, however these impacts are uncertain and likely small.

NCH CAZ has higher **implementation costs.** It has not been possible to capture some of these in the quantitative analysis but those that have been captured bring the implementation costs of NCH CAZ above those under the CAZ B. In particular, the costs of implementing shore-side power could be fairly large.

Furthermore, there are other effects which influence the balance of benefits and costs. Specifically, the SDC under the NCH CAZ delivers significant benefits in terms of **travel time reduction**. The impacts captured in the analysis represent driver time savings through use of the SDC which takes HGV and LGV vkm off the road. These impacts can be significant: for this sub-measure they are greater than the air quality benefits delivered. Furthermore, these greater impacts on travel time also have secondary benefits of reductions in noise and accidents and improved accessibility.

Overall, based on the analysis conducted, it appears that the CAZ B would deliver a positive NPV on central assumptions: (i.e. the benefits of implementing these options would be greater than the costs), but the NCH CAZ would deliver a net cost. That said, the NCH CAZ delivers emissions reductions in a different way affecting many fewer vehicles. In fact, it is useful to look at the impacts of the NCH CAZ at sub-measure level. In summary:

- Taxi licence uplift in 2023 delivers a slight net cost but the BCR is close to 1 hence the assessment could change under different sensitivities around the central analysis.
- Sustainable distribution centre delivers a positive NPV - even where only one DSP is implemented as assumed in this economic analysis (albeit for a fairly large site), the benefits outweigh these upfront costs.
- Port booking system: the NPV of this measure is negative but an air quality impact could not be valued given the damage cost methodology does not account for time of day of emission
- Shore-side power: overall the NPV is negative, predominantly due to large upfront investment cost. However, if the number of vessels using the shore-side power facility scales up over time and/or the installations lasts longer than 10 years, the NPV may be close to/at NPV neutral.

This CBA was facilitated through the use of several simplifying assumptions. When viewing this analysis, it is important to recognise the uncertainty and caveats around these results and that risks exist which may impact on the ability of the CAZ options to achieve these anticipated effects in practice. Risks exist around both:

1. **CAZ charging:** The analysis assumes the charge levels and behavioural response recommended nationally by JAQU and does not account for local characteristics which may influence these responses. Furthermore, the response assumed is immediate on the date the CAZ comes into force and the analysis does not recognise the potential implementation issue of identifying taxis in the absence of a national database.
2. **Non-charging measures:** The impact of these measures also critically relies on behavioural change from vehicle owners, but in this case on voluntary responses to incentives rather than a CAZ charge. There are several issues which may affect the response in practice:
    a) vehicle owners do not hold complete information on trade-offs between strategies
    b) vehicle owners may still not act rationally – e.g. agents are more averse to loss than attracted to benefits of equal amount
    c) other barriers exist which may prevent take up of non-charging measures, in particular in the short term, e.g. contractual arrangements.

Given these factors, it could be considered that there is greater uncertainty and risk around the ability of non-charging measures to deliver anticipated air pollution emissions reductions than around the CAZ charging options. To a certain extent this is already reflected in the fact that ‘Option 1’ in the Financial case for SDC targets 6 DSPs, whereas we have modelled take-up of only 1 in this CBA.

Table 23 – Options summary

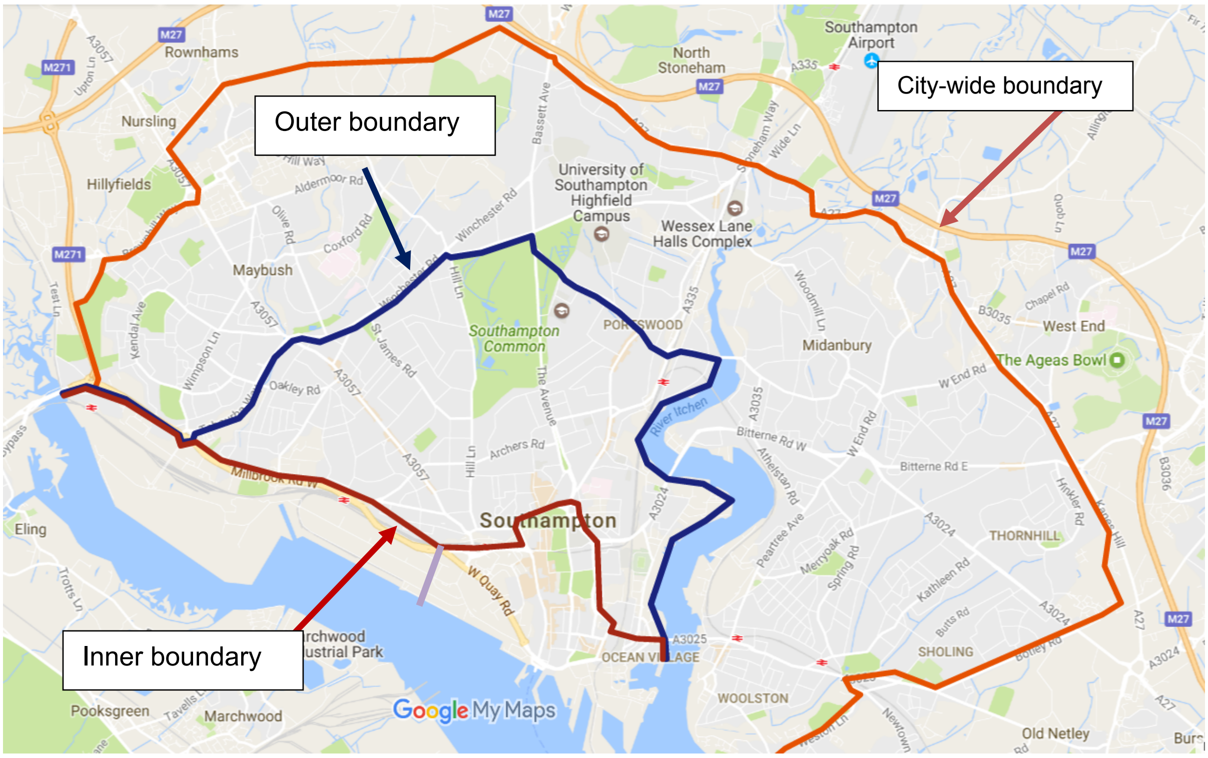
Option	Rationale
CAZ B	• Positive NPV – delivers largest air pollutant emission reductions with largest costs • Avoids high risk around deliverability of HGV non-charging options. • Delivers large air quality emissions reduction, which will deliver greatest health and environmental benefits, from which poorer households will benefit most • Largest impact on businesses, with potential adverse effects on HGV and coach operators, and taxi drivers who may struggle most with affordability of upfront costs of compliance ○ Also will be some indirect impact on household affordability (although less so than for businesses) • Potential risk around deliverability of identifying taxis under charging CAZ in absence of national database

NCH CAZ	• Negative NPV – delivers smaller air pollutant emission reductions and secondary benefits, and higher implementation costs (in particular shore side power) push NPV of option to negative
	• But has much smaller impact on businesses and affordability risk
	  ○ Likewise, has much smaller impact on household affordability
	• It is informative to look at results at a sub-measure basis:
	  ○ Taxi licence uplift in 2023 delivers a slight net cost but the BCR is close to 1 hence the assessment could change under different sensitivities around the central analysis.
	  ○ Sustainable distribution centre delivers a positive NPV - even where only one DSP is implemented as assumed in this economic analysis (albeit for a fairly large site), the benefits outweigh these upfront costs.
	  ○ Port booking system: the NPV of this measure is negative but an air quality impact could not be valued given the damage cost methodology does not account for time of day of emission
	  ○ Shore-side power: overall the NPV is negative, predominantly due to large upfront investment cost. However, if the number of vessels using the shore-side power facility scales up over time and/or the installations lasts longer than 10 years, the NPV may be close to/at NPV neutral.
	• There are risks around deliverability - Several barriers exist to implementing and delivering these measures, creating potentially higher risk to delivering additional savings

Appendices

Appendix 1 – Maps of proposed CAZ areas

Figure 3 – Map of proposed CAZ boundaries



Note: Orange line refers to the City-Wide CAZ boundary; red line to 'inner boundary'; and red and purple lines together to city centre CAZ boundary (blue line old city centre boundary that was not included in the analysis)

Appendix 2 – Summary of data inputs and assumptions

Data inputs

The economic model is based on the data sources recommended by JAQU, outputs of Ricardo's air quality model, Systra's transport model, SCC ANPR data and additional sources where necessary. A catalogue of all data inputs used is provided in Table 24.

