Economic appraisal methodology report

Southampton Clean Air Zone feasibility study

Report for Southampton City Council

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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]. This guidance stipulates that deliverables to be provided by the Local Authority are:

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

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 as set out above. The results section of this paper forms the basis of the write up of economic appraisal (point 4 above), which is presented formally in the overarching Economics Case. The economic model used to produce the economic appraisal set out in this report is provided to JAQU separately (meeting deliverable E2).

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.

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

[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

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 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).

This report does not present outputs of any quantitative distributional analysis as this will be undertaken at the next phase of the feasibility study. As a result, no Distributional Analysis Methodology report (meeting deliverable E3) is provided as part of this document or separately. However, an initial qualitative distributional analysis has been undertaken to help inform the selection of the preferred option at this stage.

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 2020 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. This model has also been provided to JAQU alongside the submission of this document to support review of the Southampton CAZ OBC (meeting deliverable E2 above).

2.2 Scope of assessment

2.2.1 CAZ options assessed

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 refined short-list comprises of 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 is also considering some 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 1Each 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.

Table 1.

[3] Unpublished – provided directly by JAQU to cities
[4] Unpublished – provided directly by JAQU to cities

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.

Table 1 – 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 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 2.

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.

A mapping showing the scope of impacts covered by the analysis is presented in: Appendix 2 – Mapping of impacts of Core CBA. Where impacts have not been assessed quantitatively, a qualitative assessment has been performed. The results of the analysis are presented in Section: 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 25 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. 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 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).

Table 25: 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 • 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.
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 / manouvering
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.

Qualitative Assessment.

Table 2 – Impact description and mapping

Impact name	Description	JAQU reference
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. Further this also captures to costs of vehicles upgraded in response to non-charging CAZ measures (i.e. bus condition, taxi incentives, and port booking and 24 delivery incentives for HGVs)	'Vehicle scrappage costs' and 'Consumer welfare impact' for 'upgrade vehicle response'
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.	'Fuel switch costs'
Implementation costs	Cost of upfront and ongoing activity and assets required to implement, monitor and enforce the charging 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.	'Government costs'/private costs
Air quality emissions	The impact on affected populations by a change in NOx and PM emissions as a result of CAZ implementation	'Health and environmental impact'
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.	'Greenhouse Gas impacts'
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 impacts on travel time given the different ways in which the measures will influence behaviour.	'Traffic flow impact'
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.	'Consumer welfare impact' applied to behavioural responses 'avoid zone', 'cancel journey' and 'mode shift'

2.3 Overarching assumptions

In Table 3 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 3 - Modelling assumptions

Option	Components	Modelling approach
Option 1 City Wide CAZ B	City Wide CAZ B	City Wide CAZ B in transport model, which feeds into AQ model
	Bus grants	Not modelled separately/no additional assumptions as we assume the charging CAZ leads to upgrade of vehicles – this measure therefore only impacts on where the costs of these upgrades fall (e.g. on vehicle owners who do not receive and incentive, or on tax-payers where incentives are provided)
	Taxi incentives	Not modelled separately/no additional assumptions as we assume the charging CAZ leads to upgrade of vehicles – this measure therefore only impacts on where the costs of these upgrades fall (e.g. on vehicle owners who do not receive and incentive, or on tax-payers where incentives are provided)
Option 1A City Wide HGV charging	City wide CAZ for HGVs only	Using transport modelling for CAZ B but only update HGV fleet
	Bus traffic condition	Assume 100% buses travelling through the centre comply, 80% elsewhere comply - accounts for fact that most buses pass through the centre.
	Taxi incentives	Assume 20% of non-compliant vehicles upgrade, 1/3 of JAQU assumption. Upgrade is assumed lower due to uncertainty around availability of funding and given this relies on voluntary vehicle owner behavioural change in response to an incentive, rather than in response to the charge
Option 2 City centre CAZ A Plus LES HGV	City centre Class A	Use base 2020 transport model results Assume 100% buses travelling through the centre comply, 80% elsewhere comply - accounts for fact that most buses pass through the centre. Taxis - Assume JAQU compliance assumptions in centre (upgrade and VKM reduction), Assume 38% upgrade elsewhere (JAQU upgrade * ratio of city centre/rest of city Tax proportions)
	Bus grants	Not modelled explicitly as scheme forces uptake
	Taxi incentives	Not modelled explicitly as scheme forces uptake
	Freight DSP and consolidation	Assume 5% reduction of HGV and LGV traffic passing through the centre, assume 2.5% reduction in HGV and LGV traffic passing through the rest of city (reduced LES assumption)
	Freight Eco, Port booking, 24hr	Assume 30% non-compliant HGVs upgrade (1/3 of JAQU assumption)
Option 3 Non-charging CAZ	Bus traffic condition plus grant	Use base 2020 transport model results Assume 100% buses travelling through the centre comply, 80% elsewhere comply - accounts for fact that most buses pass through the centre.
	Taxi incentives	Assume 20% of non-compliant vehicles upgrade, 1/3 of JAQU assumption
	Freight DSP and consolidation	Assume 5% reduction of HGV and LGV traffic passing through the centre, assume 2.5% reduction in HGV and LGV traffic passing through the rest of city (reduced LES assumption)
	Freight Eco, Port booking, 24hr	Assume 30% non-compliant HGVs upgrade (1/3 of JAQU assumption)

2.4 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.