Table 24 – Data Inputs

Assumption	Value	Source
General – JAQU key data		
Discount Rate	3.5%	JAQU Guidance
Price Index	Price year 2018, various values	HM Treasury GDP Deflators[18], as recommended by JAQU
Vehicle fleet composition	Various values	ANPR data for 2016, projected using Ricardo modelling of fleet turnover to 2020, based on NAEI/JAQU assumptions
Emission factors	Various values	Emissions factor Toolkit 2017 v8.0
Annual emissions of NOx and other pollutants (baseline and scenarios)	Various values	Ricardo air quality modelling for NOx and PM; simplified runs of EfT for coach emissions
Composition of vehicle kms driven (by Euro standard and vehicle type) and length of trips	Various values	ANPR data for 2016, projected using Ricardo modelling of fleet turnover to 2020, based on NAEI/JAQU assumptions
Fleet projection (vkms/vehicles)	Various values	Systra transport modelling
Average speeds on each road	Not used directly in economic analysis	
Number of vehicles entering the target area	Various values	ANPR data for coaches and HGVs, with uplifts applied based on expert judgement/wider sense-checking. Fleet data from licencing (taxis) and bus operators (buses). Adjustments applied to reflect changes in fleet from 2016-20.
Days per year spent in target area	Multiply weekly frequency data for unique vehicles data by 52	SCC ANPR data
Damage Costs (air quality and GHGs)	Various values	JAQU Guidance for damage costs; carbon prices taken from: BEIS Supplementary Green Book Guidance (2016)
Marginal External Costs of congestion	Not used directly in analysis	
Average value of new vehicle by type		Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished) Cost for bus retrofit taken from SCC CBTF bid (unpublished)
Vehicle depreciation	Various values	JAQU guidance
Fuel consumption per vehicle	Various values	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
Fuel costs	Various values	LRVC from BEIS Supplementary Green Book Guidance
Behavioural response proportions	Various values	JAQU assumptions used for proportion upgrading; remaining behavioural responses for HGVs determined by local

18 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/624528/GDP_Deflators_Qtrly_National_Accounts_June_2017_update.xlsx

Assumption	Value	Source
		transport model; remaining responses for taxis and coaches follow JAQU assumptions
Search/transaction cost	Not used directly in analysis	
Index of multiple deprivation	Various values	DCLG / ONS data
ONS mid-year population estimates	Not used directly in analysis	
2011 census	Not used directly in analysis	
UK Business Counts	Not used directly in analysis	
Local authority and built up area	Not used directly in analysis	
General - other		
Impact extrapolation factor	Various values	Derived from analysis of scenario concentration results from Defra Air Quality National Plan
Average vkm per vehicle	Various values	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
GHG Emissions		
CO_2 Emission factors	Various values	BEIS Supplementary Green Book Guidance (2016), as recommended by JAQU
Conversion Factors	Conversion factors to allow conversion from fuel consumption to CO2 emissions	DECC DUKES Annex A[19]
Congestion impacts		
Transport Outputs	Aggregate time and distance travelled for different scenarios	Systra transport modelling for impacts of charging zones; bespoke calculations undertaken for non-charging measures
Occupancy and purpose of travel	Occupancies per trip and km travelled and proportion of travel for different purposes	WebTAG Data book[20]
Fuel/ maintenance cost		
Operating cost	Various values	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
Implementation		
CAZ Charge	£12.50 / day Car, LGV, TAXI, Private Hire £100 / day HGV, Coach, Bus	JAQU/Local Authority
Implementation costs	Costs of charging CAZ (capital costs and operating costs) and non-charging measures	Various – Charging CAZ estimates based on unit costs from Leeds CAZ Financial Case, combined with initial review by SCC

Key assumptions

A summary of the key assumptions applied in the analysis is set out in Table 25.

Table 25 – Summary of Key Assumptions

Assumption	Assumption	Source
General – JAQU key assumptions		
Discount Year	2018	JAQU
Price Year	2018	JAQU

[19] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/642725/Annex_A.pdf
[20] https://www.gov.uk/government/publications/WebTAG-tag-data-book-december-2017

Assumption	Assumption	Source
Appraisal Period	10 years (2020 to 2030)	JAQU
Discount Rate	3.5%	JAQU
Upgrade to new	If upgrade response is triggered, then 25% of those upgrading will purchase a new vehicle and 75% will replace their non-compliant vehicle with a second-hand compliant vehicle	JAQU
Fuel switch	Of those replacing their vehicle with a second-hand complaint variant, 25% will purchase the cheapest complaint vehicle of the same fuel type, while 75% will purchase the cheapest compliant vehicle (for example, in a charging clean air zone diesel will switch to petrol).	JAQU
Scrappage/Fleet size	For every vehicle purchased new, due to an upgrade response, another vehicle will be scrapped.	JAQU
Average days spent in the target area	Median days spent in the target area better represents the average driver than the mean (not directly applied in economic modelling)	JAQU
Trips proportional to response	Those vehicles making the most trips into the zone are the most likely to upgrade.	JAQU
Vehicle values	The market values for non-compliant vehicles do not reduce in response to the CAZ policy	JAQU
General - other		
Optimism bias assumptions	No additional sensitivity for optimism bias has been applied in the analysis given sensitivity analysis is already undertaken around the vehicle uplift assumptions, which in turn affects the number of unique vehicles travelling to the CAZ from which a range around the upgrade costs is derived.	Expert judgement
Vehicle Types	As defined by JAQU – but the model combines HGVs (rigid and articulate) and Coaches (coach, minibus) and buses (single and double) into single categories to make the model more manageable.	JAQU/ Expert judgement
First Order Behavioural Response (upgrade, cancel, change mode, avoid, pay)	Proportion upgrading vehicle as defined by JAQU. Proportion adopting other behaviour assumptions are determined endogenously within the transport model for HGVs, but otherwise follow JAQU assumptions (with car assumptions adopted for taxis) Southampton specific assumptions are applied for buses given confirmation of CBTF grant - 100% buses assumed to 'upgrade', in this case retrofit.	JAQU/SCC
Developing the fleet baseline		
ANPR assumptions	Conversions to inflate ANPR data from weekly to annual vehicle based on expert judgement / discussions with Systra	Expert judgement
Growth in overall vehicle fleet	How much will the vehicle fleet grow between 2016 (ANPR year) and 2020	Systra Transport model
Change in fleet composition projection	How will the fleet composition change between now and 2020? Private hire vehicles are assumed to have the same fleet composition and cars.	Ricardo projection based on NAEI / JAQU assumptions
Costs associated with fleet change		
Ownership profile	A four-year ownership profile is assumed for vehicle users. I.e. on average vehicle users own vehicles for 4 years, before replacing them. In 2020 vehicles that are resold are expected to be halfway through this profile (2 years remaining).	Expert judgement
Euro standard age	Vehicles of different Euro standards are assumed to the youngest possible age for that standard in 2020.	Euro standard introduction dates
Remaining life of vehicle	Where the age of the vehicle is greater than the life of vehicle, 2 more years is assumed.	Expert judgement
Resale of used, non-compliant vehicles profile	Different resale profile for different Euro standards – different proportions of vehicles are either scrapped or resold depending on vehicle age. Older vehicles are more likely to be scrapped, newer vehicles likely to be resold.	Expert judgement

Assumption	Assumption	Source
Scrappage of non-compliant vehicles replaced by new vehicles	Older vehicles are likely to be scrapped first	Expert judgement
Welfare impact		
Consumer Preference	Impact of welfare loss associated with an avoided, cancelled or mode-shifted trip can be valued as half of the CAZ charge.	JAQU

Baseline assumptions

Developing the baseline scenario against which CAZ options are compared is of critical importance to an economic appraisal. Baselines are developed for each impact explored in this analysis. These are detailed below in Table 26.

Table 26 – Baseline Construction for each impact category

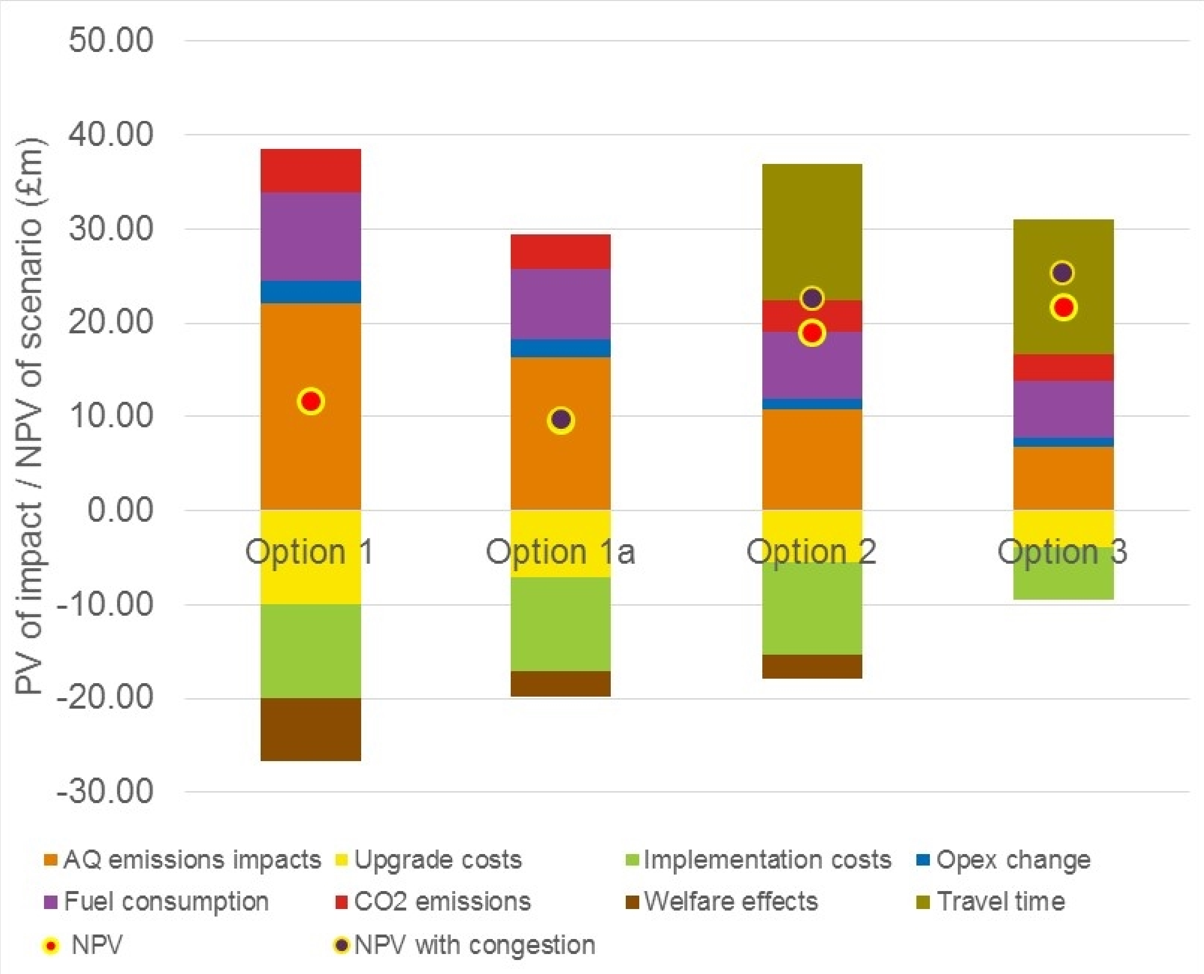
Impact	Baseline
Upgrade costs	Vehicle fleet projection based on ANPR and fleet data, uplifts based on expert judgement and assumptions from Systra transport modelling. Only those vehicles that are replaced in the CAZ scenarios are of interest in constructing the baseline. Therefore, to ensure proportionality in approach the economic model focuses only on those vehicles that are replaced under each CAZ scenario (rather than e.g. demonstrating patterns in overall vehicle changes as depicted under a more comprehensive fleet turnover model). Then baseline assumptions are applied to those replaced vehicles. Under the baseline vehicles meet the same fate as under the CAZ scenario: the same proportion are scrapped, bought new, sold and replaced. But the CAZ simply brings forward the activity which otherwise would have happened in the future. In the baseline, the change happens instead when vehicles run to the end of their useful life or ownership profile (defined by the age of the vehicle). The upgrading of vehicles is modelled in detail using defined assumptions around the years of delay before the activity would otherwise have happened (as opposed say to using a generic extrapolation factor as applied for other impacts).
Air Quality Emissions, GHG Emissions, Congestion, CAZ charge, fuel / operating costs, Welfare loss	Impacts assessed against ‘do nothing’ baseline. For vehicle upgrades, charging CAZ assumed to bring forward actions that would otherwise have been taken, just at a later date. Hence over time baseline fleet catches up with improvements brought forward by CAZ to erode impacts. For other behavioural responses, the same logic is followed but applied slightly differently: in these cases, the CAZ forces vehicle users to adopt a different behaviour (i.e. avoid, cancel, mode shift). They do so until they otherwise would have upgraded their vehicle in the baseline, after which they revert to their original behaviour and travel patterns. Hence as under vehicle upgrade, this behaviour pattern also leads the baseline to ‘catch-up’ with the CAZ scenario over time. Rate at which baseline catches up with CAZ scenario is based on the extrapolation factor derived from the convergence of air pollutant concentrations between baseline and CAZ scenarios analysed by Defra as part of the National AQ Plans. For non-charging measures, some of the impacts are assumed not to degrade over time as these will not be eroded to the same extent with an upgrading baseline fleet – e.g. travel time savings of freight drivers using the SDC.

Appendix 3 – Results – Initial shortlist

A.1 Quantification and valuation of impacts

The results of the economic analysis are presented in Table 27 and Figure 4.

Figure 4 – PV of impacts and NPV of CAZ options



Note: Bars represent present value (PV) of impacts; dots represent aggregate net present value (NPV) of all impacts associated with CAZ option; all impacts are assessed relative to 'do nothing' baseline; NPV is also presented with congestion costs as a sensitivity to the central NPV estimate; all impacts presented in 2018 prices and impacts discounted to 2020

Table 27 - Monetised impacts associated with CAZ options (cumulative discounted impact (PV) from 2020-30 (£m 2018 prices))

Option	AQ emissions impacts*	Upgrade costs	Implementation costs	Opex costs	Fuel costs	CO_2 costs	Welfare effects	Travel time	NPV	*Sensitivity analysis*
Option 1 (CW CAZ B)	22.14	-9.91	-10.09	2.32	9.37	4.62	-6.74	0.00	**11.71**	*0.00*
Option 1a (CW CAZ B HGV only)	16.32	-6.99	-10.09	1.99	7.44	3.68	-2.76	0.00	**9.60**	*0.04***
Option 2 (CC CAZ A)	10.78	-5.51	-9.83	1.05	7.14	3.45	-2.56	14.41	**18.95**	*3.86****
Option 3 (non-charging)	6.83	-3.81	-5.61	0.85	6.06	2.92	0.00	14.41	**21.65**	*3.86****

Notes: +ve values denote benefit / -ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2020;

(*) Air quality impacts represent reductions in emissions valued using the damage costs. These results are distinct from those presented in the air quality modelling report, which focus on concentrations and comparison to the legal limits, although a key input into this economic work is the underlying air quality modelling used to form compliance assessment.

There is not sufficient confidence around the estimation of the impacts denoted with an (**) or (***) to present these as part of the core CBA; congestion presented as sensitivity given modelling only available for Option 1a; travel time savings for other road users under Options 2 and 3 are valued using unit valuation for removing car not HGV from the road.

A.1.1 Detailed analysis

Air quality emissions impacts: All CAZ options are seen to deliver positive improvements in air quality through reduction in emissions, which in turn carry with them a range of benefits for human and environmental health. The impact on NOx and PM emissions has been modelled in detail using Ricardo's air quality models, which capture impacts within a defined domain. However, this modelling did not capture impacts of the CAZ options on coaches. To fill this gap, a simplified run of the EfT was undertaken to illustrate the potential size of these effects. The results have been included as part of the NPV and demonstrate that the impacts on coach emissions could be significant. Note: unlike for other vehicle types, the calculations for coaches will capture emissions impacts inside and outside the city boundary.

Taken together, the air pollutant impacts represent the largest net effect across the CBA (with the exception of driver time savings for Options 2 and 3, which is discussed in more detail below). Each option delivers a large benefit through reduction in emissions, which scales with the size of the CAZ and vehicle types included, and hence the number of vehicles affected. The options deliver largest emissions reduction in NOx. However, although the reductions in PM emissions are smaller, the value of these reductions is significant and almost matches the reductions in NOx – however this result may be skewed by the valuation methodology[21].

Option 1 delivers the greatest reduction in emissions, followed by Option 1a, 2 then 3. Option 1 represents a charging scheme with the largest geographical boundary and variety of vehicles covered – hence this will affect the greatest number of vehicles. Option 1a maintains the city-wide charging scheme for HGVs so still affects a large number of vehicles. Focusing the charging scheme on the city-centre, reducing the CAZ classification and substituting non-charging measures instead of including vehicle types in the CAZ all reduce the number of vehicles affected. In terms of non-charging measures, the assumption that fewer vehicles are affected reflects greater uncertainty around these measures, both in terms of these being mainly behavioural measures which rely on take up by of incentives by vehicle owners, and in terms of how much support funding will be available which will have a direct impact on how ambitious these measures can be.

Vehicle upgrade costs: A key impact in the CBA is cost of upgrading non-compliant vehicles. This covers a number of impacts: the scrappage cost of non-compliant vehicles, cost of purchasing new compliant vehicles, retro-fit of non-compliant vehicles and the cost of swapping a non-compliant used for a compliant used vehicle.

There is a significant cost associated with each CAZ option as under each, the majority of non-compliant vehicle owners are assumed to choose to upgrade their vehicle in response to the CAZ.

This impact is a net effect associated with the CAZ scenario: there are also costs in the baseline scenario as the predominant impact of the CAZ is simply assumed to be to bring forward activity (in this case upgrading vehicles) which otherwise would have happened anyway, just at a later date. Hence the costs of the baseline activity are removed from those of the CAZ scenario to present the net cost of the CAZ. In fact, the absolute costs for the CAZ and baseline scenario are in the £100m's with the net impact therefore being the difference between two large numbers. Hence the overall NPV is particularly sensitive to assumptions made in modelling the upgrade costs.

Costs increase with the size of the CAZ size and classification as more vehicles are affected: e.g. the costs of a Class A option will be lower than a Class B. Further given uncertainty around the impact of non-charging measures, the costs for these measures tend to be smaller than the charging options. As such the costs are greatest for Option 1 given this contains a charging CAZ which has the greatest reach in terms of size and classification. The costs are similar for Option 1a and 2, but for different reasons. Option 1a retains charging for HGVs and hence affects a large number of vehicles, whereas Option 2 places non-charging measures on HGVs so affects less freight vehicles but does capture coaches affecting the city centre, which are not assumed to be impacted by Option 1a.

Implementation costs: The cost of implementing a charging CAZ have been estimated based on an assessment of the number of links crossing the cordon, combined with initial implementation structure and costs taken from the Leeds CAZ Feasibility Study and Financial Case. Where possible,

[21] There is an overlap between the effects of NOx and PM on health impacts, in particular chronic mortality. This is handled in the damage costs by scaling back the damage cost associated with NOx, when in practice it is difficult to disentangle which effect is associated with which pollutant. Hence valuation of impacts on air pollution should be viewed in aggregate, rather than comparison between pollutants.

implementation costs for non-charging measures have been included although generally information on which to base cost estimates is less readily available for these measures.

Over the ten-year appraisal period, implementation costs are not an insignificant impact in comparison to other impacts. These costs are broadly similar for Options 1 and 1a given these contain a larger CAZ area that requires greater infrastructure to signal and enforce the CAZ. These costs are also comparable to the implementation costs for Option 2 – this entails a smaller charging zone with smaller cost, but has costs associated with non-charging measures proposed, in particular implementing DSPs and increase levels of freight through the SDC.

However, the ranking of costs will likely be affected by the lack of information around the costs of non-charging measures. In particular, it is important to note that this assessment does not capture:

- Policy costs of designing / developing / implementing the bus control order and taxi incentives (all options)
- Policy costs of designing / implementing a 24-hour freight delivery scheme (Options 2 and 3).

These costs which have not been captured are predominantly anticipated to occur in terms of time to design and deliver the measures, many of which will fall on SCC. These omissions will increase the implementation costs of all options, but in particular Options 2 and 3, serving to reduce the NPV relative to that presented as a result of the quantitative analysis.