2.4.1 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 taxis, licence data was used to identify the size of the current fleet of taxis and private vehicles in Southampton and the surrounding areas (taxi data covered Southampton, New Forest and Eastleigh). This data also included the relevant Euro standard of each vehicle.

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.

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

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).

2.4.2 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
%age change over 5 years	**veh-km**	**8.17%**	**8.7%**	**10.6%**	**3.19%**	**-0.1%**

2.4.3 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%

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

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.

2.4.4 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 and city-wide areas in 2016, and the resulting numbers of vehicles that result from application of the uplift factors, fleet growth, and fleet composition adjustments in 2020 as described above.

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
	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

2.4.5 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 9 – 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.

2.5 Approach to assessing the impacts

2.5.1 Upgrade costs

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 in 2020' 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).
    a. With the exception of buses – all non-compliant buses are assumed to be upgraded to be consistent with funding received through CBTF bid
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.
    a. With the exception of buses – all non-compliant buses are assumed to be retro-fitted to be consistent with funding received through CBTF bid
4. Calculation of upgrade costs for CAZ scenarios:
    a. Lost residual value from scrapped vehicles based on depreciated value of non-compliant vehicle in 2020
    b. New compliant vehicle purchase costs are cost of new vehicle in 2020
    c. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles with same fuel in 2020
    d. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles of different fuel in 2020
    e. Cost of retrofit of non-compliant buses
    f. Aggregate the relevant costs for different CAZ scenarios (e.g. CAZ B aggregates Buses, 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 in 2020 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 2020
    c. Net costs of selling non-compliant used vehicles and purchasing compliant used vehicles with same fuel
        i. The non-compliant used vehicles are 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 in 2022

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 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 2020

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. Retro-fit costs of buses

i. Retrofit cost only included in CAZ scenario, along with cost of replacement compliant vehicle after 5 years (representing extension to vehicle lifetimes achieved through retro-fit)

ii. Baseline only includes cost of replacement compliant vehicle. However, under baseline, vehicles do not have lifetime extended, so replacement occurs sooner in baseline (at end useful life) that it does in the scenario

iii. Discount costs to 2020

f. 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 10.

Table 10 – 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

	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 taken into account
    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 11.

Table 11 – NO_x and PM impacts of CAZ scenarios in 2020

Scenario	NOx Difference from Baseline (tonnes)	PM Difference from Baseline (tonnes)
Option 1	278	10.0
Option 1a	282	9.93
Option 2	155	2.77
Option 3	150	2.41

2.5.2.2 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 Table 12.

Table 12 – Illustrative impacts of emission related to coaches

Pollutant	Baseline emissions in 2020	Difference to the baseline in 2020, Option 1	Baseline emissions in 2020	Difference to the baseline in 2020, Option 1
	City-centre	City-centre	City-wide	City-wide
NOx	283.0	-87.8	474.9	-147.4
PM	11.6	-1.05	19.5	-1.76

2.5.2.3 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.

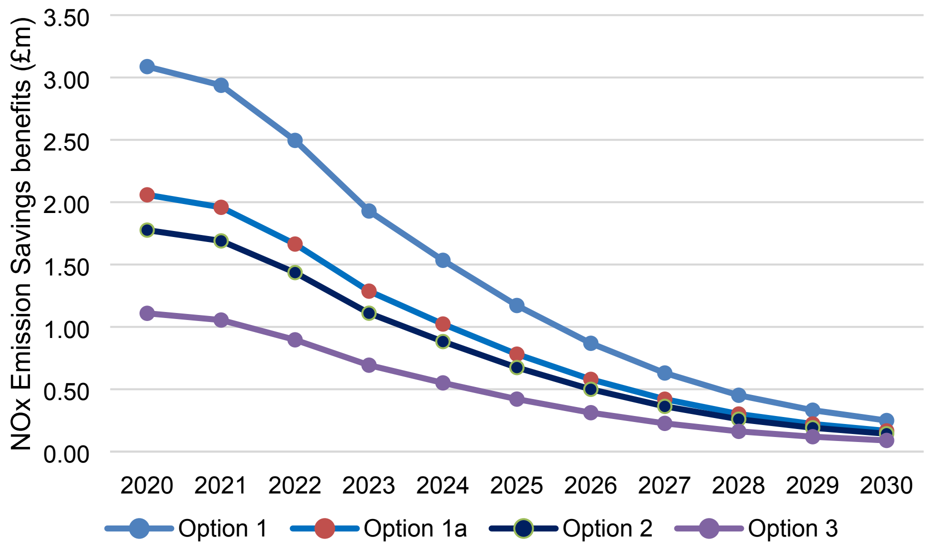
National AQ plans scenarios*[6]*: The supporting evidence for the national plans included scenarios run by JAQU presenting resulting concentrations in cities for the baseline and illustrative CAZ scenarios. This information could be analysed to produce a factor with which impacts can be extrapolated 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. However, this evidence presented concentrations on a link-by-link basis. Hence there is an issue of how to derive a factor to extrapolate city-wide emissions impacts. In this case, concentrations for all links in Southampton were simply summed under baseline and CAZ scenarios. The extrapolation factor is then the difference in summed concentrations between baseline and CAZ scenario, expressed as a ratio relative to the difference in 2020 (Although technically speaking it is unusual to add concentrations between different links, this analysis would produce the same result were a straight average be taken across all links). Further, this is considered appropriate in this case as it allows consideration of convergence across all links covered by the CAZ, rather than based on one link which may not be representative. The applicability of such factors will also depend on the CAZ scenario run by JAQU to develop the plans, which is not fully detailed in the published plans themselves.