Operating, fuel consumption and CO_2 emission savings benefits: By affecting the types and patterns of road transport in different ways, the CAZ options could have a range of different impacts on operating costs of vehicles, fuel consumption and CO_2 emissions. Given limitations in data and methodology, only the two most significant impacts have been captured as part of the quantitative analysis (with the rest explored through the qualitative analysis):

1. Newer, compliant vehicles are likely to be much more efficient and less costly to maintain (e.g. they are likely to require fewer repairs), hence upgrading to these vehicles will deliver additional benefits to the vehicle owner through operating and fuel cost savings.
2. An increasing flow of freight through the SDC as a consequence of updating DSPs will lead to a reduction of freight vkm on Southampton's roads. This will lead to a direct reduction in operating and fuel costs, and CO2 emissions which move in line with distance travelled.

Comparing this to the other impacts captured, these impacts form a significant secondary benefit (after air pollutant emission reductions). In particular, fuel savings and CO_2 emission reductions.

As with upgrade costs, the impacts scale with the CAZ area and number of vehicles affected. Hence, they are greatest for Option 1, followed in descending order by Options 1a, 2 then 3.

Welfare effects: this captures a range of impacts associated with the alternative behavioural responses (i.e. other than upgrade vehicle or pay the charge[22]) to a charging CAZ.

The quantitative analysis shows that this impact is an important element of the CBA.

The size of the impact increases with the range of vehicles covered by and the geographical size of the CAZ. Hence the welfare costs are highest for Option 1 which affects the greatest number of vehicles, and hence also has the greatest number of HGVs, taxis and coaches which may either avoid the zone or cancel their journey in response to the CAZ charge.

However, the effect appears to be similar for Options 2 and 1a, even though the latter has a CAZ which covers a bigger area and affects more vehicles. This result may in part reflect a nuance of the approach. HGVs are modelled directly in the transport model and their response to a charging CAZ has been captured endogenously within the demand response model. The transport modelling showed that only a very small amount of non-compliant HGVs would 'avoid' the zone (given this is limited to HGVs which travel through the zone – those travelling in and out do not have this option) and the majority either pay the charge or upgrade. By comparison, Option 2 does not capture HGVs in the charging CAZ but does capture taxis and coaches. These modes are not modelled directly in the transport model, hence response and welfare effects are estimated using the basic set of assumptions provided by JAQU,

[22] No impacts associated with 'pay the charge' are captured as part of the societal CBA. There is no change in behaviour, so no impact on emissions or other impacts associated with this response. There is a cost to vehicle owners paying the charge, although this is wholly offset by the benefit to the authority to which the charge is paid. Hence this impact is a 'transfer' and hence does not need to be captured as part of societal CBA.

which anticipate a higher level of adoption of the 'alternative responses'. Hence even though a fewer number of vehicles are affected, a much greater 'avoid' or 'cancel' response is anticipated.

This does not include buses that access the bus depot within Southampton on an annual basis for servicing. However illustrative estimates suggest even if all journeys are cancelled the welfare impact would be small compared to the wider welfare losses estimated.

Travel time/Congestion effects: As with changes in fuel and operating costs, given the variety of different sub-measures captured, the CAZ options could have a range of different impacts on congestion on Southampton's roads and hence on travel time (which carries an economic value). Again, given limitations in data and methodology, only a handful of the key impacts have been captured and then some are presented as part of the sensitivity analysis. The quantitative analysis has captured:

1. Impact of DSP/SDC on freight driver time (i.e. reduction associated with freight journeys re-routing and consolidating through the SDC.
2. Indirect impact of DSP/SDC re-routing freight on journey time for other road users and wider congestion (only included as a sensitivity around Options 2 and 3 given congestion values per km taken from WebTAG are only available for cars but applied to HGVs)
3. Change in travel time associated with alternative behavioural responses to charging CAZ - this is not included again as part of the travel time effects given it will already be captured by the welfare effects estimated above[23].
4. Indirect impact of alternative responses to charging CAZ on journey time for other road users/ wider congestion effects (only included as a sensitivity around Option 1a given transport modelling was only produced for one option.

The results suggest that travel time savings, in particular for HGV freight drivers, could be a significant benefit associated with the non-charging measures (e.g. DSP/SDC). These accrue to Options 2 and 3 where these initiatives are included and are the greatest benefit associated with these options (outweighing the air quality impact) and clearly sway the NPV balance for the options and the relative ranking of NPV across the options. This mirrors the results of the study undertaken by Transport Catapult looking at the impacts of greater uptake of the SDC in Southampton, finding that driver time savings are the most important amongst a range of potential benefits associated with increasing uptake[24].

The wider congestion impact of non-compliant vehicles responding to the CAZ charge (including as a sensitivity around Option 1a) are very small. This is because only few HGVs have the opportunity and choose to 'avoid' the zone in response to the CAZ charge. Further, the transport modelling observes a small 'rebound' effect as car drivers take advantage of fewer HGVs on the road, potentially eroding further any improvement in travel time for other road users.

A.1.2 Comparing the options

The CBA results present an assessment of the key monetised costs and benefits associated with the CAZ options and a partial NPV (it has not been possible to quantitatively assess some of the impacts.

Based on the analysis conducted, it appears that all options could deliver a positive NPV on central assumptions: i.e. the benefits of implementing these options would be greater than the costs.

Comparing between the options, the result seems to sway depending on whether a charging or non-charging approach is selected for each vehicle type, with the options being critically affected by what approach is taken for HGVs.

Where HGVs are addressed through a charging CAZ (options 1 and 1a), these options affect a greater number of vehicles and hence deliver the greatest air pollutant emission reductions and associated health benefits. They also deliver the largest secondary benefits in terms of operating and fuel cost savings, and GHG emission reductions. However, these options also have higher upgrade costs (also a consequence of affecting a greater number of vehicles) and have higher implementation costs given a larger CAZ area requires a greater level of signage and more cameras (although several costs

[23] The 'welfare impact in theory will also capture changes in travel time for those adopting the avoid zone, cancel journey or mode-shift behavioural responses. However, what this will not capture is the wider impacts that these responses will have on general congestion around the network, and hence on the time spent travelling by other vehicle users. Both impacts would be captured by assessing the aggregate travel time however (as described above) a significant effect could not be identified for all options.

[24] Transport Systems Catapult (2017); 'Quantifying the benefits from consolidation centres' (unpublished, provided by SCC)

associated with implementing non-charging measures have not been captured, but these are not considered likely to be significant enough to affect the pattern of results).

However, most important for the overall ranking of options is that the charging CAZ measures do not result in the substantial freight driver time savings and wider congestion benefits associated with freight re-routing through the SDC under the non-charging HGV measures (Options 2 and 3). These benefits are significant, have a value greater than the air quality improvements delivered and critically affect the ranking of NPV across the options.

For taxis and buses, the trade-off between charging and non-charging options remain but has less impact on the overall results. This is because the same effects are anticipated in response to the non-charging as the charging options (i.e. upgrade vehicles), but a greater number of vehicles are assumed upgraded through the charging CAZ. This reflects uncertainty around the funding available to support upgrades through non-charging measures, and also that these incentives rely on an uptake behavioural response from vehicle owners. Given charging options (Options 1 and 2) affect more vehicles, these deliver greater air pollutant emissions and secondary benefits. However, they also carry higher upgrade and implementation cost, and a welfare cost associated with ‘alternative’ behavioural responses which do not occur in response to non-charging measures.

One further distinction is that coaches are only affected under the charging options (Options 1 and 2) – no non-charging provision has yet been considered as part of the options. Hence Options 1 and 2 deliver additional benefits and costs associated with upgrading these vehicles, whereas no effects are included in Options 1a and 3.

A.2 Uncertainty - Sensitivity analysis

Economic modelling is only an approximation of the real world and it is inevitable there will be uncertainty and error around the inputs and assumptions that form the model. Failing to accurately predict future states of the world, using input values developed in different locations (i.e. hence not specific to Southampton) or using expert judgement where no data is available are all potential sources of uncertainty in assumptions and input values. We have identified those assumptions and input values where errors are relatively probable and potentially significant (i.e. could have a material effect on the results of the quantitative analysis and could affect the ranking of options).

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

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

The sensitivity analysis is constructed around the following key inputs:

- Damage Costs
- Uplift factors (applied to identify number of unique vehicles travelling into the CAZ areas)
- Growth in fleet (again affecting number of vehicles)
- Price reduction of non-compliant vehicles in response to CAZ
- Ownership profile.

At this stage, it has not yet been possible to test the sensitivity of the results to a further key assumption – the charge-response relationship (i.e. the proportion of vehicles which adopt different behavioural responses when faced with a CAZ charge in Southampton). Sensitivity analysis around these parameters is proposed for the next round of analysis.

Damage costs: Air quality is the biggest impact in our economic analysis. The economic costs associated with air quality are driven by the damage costs supplied by JAQU. The damage costs applied in this case are those for ‘urban big’ and are applied to all PM and NOx emissions reductions under the CAZ scenarios. This is not a value that has been tailored to the circumstances in Southampton – hence this is one source of uncertainty. Furthermore, there is underlying uncertainty in the methodologies and techniques used to construct the damage costs (e.g. impacts included, valuation of endpoints, etc) which should be reflected in the analysis.

No upper and lower bound for damage costs has been provided in the JAQU guidance on CAZ appraisal. Instead, to test this sensitivity the damage costs are inflated and deflated by 20%.

This analysis demonstrates that those scenarios with the largest air quality impact are the most sensitive to changes in damage costs. This is an intuitive result with Option 1 demonstrating the largest change in NPV. Despite these changes in NPV, Option 3 remains the option with highest NPV and the ranking of options does not change.

Table 28 – Damage costs sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Damage Costs	Low	-20%	7.29	6.34	16.8	20.3	Option 3
	Central	No change	11.7	9.60	19.0	21.6	Option 3
	High	+20%	16.1	12.9	21.1	23.0	Option 3

Uplift factors: The 'uplift factors' are applied in transforming weekly ANPR data to annual data to produce an initial starting point for the number of unique vehicles entering each CAZ area. The number of unique vehicles entering the CAZ area is a key source of uncertainty in the analysis given relevant and comprehensive data regarding this parameter is not available from any single source. These factors are mostly based on expert judgement, sense checking against multiple sources of information which are available, which makes sensitivity analysis key.

Sensitivity was conducted through constructing a set of low and high uplift factors. These were constructed based on expert judgement and of wider analysis of CAZ schemes where greater level of data is available. Further detail on how these assumptions were constructed is presented in the methodology section above.

Table 29 - Uplift factors – Weekly to Annual ANPR data

	Low		Central		High	
Vehicle	**CC**	**CW**	**CC**	**CW**	**CC**	**CW**
Coach	1.0	1.0	2.0	2.0	3.0	3.0
HGV	1.0	1.0	2.5	2.5	3.0	3.0
Taxis	0.75	1.0	1.0	1.5	1.5	2.0

Table 30 - Uplift factors sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Uplift factors	Low	See above	6.75	4.71	17.2	19.8	Option 3
	Central	See above	11.7	9.60	19.0	21.6	Option 3
	High	See above	13.5	11.3	19.7	22.3	Option 3

The results indicate that Options 1 and 1a are particularly sensitive to uplift factors, which is intuitive as these options affect the greatest number of vehicles. But there is no change in the ranking of options.

Growth in fleet: ANPR data is available for 2016 and therefore assumptions must be made to provide a vehicle fleet in 2020 to which the options are applied. Growth to 2020 is based on transport model outputs using vehicle kilometres as a proxy indicator for number of vehicles. The sensitivity analysis assumes that in the lower bound there is no growth (with a slight decrease for buses) in the vehicle fleet, while the higher bound assumes that 10% is added to the calculated growth factor. This has relatively little impact on the outputs from the model and has no impact on the favoured option or the ordering of options.

For Option 1, testing seems to provide a counterintuitive result, with both the 'no growth' and 'high growth' scenarios providing NPVs above the central result. This has been checked and is correct and is due to how different effects captured in the CBA move as a result of the sensitivity, and then how the effects combine into the overall result.

Table 31 – Growth in fleet sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Growth in fleet	Low	No growth	11.9	9.56	19.1	21.7	Option 3
	Central	Calculated	11.7	9.60	19.0	21.6	Option 3
	High	+10%	11.7	9.92	18.8	21.7	Option 3

Price reduction in response to CAZ: JAQU guidance assumes that vehicle values do not change in response to introduction of a CAZ. This is reflected in the central CBA. However, it is conceivable that if air quality action is introduced in Southampton there could be a negative impact on the resale value of used non-compliant vehicles, in particular given many may be re-sold locally. This assumption departs from JAQU's guidance and analysis reruns the model if there is a 10% and 20% reduction in resale value of non-compliant cars. This sensitivity has the greatest impact where more vehicles are replaced. But the order of favoured CAZ options does not change.

Table 32 – Non-compliant used vehicle price reduction sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Price reduction in response to CAZ	Central	No change	11.7	9.60	19.0	21.6	Option 3
	Low 1	10% reduction	8.51	7.44	17.5	20.8	Option 3
	Low 2	20% reduction	5.23	5.28	16.1	20.0	Option 3

Ownership profile: The length of time over which individuals own vehicles before selling is defined by the ownership profile. This assumption impacts the sale of non-compliant used vehicles in the baseline – it represents the length of time that vehicle owners would have otherwise waited before swapping their non-compliant used vehicle for a compliant used vehicle, in the absence of the CAZ options. Four years is assumed in the economic model based on expert judgement. To determine how important this assumption is within the model a sensitivity analysis is conducted. An ownership profile of 10 years is assumed to be the upper bound, and 2 years is the lower bound. This has a significant impact on the results but does not change the order of the NPV.

Table 33 – Ownership profile sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Ownership Profile	Low	2	8.63	6.81	17.8	20.6	Option 3
	Central	4	11.7	9.60	19.0	21.6	Option 3
	High	10	20.9	17.9	22.5	24.7	Option 3

Optimism bias: Optimism bias represents a systematic tendency for appraisers to be overly optimistic in their assessment of schemes, in particular regarding the costs (and time) associated with implementing a policy.

An adjustment for optimism bias has already been included in the estimation of implementation costs. The is the most important adjustment and hence has been included as part of the core analysis given costs have been estimated directly for scheme implementation.

As a sensitivity, we also apply an adjustment for optimism bias in the estimation of the other key cost category in the appraisal – upgrade costs. Upgrade costs are likely to be less susceptible to optimism bias given the estimation is the combination of a number of parameters, with unit costs which are fairly known and derived in established markets (e.g. the price of a compliant vehicle). Furthermore, it is considered that the approach to estimating costs was sense checked to be conservative at each step. Nonetheless we apply an adjustment factor to test potential susceptibility of the NPV to potential bias in this estimation. The results are presented in Table 34**Error! Reference source not found.**. As can be seen from the table, the results and ranking of options remain unchanged whether this adjustment is included or not.

Table 34 – Optimism bias sensitivity analysis - NPV result (£m 2018 prices)

	Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Include optimism bias adjustment?	No	11.7	9.60	19.0	21.6	Option 3
	Yes	9.43	7.99	17.7	20.8	Option 3

Conclusion: Although the sensitivity analysis shows that the NPV assessment of each option is sensitive to the assumptions, and more so those options having greater effect through a charging CAZ (Options 1 and 1a), it demonstrated that uncertainty around the parameters tested does not influence the relative ranking of the options. This suggests that the analysis is robust and provides recommendations which stand up to potential uncertainty in the CBA assumptions and methodology.

A.3 Uncertainty - Delivery risk

The impact of the CAZ options will critically depend of the behavioural response of the transport users. The assumptions used in this analysis to appraise the charging CAZ options are derived from two sources:

1. Response of HGVs (which do not upgrade) to the charging CAZ is produced endogenously in the demand module of the transport model
2. Other vehicle responses to the charging CAZ are from a Transport for London (TfL) study on behavioural responses in London and elaborated in the JAQU guidance CAZ implementation.

Therefore, the impact of the CAZ measures in Southampton are affected by the extent to which the behavioural assumptions are applicable in Southampton context. No attempt has been made to adjust the assumptions to differences in economic, business and social environment or transport infrastructure in which the CAZ will be introduced and implemented.

In addition, there are several other areas of uncertainty around many assumptions made to simplify the economic analysis which may affect the ability of the CAZ options to achieve their intended objectives:

- A CAZ is not a binary policy instrument (it is there or it is not). Responses and resultant impact will be determined by the stakeholder engagement, communication, public transport, signs, cameras and enforcement, and complementing policies that go with/alongside CAZ implementation.
    - There is also a wider link to national policy and communications around air quality and CAZ agenda
- The response will also depend on the charge levels set. This analysis is based on the national recommended charges, which are assumed consistent with the JAQU behavioural responses in the Soton context

- The modelling assumes all responses will occur immediately upon implementation in 2020. However, in practice it may take vehicle owners time to realise the additional costs and select their behavioural response
  - Responses will start when the scheme announced to try and achieve compliance when scheme opens (e.g. London LEZ) so some may react before 2020, but some may do so afterwards
  - Also, vehicle owners may switch between behavioural responses over time, and potentially multiple times.

Furthermore, there may also be challenges around the implementation of the options which could affect the feasibility of some of the CAZ options. In particular, the availability of a national database in order to identify taxis entering the CAZ area will critically affect the effectiveness of the CAZ to charge and ultimately instigate behavioural response from these vehicles. Where such a database is not available, there is substantial risk that taxis will simply register outside Southampton were registration data used for the basis of charging, undermining the ability to capture these vehicles entering the zone.

There are also specific risks related to the implementation and effectiveness of the non-charging measures. The impact of these measures also critically relies on behavioural change from vehicle owners, but in this case in response to incentives rather than a CAZ charge.

a) Firstly, vehicle owners often do not hold complete information on the trade-offs between different strategy - i.e. some measures rely on users recognising and capturing benefits such as those associated with night-time deliveries.

b) Second, even where users may know an alternative would be more beneficial they may still not act rationally. This can be the case for several reasons, but one may be down to the design of the incentive given in general economic agents are more averse to loss than attracted to benefits of equal amount.

c) Finally, there may be other barriers related to contractual arrangements, procurement, financial information/commercial sensitivity and feasibility among others that may delay the uptake of these measures.

The specific risks and barriers to implementing these measures are set out in more detail in Table 20 below.

Recent attempts to implement non-charging measures in other cities and locations illustrate the barriers and challenges in delivering these measures and their intended objectives. For example:

- During the London Olympics 2012 delivery time regulations were relaxed. As a result, 15% of businesses and 33% of freight operators made or received night time deliveries[25]. However, this has only led to a small level of sustained change - 5% of business and 3% of freight operators have continued to make deliveries at revised times (note this refers to numbers of businesses, not volume of freight).
- In New York, a study[26] found between 10-20% of recipients could switch to out-of-hours, but only if a financial incentive is offered to recipients to cover out of hours costs (based on the assumption carriers follow if recipients switch - in Southampton, under current assumptions, the delivery companies would to face a cost from upgrading the vehicle to take advantage of 24-hour delivery).