Fleet projection assumptions: turnover in fleet can be modelled 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. This offers the advantage that trends in fleet can be explored directly. However, when applying this in practice, convergence is modelled separately for different vehicle types and was unable to cover all vehicle types. Hence there is an issue of how to combine different convergence profiles for different vehicle types, and how to incorporate those vehicle types which will be impacted by the CAZ but are not part of the modelled. Further 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.

Given the national plans provided a summary output which already accounted somewhat for the aggregation across vehicle types and relative emissions, a representative factor can be more easily derived. Hence the factor applied in the tool has been derived from the data set out in the national plans.

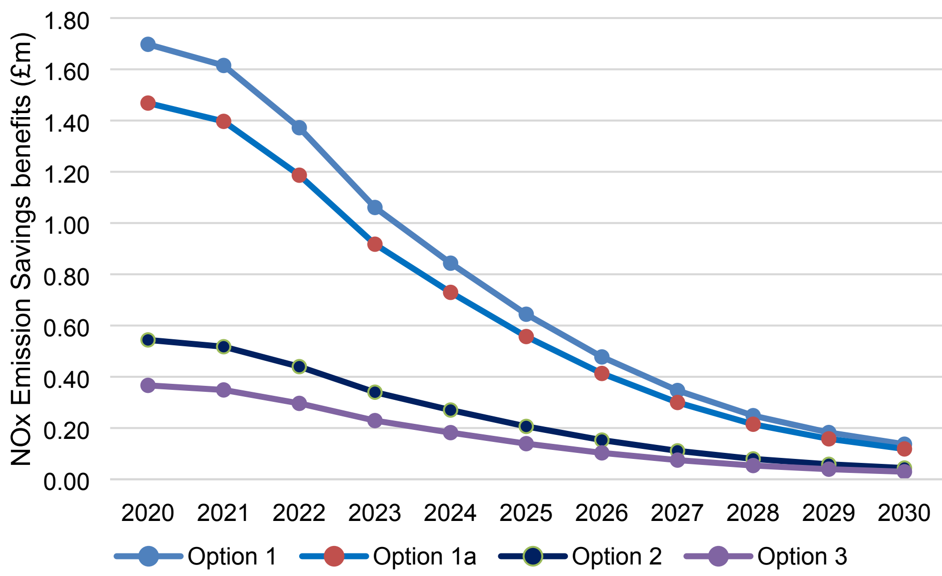
The trend in NOx and PM emissions impacts over the appraisal period depicted using the extrapolation factor are illustrated in Figure 1 and Figure 2 .

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



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

Figure 2 - Trend of PM emissions impacts of CAZ over appraisal period (undiscounted)



2.5.3 Operating costs

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 and operating costs.

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 5 – 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.

In addition, the fuel/opex cost savings associated with alternative responses to a charging CAZ will be captured by welfare loss impacts described below.

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 [7]
    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
4. Changes in fuel consumption are combined with Long-run variable costs (LRVC) from BEIS' Green Book Supplementary guidance

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

[7] 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.

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.

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

2.5.4 Greenhouse Gas (GHG) emissions

Where vehicle owners upgrade vehicles or cancel their journeys, this will have an impact on fuel consumption and in turn on the emissions of GHG's. Any change in GHG emissions will influence the ability of the UK to meet its climate change targets.

As with fuel consumption impacts, there will be a variety of different impacts given the range of measures which make up the CAZ options. As above, two components have been captured in the quantitative analysis (again with wider impacts described as part of the qualitative analysis):

1. The impact of upgraded vehicles in response to charging/non-charging measures
2. Direct savings associated with greater routing of freight through the SDC.

(Different to fuel/opex savings above, in this case, 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. This is discussed further as part of the qualitative analysis).