[25] http://content.tfl.gov.uk/olympic-legacy-freight-report.pdf

[26] http://content.tfl.gov.uk/integrative-freight-demand-management-in-new-york.pdf

Table 35: Delivery risks related to non-charging measures

Measure	Barriers
DSP/SDC	• **Existing delivery contracts** / procurement arrangements could last several years and be difficult to change/alter in the short term • Majority of benefits accrue to delivery company, not recipient – but recipient has decision making power (and may need to bear additional cost of consolidation)[27] • Companies do not have perfect information on the **potential costs and benefits** to inform a decision – identification of true costs is not always easy as common practice to use standard cost per mile • Fear of loss of control of stock • Limitations around **feasibility** given type of product • Perception that consolidation is expensive • Delivery costs can be centralised in large organisations, hence savings accrued against central (not store specific) bottom line • Reluctance to take 'non-standard' approach to distribution to one store as opposed to the other stores in a chain • Increasing complexity and costs of operation • Loss of contact between suppliers and customers • Difficulties in co-ordinating a DSP across multiple businesses on single site with differing wants and needs.
24-hour delivery	• The timing of the deliveries do not only depend on the delivery company, but also **convenience for recipient**; and feasibility given type of freight and storage options at site • Majority of benefits accrue to delivery company, not recipient, in first instance – driver time, fuel costs, etc. (but more certainty around delivery time / faster unloading…), but client has decision making power • Option less accessible to carriers who have multiple delivery stops (need to co-ordinate with multiple recipients) • Recipients may have to pay staff greater wage out-of-hours to receive delivery; and likewise, freight drivers for out-of-hours driving • Although 53% businesses in London experienced not change, 38% reported cost increases with out-of-hours deliveries • Companies do not have perfect information on the **potential costs and benefits** to inform / instigate a decision • Noise concerns for local residents – in particular during arrival / manoeuvring
Port booking	• A private company is in charge of the port ➔ delivery impact / timing of port charging relies on will / effectiveness of port companies
Fleet recognition scheme	• Impacts of driver training tend to reduce over time, so would need to be repeated • Fleet recognition scheme relies on operators taking up efficiency recommendations once made

Given these factors, it could be considered that there is greater uncertainty and risk around the ability of non-charging measures to deliver anticipated air pollution emissions reductions than around the CAZ charging options.

A.4 Qualitative Assessment

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

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

a) AQ impacts outside modelling domain (NOx and PM, not coaches)
b) AQ impacts associated with alternative responses of coaches and taxis

[27] TRL (2018); 'Business Case Support for the Implementation of a Clean Air Zone in Southampton' (unpublished)

c) Implementation costs of non-charging measures
d) Wider fuel/opex/GHG impacts associated with charging and non-charging measures
e) Wider congestion/travel time effects associated with charging and non-charging measures
f) Noise / accidents / infrastructure effects associated with charging and non-charging measures

Further several impacts were identified as associated with the CAZ but were deprioritised for assessment as less significant effects. Specifically:

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

A summary of the assessment is included in Table 36**Error! Reference source not found.**.

Table 36 – Summary of impacts assessed qualitatively

Impact category	Option 1 (City-wide CAZ B)	Option 1a (City-wide charging HGVs only)	Option 2 (city-centre CAZ A)	Option 3 (Non-charging measures)
AQ impacts outside modelling domain (NOx and PM, not coaches)	✓✓	✓✓	✓	✓
AQ impacts associated with alternative responses of coaches and taxis in response to charging CAZ	✓/×	-	✓/×	-
Implementation costs of non-charging measures	×	×	××	××
Wider fuel/opex/GHG impacts	✓/×	✓/×	✓	✓
Wider congestion/travel time effects	✓/×	✓/×	✓	✓
Noise / accidents / infrastructure	✓/×	✓/×	✓(/×)	✓(/×)
Transaction costs	×	×	×	×
Welfare loss associated with upgrading vehicles	✓/×	✓/×	✓/×	✓/×

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

The impacts not captured by the quantitative analysis could represent both costs and benefits for the CAZ options. In summary:

- All options could deliver additional air quality emissions reductions outside the modelling domain, but these are likely higher for Options 1 and 1a which affect a greater number of HGVs
- Upgrading of vehicles under all options will carry transaction costs, which scale with the number of vehicles upgraded. Hence these will be greatest for Option 1, followed sequentially by 1a, 2 and 3.
- There will be additional implementation costs not captured by the core analysis to design and deliver the non-charging measures, specifically 24-hour delivery under Options 2 and 3.
- The non-charging measures under options 2 and 3 will deliver additional fuel, operating cost, GHG savings, congestion/travel time and accident benefits not captured under the core analysis. Some will also reduce noise exposure (e.g. SDC) but some could increase this effect (e.g. 24-hour delivery).

To demonstrate the potential emissions impacts which fall outside of the zone further, an illustrative run of the EfT has been undertaken for Option 1. The results are presented in Table 22. This analysis has only been undertaken for one option as:

4. A comprehensive illustration of emissions impacts cannot be produced for all options. For Options 2 and 3, not all non-charging measures can be modelled in this simple way (and a breakdown of savings by sub-measure is not available from the core AQ modelling to be able to clearly see where the estimates from the core AQ modelling could overlap with the results of an illustrative EfT run)
5. This modelling is illustrative and does not go into the same level of detail as the core AQ modelling. These results will not therefore displace the core AQ modelling as part of the core results given there is a greater confidence in the outcomes of this modelling, and hence results for all options are not needed for this purpose
6. Assessing this option will also serve to illustrate the maximum possible impact given this option is assumed to have the largest impact on air quality.

Table 37 – Illustrative run of EfT for Option 1

	Change in NOx emissions (2020, tonnes)	Change in $PM_{2.5}$ emissions (2020, tonnes)	£ impact in 2020	PV impact over appraisal period
Core AQ modelling	-431	-13.2	£4.78m	£22.1m
Illustrative EfT run	-1,476	-14.94	£8.28m	£38.3m

As can be seen from the results in Table 22, the value of emissions impacts outside the modelled zone could be significant, almost doubling the emissions benefits under Option 1. This would push the NPV of this option further positive. But what is more interesting is perhaps what this means for the relative NPV of options.

These additional impacts are driven predominantly by HGV mileage outside of the AQ domain – these are the largest vehicle category affected and also one of the highest annual mileage. Further, an illustration of the coach impacts is already included in the 'core' modelling, further underlining the difference will predominantly be associated with HGVs. Hence this additional £16m or so of benefits will be associated with Option 1 and Option 1a, which both place charges on HGVs. The impact will be slightly lower for 1a as fewer taxis upgrade in response to incentives relative to the charges under Option 1, but it is assumed the majority of their mileage will be in and around the AQ modelling domain anyway.

However, for Options 2 and 3 the number of HGVs which upgrade is a third of that under Options 1 and 1a. Hence perhaps only around £5m of the additional impact may accrue to these options (on top of the core modelling of emissions impacts for these options).

If these additional impacts were added to the central NPV analysis (£16m for Options 1 and 1a and £5m for Options 2 and 3), this closes the gap in the NPVs between Options 2 and 3 and Options 1 and 1a, and all options end up with near enough the same NPV.

A.5 Summary assessment

The economic analysis conducted on the CAZ options has taken three forms: the focus has been on undertaking CBA of the options and monetisation of impacts. This has been complemented with exploration of some of the delivery risks around the CAZ options, and with distributional analysis exploring how the impacts may fall across different groups in society.

A summary of the results is presented in Table 38. Note: this assumes all options can achieve the gateway criteria of achieving legal compliance limits. Where this is not the case for any option, this should be removed from the ranking completely as the option is no longer viable. This is not addressed directly as part of the economic analysis, which focuses instead on total reduction in emissions which are valued using the damage cost.

The key focus of the CAZ options is to reduce emissions and help meet legal limits for **air pollutant** concentrations. From the CBA, Option 1 has the greatest impact on emissions, followed by Options 1a, 2 then 3[28]. This is predominantly driven by Option 1 and 1a capturing HGVs within a charging CAZ,

[28] As noted, the air quality impact captured in the economics focuses on emissions. This is different to the air quality impact taken directly from the modelling which focuses on concentrations and the achievement of legal limits. Although both are linked (and the air quality modelling is a key input to the economic analysis), the economic analysis also takes into account emissions of coaches and therefore presents a slightly different pattern of results. The results of the economic analysis are consistent with the concentrations modelling - the analyses simply differ in scope and objectives which lead to different metrics being extracted from the same modelling.

which instigates greater improvements in HGVs which are a key source of emissions for Southampton. This result includes the emissions impact of the options on coaches, considering the total mileage driven by the coaches, which is not included in the core air quality modelling. However, it does not capture further emissions reductions for other vehicle types which will occur outside the modelling domain – as shown in the sensitivity analysis these impacts could be significant for Options 1 and 1a, and for the comparison between options.

Alongside greater reductions in air pollutant emissions, the higher level of vehicle upgrades under Options 1 and 1a also deliver a higher level of **secondary benefits** – i.e. fuel and operating cost savings, and GHG emission reductions as newer and more efficient vehicles come into the fleet at an earlier stage.

However, Options 1 and 1a also carry with them a higher **cost of upgrading vehicles.** Costs will move in proportion with number of vehicles affected: hence the costs are smaller for Class A, than Class B. Likewise **welfare costs** from avoided trips will be associated with the options containing a CAZ charging area and are higher the larger the area and greater number of vehicles affected. Given that the CAZ options predominantly target commercial vehicles, these costs (and others associated with CAZ compliance – such as charge payments) will be borne by businesses, raising questions around the affordability of such effects in particular for smaller firms. Who will be affected and to what extent will differ by option and scale with the size and class of CAZ. The greatest effects are likely to be those direct felt by affected vehicle owners – taxi drivers, scheduled bus operators, coach firms and HGV businesses.