The analysis assessed changes in GHG emissions associated with vehicle upgrades by applying the approach as follows:

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 fleet between baseline and scenario
3. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with the average annual fuel consumption[8]
    a. By applying average fuel consumption over the full year and average vkm travelled per annum, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the AQ modelling domain
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 GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary Guidance[9].

In addition, the impacts of greater use of the SDC are calculated as follows:

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.

2.5.5 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.

[8] Ibid

[9] JAQU have provided updated guidance on emissions factors to assume for the economics assessment. However, the assessment was at too an advanced stage when these were received for these to be included as part of this analysis.

Three impacts 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 effect of SDC reducing HGV vkm in city area on other road users (although this is only included in sensitivity analysis given methodology available)
c) 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. Extract data from the AQ modelling regarding changes in total HGV vkm travelled
2. 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)
3. Combine this result with WebTAG data on value of time for HGV drivers.

The indirect effects of the SDC were estimated as follows:

1. Extract data from the AQ modelling regarding changes in total HGV vkm travelled
2. Calculate weighted average congestion impact per km from WebTAG Marginal External Costs (MEC) (Table A5.4.2) and WebTAG data on proportion of roads in each congestion category for south-east (Table A5.4.1)
3. Combine vkm with average congestion impact per km

It is important to note that WebTAG's MEC are only available per km or car travel. As such the estimation of this effect is only included as a sensitivity around the core analysis. However, given HGVs take up much more space on the road, their congestion impact per km travelled could be much larger than cars, resulting in the estimate presented as a sensitivity could be an underestimate of the total effect.

To estimate the impact of charging CAZ on other road users, our intention was to use total changes in vehicle hours (veh-hours) travelled from the transport modelling. The monetisation of these effects would adopt the following approach:

1. Take changes in total veh-hours travelled from the transport modelling, for each CAZ scenario and baseline, split by transport model vehicle categories
2. Uplift changes from 12 hour basis to yearly impact
3. Split LGV travel time by journey purpose (not split in transport model)
4. Project changes in travel time over appraisal period using extrapolation factor to represent that vehicle behaviour will revert to original pre CAZ patterns once baseline has caught up with CAZ scenario
5. Combine change in travel time with values of time from WebTAG[10].

However, transport modelling was only available for one option (Option 1a). Hence the estimated effect has only been included as a sensitivity to the core analysis. A qualitative discussion of the impacts of the other Options is included in the Appendix (Appendix 5 – Qualitative assessment of wider impacts), however analysis of the impacts of the option for which modelling is available suggest such impacts could be very small.

2.5.6 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

[10] https://www.gov.uk/government/publications/WebTAG-tag-unit-a1-3-user-and-provider-impacts-march-2017

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 in the transport model. The proportion which upgrade is taken from JAQU standard assumptions, with the remaining responses being determined endogenously within the 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.

This captures the impact for 'avoid the zone', 'cancel journey' and 'mode shift' behavioural responses only. The effects of upgrading vehicles are assessed separately and in greater detail elsewhere in the analysis, so they are omitted here to avoid overlap.

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.

The impact is calculated based on ANPR from the transport model. This is different from the starting point for the calculation of welfare impacts in other studies (e.g. Leeds feasibility study used trip data from the transport model), but is consistent with other impacts assessed for Southampton, in particular the baseline fleet and upgrade costs. The underlying rationale and additional assumptions are presented in Information Box #2 below.

Information Box #2: Alternative methods to estimate welfare loss

The majority of impacts assessed as part of the CBA use as their basis the number of unique vehicles assumed to enter the CAZ area, which in turn is (predominantly) derived from ANPR data. In the case of estimating welfare loss, this study also uses fleet and ANPR data as a key input. However, in other CAZ studies a better starting point was deemed to be trip data from the transport model.

The value of welfare loss is calculated on the basis of half-the-charge per avoided trip (simplifying for now to one trip into the CAZ per day per vehicle).

Using trip data from the transport model has the advantage that an exact boundary can be drawn around the area to be assessed, more accurately counting affected trips. However, in this case the ANPR data has reasonable coverage of both city-centre and city-wide zones, in particular covering most key routes in/out of the zones, so the relative benefit of using trip data in this case is smaller.

In addition, the transport model also offers a more validated starting point, given the high level of testing and checking undertaken on the transport model.

In both cases, additional assumptions are required to go from the basic input data to the number of days spent in CAZ over the course of a year by all vehicles. For the ANPR, an additional assumption would be required to convert number of unique vehicles per week into number of CAZ days per annum. For the transport model, an adjustment is required to identify how many of the trips per day are unique – one vehicle may make more than one trip into the CAZ, but will only be charged once.

In this case, ANPR data is used given transport modelling is only available for one option (Option 1a), and given two key transport modes (taxis and coaches) are not addressed directly by the model, there are limitations around the ability of the transport model to provide the required input information to look at numbers of trips either avoiding/cancelling in response to the CAZ.