Many of the potential negative effects for scheduled bus operators have been mitigated through the confirmation of funding for retrofit of buses operating routes within the city. However other buses using the regional depot would still be captured by Option 1. Owners of vehicles in the other categories affected by a charging CAZ (i.e. taxis and coaches under Options 1 and 2, and HGVs under 1 and 1a) will likely capture to some extent smaller firms and operators, in particular taxi drivers, which may find it more difficult to meet any upfront costs of CAZ compliance. In addition, the air quality benefit to Southampton of including coaches in the charging CAZ may be limited given these vehicles typically do less mileage in the city area.

Options 1 and 2 could also have a more prominent indirect impact on household affordability through costs being passed on by taxi operators, however these impacts are uncertain and likely small.

In addition, Options 1 and 1a have high **implementation costs** given they propose a much larger CAZ area (relative to Option 3 which does not include a CAZ charging area at all). However, there will also be implementation costs associated with the non-charging measures, in particular those for HGVs implemented under Options 2 and 3. It has not been possible to capture some of these in the quantitative analysis but those that have been captured bring the implementation costs of Option 2 in line with those under the larger charging zone options. In particular, the costs of handling additional freight through the SDC could be fairly large (even though many would fall away given the SDC is already established and has spare capacity - This assumption has been checked and confirmed as appropriate with the Transport team at SCC) and could present an additional barrier to the take up of this option.

Furthermore, there are other effects which influence the balance of benefits and costs. Specifically, the non-charging measures for HGVs under Options 2 and 3 deliver significant benefits in terms of **travel time reduction**. The impacts captured in the analysis represent driver time savings and wider impacts on traffic through use of the SDC which takes HGV vkm off the road. These impacts can be significant: for these options they are greater than the air quality benefits delivered and directly influence the overall ranking of options. Furthermore, these greater impacts on travel time also have secondary benefits of reductions in noise and accidents and improved accessibility.

Overall, on central assumptions, all options assessed deliver a positive NPV – i.e. the benefits outweigh the costs. In terms of ranking, it appears that the additional benefits gained through having a larger CAZ outweigh the costs under Options 1 and 1a, but the secondary benefits delivered by the alternative non-charging measures for HGVs result in Options 2 and 3 having a higher positive NPV than Options 1 and 1a under the core analysis. However, applying the additional benefits of emission reductions outside the modelling domain results in all options having near enough the same NPV.

This CBA was facilitated through the use of several simplifying assumptions. When viewing this analysis, it is important to recognise the uncertainty and caveats around these results and that risks exist which may impact on the ability of the CAZ options to achieve these anticipated effects in practice. Risks exist around both:

1. **CAZ charging:** The analysis assumes the charge levels and behavioural response recommended nationally by JAQU and does not account for local characteristics which may influence these responses. Furthermore, the response assumed is immediate on the date the CAZ comes into force and the analysis does not recognise the potential implementation issue of identifying taxis in the absence of a national database.
2. **Non-charging measures:** The impact of these measures also critically relies on behavioural change from vehicle owners, but in this case on voluntary responses to incentives rather than a CAZ charge. There are several issues which may affect the response in practice:
    a) vehicle owners do not hold complete information on trade-offs between strategies
    b) vehicle owners may still not act rationally – e.g. agents are more averse to loss than attracted to benefits of equal amount
    c) other barriers exist which may prevent take up of non-charging measures, in particular in the short term, e.g. contractual arrangements.

Given these factors, it could be considered that there is greater uncertainty and risk around the ability of non-charging measures to deliver anticipated air pollution emissions reductions than around the CAZ charging options.

Table 38 – Options summary

Option	Rationale

Option 1	• Positive NPV – delivers largest air pollutant emission reductions with largest costs
	  ○ Does not capture wider travel time benefits of HGV non-charging measures
	  ○ But core analysis does not capture large emission reductions outside the modelling domain delivered by this measure
	• Largest impact on businesses, with potential adverse effects on HGV and coach operators, and taxi drivers who may struggle most with affordability of upfront costs of compliance
	• Avoids high risk around deliverability of HGV non-charging options. Hence lower risk in terms of achieving legal limits in shortest possible time.
	• Potential risk around deliverability of identifying taxis under charging CAZ in absence of national database
	• Delivers large air quality emissions reduction, which will deliver greatest health and environmental benefits, from which poorer households will benefit most

Option 1a	• Lowest NPV (but still positive) in core analysis – delivers large air pollutant emission reductions with large upgrade and implementation costs
	  ○ Does not capture wider travel time benefits of HGV non-charging measures
	  ○ But core analysis does not capture large emission reductions outside the modelling domain delivered by this measure
	• Large impact on businesses, in particular HGV operators. But mitigates negative impact on taxi and coach operators relative to option 1
	• Avoids high risk around deliverability of HGV non-charging options, and of including taxis in the CAZ. Hence lowest risk in terms of achieving emissions reductions and legal limits in shortest possible time
	• Delivers large air quality emissions reduction, which will deliver wider health and environmental benefits, from which poorer households will benefit most

Option 2	• Positive (second highest) NPV in core analysis – delivers moderate air pollutant emission reductions with moderate cost, and large secondary benefits through travel time savings which swing NPV ranking in favour of this option
	  ○ But when AQ impacts outside domain are included, NPV is comparable to Options 1 and 1a
	• Smaller impact on businesses as less HGV operators affected, however captures coach operators and taxi drivers who may struggle most with affordability of upfront costs of compliance
	• But significant concerns around deliverability of non-charging measures, in particular for HGVs which are most important vehicle category under consideration.
	  ○ Several barriers exist to implementing and delivering savings through these measures, creating high risk around achievement of air quality limits in shortest possible time

Option	Rationale
	• Potential risk around deliverability of identifying taxis under charging CAZ in absence of national database • Potential negative noise impacts associated with 24-hour delivery

Option 3	• Largest NPV – delivers smallest air pollutant emission reductions, but with smallest cost and large secondary benefits through travel time savings which swing NPV ranking in favour of this option
	    o But when AQ impacts outside domain are included, NPV is comparable to Options 1 and 1a
	• Smallest implementation costs given no requirement for a charging CAZ, but some non-charging measures carry substantial effort to put in place
	• Smallest impact on businesses
	• But significant concerns around deliverability of non-charging measures, in particular for HGVs which are most important vehicle category under consideration.
	    o Several barriers exist to implementing and delivering savings through these measures, creating high risk around achievement of air quality limits in shortest possible time
	• Potential negative noise impacts associated with 24-hour delivery

Appendix 4 – Qualitative assessment of wider impacts

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

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

a) AQ impacts
   - outside modelling domain (NOx and PM, not coaches): the air pollutant impacts captured have been limited by the domain of the air quality model. However, where affected vehicles travel outside of this area, there will also be impacts through upgrading of vehicles and other behavioural responses associated with the CAZ[29]. The effects for coaches outside the modelling domain have been demonstrated through the illustrative runs of the EfT, hence the effect not captured is predominantly associated with HGVs (taxis and buses, the other affected vehicles will travel predominantly within the city area)
   - associated with alternative responses of coaches and taxis: taxis and coaches are not addressed separately in the transport model. Hence only the demand response to a charging CAZ has only been modelled for HGVs exploring what proportion adopt response strategies other than to upgrade vehicles. In practice, some coaches and taxis affected by the charging CAZ could avoid zone or cancel journeys, with impacts on emissions inside/outside the CAZ area (note: key impact of upgrading these vehicles has been captured by the AQ modelling).
   - Associated with port booking measure: no significant impact could be discerned from the aggregate modelling. In addition, this measure will shift trips and emissions off peak. Although this will reduce exposure, this will not show in the economic analysis which simply combines total emission reductions with damage costs (and does not account for time of day of emission)

b) Implementation costs of non-charging measures: the quantitative CBA has captured costs associated with the set up and operation of a charging CAZ structure and associated with the implementation of some of the non-charging measures (i.e. implementation of the port booking incentives, designing and implementing DSPs and increasing freight through the SDC). However, there are a number of non-charging measures for which implementation costs have not been captured in the analysis. The costs associated with the following are not captured:
   - Additional stack management costs associated with port-booking scheme
   - It is assumed that there is spare capacity at the SDC to cover additional use. Where this is not the case, there may be additional vehicle and warehouse space costs

c) Wider fuel/opex/GHG impacts: given the varying nature of the measures included, the CAZ options have the potential to have a range of effects on fuel consumption, operating costs incurred and GHG emissions. Two key effects have been captured as part of the core analysis: impact of upgraded vehicles in response to charging/non-charging measures and the direct savings to freight operators (and cost to SDC) associated with greater routing of freight through the SDC. But due to limitations in data, several effects have not been captured:
   - Changes associated with the alternative behavioural responses to the charging CAZ: Where vehicles avoid/cancel, this will impact on distance travelled by these vehicles and in turn on fuel consumption and opex. In addition, there will be an indirect effect on other road users from affected vehicles being removed from roads within the CAZ –

[29] The Systra modelling was also unable to provide emissions savings for coaches, however these gaps have been filled through illustrative runs of the EfT.

this will reduce congestion and increase the speed with which these wider journeys can be made.

For direct effects, fuel and operating cost changes will be captured by the 'welfare loss' estimated as part of the core analysis, so only changes in GHG are additional.

For indirect effects, it is difficult to extract these results from the transport modelling given the implied changes are in speed, not trip distance. Furthermore, the transport modelling is only available for one option.

Looking at the aggregate impacts of the transport modelling of the initial shortlist, both are likely to be small: the total change in vkm of non-compliant vehicles is small as most upgrade/pay the charge, and only those travelling through the area have the option to avoid. Further the two responses will have opposing effects, with avoid responses increasing and cancel journey responses decreasing GHG emissions. In turn, any improvement in congestion in the centre is small, and is further reduced by the rebound effect observed through car travel.