The results of the assessment are presented in

Table 13.

Table 13 – Welfare loss impacts

Scenario	Total CAZ days affected (per week)	Total CAZ days avoid / cancel (per week)	Total welfare cost in 2020 (£m)	PV welfare cost 2020-30 (£m)
Option 1	13,200	2,051	1.27	5.58
Option 1a	5,673	140	0.365	1.60
Option 2	5,406	1,393	0.581	2.56
Option 3	0	0	0	0

2.5.7 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.

No formal costing has been developed by SCC to date to inform the financial case. Hence illustrative estimates were developed for inclusion in the economics case, but have yet to be fully checked and reviewed by transport and planning teams in SCC.

For the charging CAZ, costs were developed based on the infrastructure requirements identified as required by Leeds City Council to implement the CAZ options considered as part of their feasibility study. In the most part this also used cost data for each of the units of infrastructure also from the Leeds study, but in places used unit costs provided by SCC as a result of an initial review (e.g. unit and operating costs for cameras). These requirements were then combined with estimates of the number of links crossing each CAZ boundary to produce an overall estimate of implementation costs.

Estimates of the costs to implement the two charging zones under consideration are set out in Table 14.

Table 14 – Initial estimate implementation costs of charging CAZ

CAZ Area	Capital cost (implementation) (£)	Revenue costs (CAZ Administration) (£)

City centre	670,000	470,000
City wide	1,600,000	582,000

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

- delivery of bus retrofits, as set out in the CBTF bid (all options)
- design and delivery of the port booking incentive scheme, based on evidence collected for the preceding Southampton LES study[11] (Options 2 and 3)
- Costs of designing, negotiating and implementing DSPs to achieve the targeted level of vkm reduction
    - These were estimated based on discussions with Transport Catapult who have undertaken a study of the potential benefits for the University Hospital of using the SDC to co-ordinate deliveries.
    - Although no formal data was available on the costs of this and a preceding project undertaken by the University of Southampton which together constitute the construction of the DSP, a cost estimate was derived based on the length of the these projects and resource commitments.
    - This was translated into an average cost per vkm saved associated with the project, adjusted to more typical rates of savings achieved through SDCs, and then applied to the level of vkm savings targeted by the CAZ measure.

There will be a number of wider implementation costs associated with the non-charging measures which have not been captured in the quantitative analysis. A qualitative discussion of these effects is included in the Appendix (Appendix 5 – Qualitative assessment of wider impacts).

2.6 Methodology summary

2.6.1 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 15.

Table 15 – 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[12], 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

[11] Ricardo (2015): 'Economic analysis of measures for Southampton LES' (unpublished)

[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/624528/GDP_Deflators_Qtrly_National_Accounts_June_2017_update.xlsx

Assumption	Value	Source
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 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[13]
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

[13] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/642725/Annex_A.pdf

Assumption	Value	Source
Occupancy and purpose of travel	Occupancies per trip and km travelled and proportion of travel for different purposes	WebTAG Data book[14]
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

2.6.2 Key assumptions

A summary of the key assumptions applied in the analysis is set out in Table 16.

Table 16 – Summary of Key Assumptions

Assumption	Assumption	Source
General – JAQU key assumptions		
Discount Year	2020	JAQU
Price Year	2018	JAQU
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,	Proportion upgrading vehicle as defined by JAQU.	JAQU/SCC

[14] https://www.gov.uk/government/publications/WebTAG-tag-data-book-december-2017

Assumption	Assumption	Source
cancel, change mode, avoid, pay)	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.	
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
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

2.6.3 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 17.

Table 17 – 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).

Impact	Baseline
	For retrofit of buses, it is assumed that the retro-fit (and planned concurrent engine refurbishments) will extend the life of vehicles to 5 years. The CAZ scenario therefore includes the cost of retrofit in 2020, then the cost of an upgraded vehicle in 2025. By comparison, the baseline only includes the cost of the upgraded vehicle which would otherwise happen earlier than 2025 in the absence of retrofit.
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.
Implementation Costs	Operating costs are constant over the full time period of operation of CAZ (i.e. costs are not eroded as under other impacts)

2.6.4 Discounting

As recommended by JAQU, our model uses a 2018 price year as the basis for all calculations. This means that past costs (for example vehicle costs) are inflated to 2018 values using HM Treasury's GDP Deflator series. Any costs projections kept in constant 2018 prices and therefore inflation adjustments are not required.

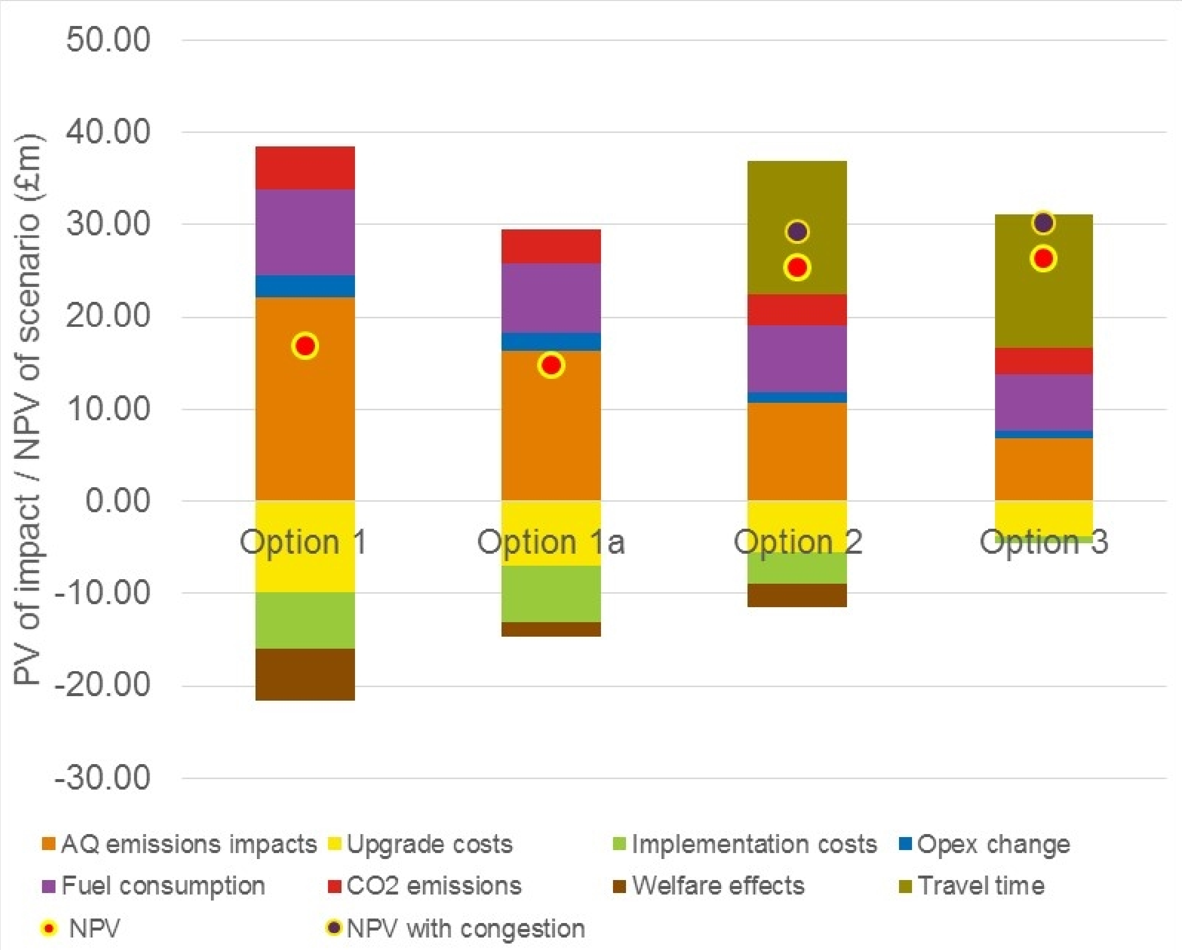
Discounting future costs and benefits takes into account the time preference of society. Discounting is done in accordance with HM Treasury's Green Book guidance. The model applies a discount rate of 3.5% to all impacts, which are discounted back to 2020.

3 Results

3.1 Quantification and valuation of impacts

The results of the economic analysis are presented in Figure 3 and Table 18.

Figure 3 – 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 18 - 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	-6.08	2.32	9.37	4.62	-5.58	0.00	**16.87**	*0.00*
Option 1a (CW CAZ B HGV only)	16.32	-6.99	-6.08	1.99	7.44	3.68	-1.60	0.00	**14.76**	*0.04***
Option 2 (CC CAZ A)	10.78	-5.51	-3.36	1.05	7.14	3.45	-2.56	14.41	**25.42**	*3.86****
Option 3 (non-charging)	6.83	-3.81	-0.83	0.85	6.06	2.92	0.00	14.41	**26.43**	*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.

3.1.1 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[15].

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,

[15] 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 (with the exception of Option 3). These costs are higher for Options 1 and 1a given these contain a larger CAZ area that requires greater infrastructure to signal and enforce the CAZ. However, the ranking of costs has been 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)
- Costs of handling / co-ordinating a greater volume of freight through the SDC that will accrue to the SDC in the first instance, but may be passed onto clients (Options 2 and 3)
- Policy and operating costs of encouraging / adopting / implementing HGV Fleet recognition scheme that will affect the council and operators (Options 2 and 3)
- 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[16]) 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 smaller for Option 2 than Option 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

[16] 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.

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, 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.

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[17].
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[18].

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.