- Indirect effects of SDC: where greater re-routing of freight through the SDC removes HGV vkm off the roads, this will improve congestion to the benefit of other on other road users. Increasing journey speed could reduce fuel consumption leading to GHG savings. It has not been possible to capture these effects as they have not been modelled using a transport model. Whether the fuel and GHG emission impacts deliver a benefit or a cost will depend on where on the vehicle emissions curve the vehicles shift from and too – increasing speed from a low speed reduces fuel consumption up to a point, after which increasing speed begins to increase emissions.

d) Wider congestion/travel time effects: as with fuel and operating cost impacts, given the varying nature of the measures which have been combined to form the CAZ options, there is the potential for a number of different effects leading to changes in congestion and travel time. Two has been captured in the analysis – a) the change in travel time for non-compliant vehicles avoiding/cancelling in response to a charging CAZ will be captured in the 'welfare loss' and b) direct benefit of reduction in driver time for freight re-routing through the SDC.

Other impacts not captured include:

- indirect effect of SDC reducing HGV vkm in city area on other road users.
- Changes associated with the alternative behavioural responses to the charging CAZ: Where vehicles avoid/cancel, this will remove trips within the CAZ area, which in turn will have an indirect effect on other road users – this will reduce congestion and increase the speed with which these wider journeys can be made.

  Looking at the transport modelling outputs for the initial shortlist, this impact is likely to be small: the change in total vehicle hours is small as most non-compliant vehicles choose to upgrade/pay the charge, and only those travelling through the area have the option to avoid, limiting the number which avoid/cancel. Any improvement in the centre is further reduced by the rebound effect observed through car travel.

e) Noise / accidents / infrastructure: changes in traffic flows (both quantity and speed) around the city will imply changes in noise levels, accident rates and potential requirement for infrastructure maintenance. As with fuel/opex and travel time savings, there will be impacts associated with the different CAZ measures:

- Charging CAZ: where non-compliant vehicles avoid/cancel journey in response to a charging CAZ, this will reduce traffic on roads within the CAZ. Given the CAZ area covers urban populated centres, the removal of traffic from within this zone is likely to reduce exposure to noise pollution, accident rates and the requirement for infrastructure expenditure. The estimation of these effects is further limited by the fact transport modelling is only available for one measure. However, the results of this measure suggest such effects are small given most HGVs either upgrade or pay the charge in response to the CAZ. An additional rebound effect from cars increasing traffic on links within the CAZ area will also counter any improvements gained through reductions in HGV traffic.

    - DSP/SDC: removal of HGV vkm from city-centre links which is instead rerouted through the SDC could significantly reduce exposure to noise pollution, accidents and infrastructure renewal requirements. However, there may be isolated increases associated with higher activity in the location of the SDC.

Further several impacts were identified as associated with the CAZ but were deprioritised for assessment as less significant effects. Specifically:

- Transaction costs: associated with upgrading vehicles. An initial analysis suggested transaction costs would be very small relative to upgrade costs, hence these were not included as part of the core analysis.
- Welfare (utility) loss associated with upgrading vehicles: the analysis captures the financial costs associated with upgrading vehicles, but not any loss in welfare associated with being compelled to switch to a (potentially less favourable) alternative. This may represent an additional impact on top of the financial costs of upgrading vehicles.

A qualitative analysis of these impacts across the scenarios is included in Table 39.

The impacts not captured by the quantitative analysis could represent both costs and benefits for the CAZ options, and an impact may switch between being a cost or benefit, depending on the option in question. In summary:

- CAZ B could deliver additional air quality emissions reductions outside the modelling domain, but the port booking measure under NCH CAZ could deliver some reduction in exposure which is not captured through the damage cost approach
- Upgrading of vehicles under all options will carry transaction costs, which scale with the number of vehicles upgraded. Hence these will be greatest for CAZ B
- There will be additional implementation costs not captured by the core analysis to design and deliver the non-charging measures, in particular stack handling costs under the port booking measure
- The NCH CAZ will deliver additional fuel, operating cost, GHG savings, congestion/travel time and accident benefits not captured under the core analysis. Some will also reduce noise exposure (e.g. SDC)

Table 39 – Qualitative analysis of CAZ options against impacts not covered by core CBA

Impact category	Option 1 (City-wide CAZ B)	Option 3 (Non-charging measures)
AQ impacts: a) outside modelling domain, b) associated with alternative responses, c) associated with port booking measure	✓✓ HGVs upgraded in response to the CAZ will travel outside the zone, delivering additional emissions benefits. Further HGVs likely to do significant proportion of annual vkm outside zone, so effects could be large. To extent impacts outside zone likely to fall outside urban areas, would have lower impact on exposure and health effects. Most vehicles affected hence impacts largest for this option. Coaches/ taxis which avoid zone could increase emissions (in this case outside of the city area), but vehicles which cancel could reduce emissions overall. Hence overall impact is uncertain	✓ Port-booking will shift timing of some emissions, reducing exposure with some health benefit
Transaction costs	× Will be a cost and will move in line with number of vehicles upgraded. Hence greatest for this option (~4,500 upgraded). However, initial assessment suggested costs are small in comparison to cost of upgrade.	× Will be a cost and will move in line with number of vehicles upgraded. Hence lowest for this option (~136 upgraded). However, initial assessment suggested costs are small in comparison to cost of upgrade.
Welfare loss associated with upgrading vehicles	✓/× Will scale with number of vehicles upgraded. However, in some cases vehicle users may derive a utility benefit from upgrading to a new vehicle. Hence overall impact is uncertain	✓/× Will scale with number of vehicles upgraded. However, in some cases vehicle users may derive a utility benefit from upgrading to a new vehicle. Hence overall impact is uncertain
Implementation costs of non-charging measures	- N/A	× Some additional costs associated with stack management, but potentially small given level of response observed in transport model
Wider fuel/opex/GHG impacts	✓/× No significant effects from avoid/cancel responses to charging CAZ – HGVs/taxis/coaches avoiding increase but those cancelling decrease emissions. Removal of HGVs/taxi/ coach vkm from CAZ will improve speeds (and reduce fuel consumption and GHG emissions) for other road users, but countered by car rebound (increase fuel consumption, opex and GHG emissions). But overall effect is small	✓ Small benefit on other road users from greater use of SDC
Wider congestion/travel time effects	✓/× Removal of HGVs/taxi/ coach vkm from CAZ will improve speeds (and reduce travel time) for other road users, but countered by car rebound.	✓ Small benefit on other road users from greater use of SDC
Noise / accidents / infrastructure	✓/× No significant effects from taxi/HGV/coach avoid/cancel responses to charging CAZ as modelled impacts small and countered by car rebound	✓(/×) DSP/SDC could have large benefit through reduction in noise, accidents and infrastructure.

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

Appendix 5 - Quality Assurance

Quality management for all Ricardo projects (and all deliverables produced) is delivered in accordance to the requirements of the International Standard ISO 9001:2008. Principles of quality assurance (QA) are integrated in all our activities and at all levels through established and implemented procedures according to the international standard. The formally appointed Project Manager and Project Director lead in ensuring the project is undertaken in accordance with the current Ricardo Quality Assurance processes and that the system is effective.

The economic analysis (including the supporting calculations, model and interpretation of analysis) for the Southampton CAZ has been developed in accordance with these over-arching Ricardo QA policies and procedures to ensure high quality and accuracy of deliverables.

Ricardo has a rigorous QA system in place to assure the quality of models and databases produced, which has been applied to the Southampton CAZ economic model. The QA system has five categories of QA processes, against which the structure and functionality of the model have been assessed:

1. Having clear and comprehensive documentation
2. Good structure and clarity
3. Formulas are correctly specified and are shown through verification to be error free
4. Validation against other sources confirms logical outcomes
5. Data and assumptions used are sensible and signed off.

All elements of the model have been developed by team members with appropriate skills and knowledge in order to specify the model correctly.

Working versions of the model have been subject to rigorous and detailed QA checking. This has been performed by someone other than the analyst which developed the original calculations. A full QA of all the functionality of the model has performed once the full model build was completed. As part of this QA, data transformations have been rigorously checked through spot checking, auto-sum and third-party validation.

The model has been developed in accordance with Ricardo's 'best practice' modelling guidance for the construction of workbooks and tools. This includes having separate sheets for data import, manipulation and results. In addition, the model has been developed with strict version control procedures (to avoid version error) and with assigned governance and responsibilities (i.e. the PM holds overall responsibility for the quality of the model, with analysts holding joint responsibility for the elements they developed).

In some cases, some data transformations have been carried out in MS Excel prior to import to the economic model. Each of those transformation workbooks has been identified and also subject to scrutiny.

All data sources used in the model are appropriately referenced and clearly marked where data is inputted into the model. All assumptions and data sources have been logged, in particular as part of this Methodology Report.

In addition, for this specific work additional QA checks have been performed with the input of SCC and the wider consultancy team. For example, where data and assumptions have been drawn from external models, we have discussed directly our interpretation of the data received, and its planned use in the economics model to sense check our approach (e.g. air quality emissions outputs, and transport modelling outputs).

A further check of the quantitative results of the economic modelling and their interpretation has been performed through the review of the documentation. The Project Director undertook a review of the Methodology Report and the inputs to the Economics Case prior to release. Given the experience of the Project Director working in this area, this has provided an additional sense check of the results and underpinning calculations, and a cross-check against other studies of this type.

In accordance with Ricardo's QA processes, all deliverables and outputs have been signed off by both the Project Manager and Project Director before release to SCC.

Ricardo
Energy & Environment

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom
t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com