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 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:

3. Response of HGVs (which do not upgrade) to the charging CAZ is produced endogenously in the demand module of the transport model
4. 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.

[17] 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.

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

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.

d) 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.

e) 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.

f) 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 25 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. 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 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).

Table 25: 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 • 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.
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 / manouvering
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.

Qualitative Assessment below).

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 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.

From the CBA an initial ranking of options can be derived:

1. Options 2 and 3 have very similar NPVs – the additional emissions and secondary benefits of Option 2 associated with the city-centre CAZ A are balanced by the additional upgrade, implementation and welfare costs
2. Option 1
3. Option 1a.

3.2 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.

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 19 – 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%	12.4	11.5	23.3	25.1	Option 3
	Central	No change	16.9	14.8	25.4	26.4	Option 3
	High	+20%	21.3	18.0	27.6	27.8	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 20 - 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 21 - 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	11.9	9.9	23.6	24.6	Option 3
	Central	See above	16.9	14.8	25.4	26.4	Option 3

	High	See above	18.6	16.4	26.2	27.1	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 22 – 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	17.0	14.7	25.6	26.4	Option 3
	Central	Calculated	16.9	14.8	25.4	26.4	Option 3
	High	+10%	17.0	15.2	25.3	26.5	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 23 – 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	16.9	14.8	25.4	26.4	Option 3
	Low 1	10% reduction	13.7	12.6	24.0	25.6	Option 3
	Low 2	20% reduction	10.5	10.4	22.5	24.7	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 24 – Ownership profile sensitivity analysis – NPV result (£m 2018 prices)

		Value	Option 1	Option 1a	Option 2	Option 3	Option with highest NPV
Ownership Profile	Central	2	13.8	12.0	24.2	25.4	Option 3
	Low	4	16.9	14.8	25.4	26.4	Option 3
	High	10	26.1	23.1	29.0	29.5	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.

3.3 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:

5. Response of HGVs (which do not upgrade) to the charging CAZ is produced endogenously in the demand module of the transport model
6. 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.

g) 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.

h) 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.

i) 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 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. 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 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).

Table 25 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[19]. 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[20] 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).

Table 25: Delivery risks related to non-charging measures

Measure	Barriers

[19] http://content.tfl.gov.uk/olympic-legacy-freight-report.pdf
[20] http://content.tfl.gov.uk/integrative-freight-demand-management-in-new-york.pdf

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 • 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.
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 / manouvering
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.

3.4 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
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 full mapping of the impacts captured and not captured by the core analysis is included in: Appendix 2 – Mapping of impacts of Core CBA. A qualitative analysis of these impacts across the scenarios is undertaken in Appendix 5 – Qualitative assessment of wider impacts.

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:

- 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, fleet recognition and SDC costs for handling greater freight volumes under Options 2 and 3.
    - In particular the additional costs of using the SDC could be significant. 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. warehouse floor-space, or requirement to expand delivery fleet). Hence the only additional costs (not captured) will be additional administrative, labour and handling costs within the warehouse. However, 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.
- 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).

3.5 Distributional analysis

Social CBA can provide an aggregate comparison of the overall effects of CAZ options. However, this high-level analysis can mask any underlying distributional effects occurring between different groups, and consideration of any complementary measures to mitigate any issues highlighted.

JAQU's 'Option Appraisal Guidance' includes detailed guidance on assessing distributional impacts.

At this stage it has not been possible to undertake detailed quantitative assessment of the distributional impacts. Instead, an initial qualitative assessment has been undertaken to explore the potential effects of the different CAZ options to inform the selection of a preferred option at this stage. The detail of the assessment is set out in: Appendix 4 – Qualitative distributional analysis. A summary of the results for each CAZ option is presented in Table 26.

They key points include:

- All options are likely to deliver improvements in air pollution which will benefit all households, but which are also likely to favour poorer households more so. The largest emission reductions are delivered under Options 1 and 1a. However, it is not possible to determine if one option will deliver a more favourable impact for poorer households than any other at this stage.
- Any direct effect on households of the options is limited given cars are not included within the scope of any CAZ option. There is the potential for indirect negative impacts via impacts on taxi and bus operators, which could disproportionately affect poorer households / households with a disabled member who rely on these services to a greater extent if costs are passed

through. These impacts will be greater for Options 1 and 2 which implement a charging CAZ and capture more vehicles. But these impacts are uncertain and likely small.

- Businesses can be affected by the CAZ and/or non-charging measures through a number of pathways. A key impact will be direct effects where businesses own non-compliant vehicles and travel within/into the CAZ. The extent of impacts will depend on a range of factors, including the availability of complementary support and funding to mitigate any potential adverse impacts.
    - All options are anticipated to have similar impacts on operators of scheduled bus services around the city. Any negative effects have been substantially limited by the confirmation of funding to support retro-fit of non-compliant scheduled buses operating on routes within Southampton. However, there is a regional bus depot in the city with buses accessing the depot but not servicing routes in the city area which will also be affected by a city-wide CAZ, with potential knock-on effects for their owners/local economy.
    - A greater number of taxi operators will be affected by charging CAZ options (1 and 2) given more vehicles will be affected and operators will directly face the costs to comply. Given the typical ownership structure for these vehicles, taxi owners may be more restricted in terms of their ability to cover any upfront costs of responding to the CAZ
    - Impacts on HGV operators will be greatest under Options 1 and 1a, given these affect the largest number of vehicles. Fewer vehicles are anticipated to upgrade under Options 2 and 3, with action targeting those servicing the port or accessing 24 hour delivery opportunities. HGV owners represent a diverse group, hence there will be concerns around the ability of smaller operators to meet any costs of upgrading vehicles to comply with the CAZ. That said, some non-charging measures could be used to mitigate these impacts and may deliver significant additional benefits for freight operators – e.g. the SDC and 24-hour delivery provide savings in driver time, fuel and operating costs.
    - Coach operators will be affected by a charging CAZ, but no non-charging provision has yet been made as part of the CAZ options. Like HGVs, the owners of coaches will likely represent a diverse group, including some smaller operators which may struggle to meet any upfront compliance costs. Furthermore, unlike taxis, coaches are assumed not to undertake a significant proportion of their mileage in Southampton and unlike HGVs no specific, viable alternatives have been identified to help mitigate any negative effects (e.g. SDC)
    - In conclusion, the potential for adverse impacts on businesses (both in terms of size of the impacts and number of businesses affected) are likely to be highest under Option 1 (city wide CAZ B), followed by Option 1a (which still affects a wide range of HGV operators), 2 (some benefits for HGV operators, but coaches and taxis captured by CAZ) and then 3 with the lowest potential effects.
- Noise and accidents are expected to reduce under Options 1 and 1a as a result of reduction in traffic and congestion, spurred as a consequence of the charging CAZ. However, such changes are anticipated to be marginal and significantly smaller than the reductions in traffic and congestion achieved by the non-charging measures for HGVs proposed under Options 2 and 3. These measures could have a significant impact on reduce noise and accidents by removing HGV vehicle kilometres and/or shifting them to a time when there is less traffic and/or pedestrians.
- Following the same pattern as noise and accidents, accessibility through reduced congestion is also likely to be much greater under Options 2 and 3 given the large impacts of non-charging measures, with Options 1 and 1a delivering a much smaller benefit.

Recognising the potential impact on business, the key measure for mitigating these impacts of CAZ compliance on businesses is to exclude certain vehicle classes from a charging CAZ and instead incentivise them using non-charging measures. This has been considered from an early stage of policy development and is illustrated in the construction of the measures – e.g. Option 1a excludes buses from the charging CAZ to avoid capturing those accessing the depot but not servicing routes in the city from the CAZ charges.

However, where vehicle classes are excluded from the charging scheme, this could bring about other issues associated with the non-charging measures. Most prominently, many of the non-charging measures are behavioural, relying on the uptake of incentives by vehicle owners. Hence the estimated savings achieved by these measures are more uncertain, and there are several barriers which need to be overcome before some can be achieved (see discussion on delivery risks above).

In fact, many of the non-charging measures could be implemented alongside the charging CAZ as mitigation measures themselves, for example:

- Freight drivers accessing the SDC would directly avoid the CAZ charge as the SDC is located outside the city-wide boundary
- Delivery service plans (DSPs) can be used to reduce the number of trips entering the CAZ (potentially in co-ordination with the SDC) and also be used to incentivise CAZ compliant vehicles for delivery
- 24-hour delivery could be combined with lower CAZ charges outside peak hours to further incentivise take up and mitigate part of the impact of the CAZ charge (although the structure and levels of charge have yet to be explored in detail).

Doing so would also overcome some of the uncertainty associated with non-charging measures in terms of achieving the estimated savings, by providing an additional incentive for uptake to avoid the CAZ charge.

Table 26 – Summary of qualitative distributional analysis

Impact	City wide CAZ B (1)	City Wide HGV only (1a)	City Centre CAZ A (2)	Non-charging (3)
Air quality	✓✓ Air pollutant reductions more disperse than City Centre CAZ, most significant reduction seem to be in M27 junction north of the centre where households generally higher on IMD. In addition, reductions also in city centre where households are generally lower on IMD.	✓✓ Air pollutant reductions more disperse than City Centre CAZ, most significant reduction seem to be in M27 junction north of the centre where households generally higher on IMD. In addition, reductions also in city centre where households are generally lower on IMD.	✓✓ Focus of reductions in air pollution will be in/around city centre, where households are generally lower on IMD.	✓✓ Focus of reductions in air pollution will be in/around city centre, where households are generally lower on IMD.
Affordability (households)	× Potential small, indirect impact likely to disproportionately affect poorer households / households with a disabled member through bus/taxi firms passing on costs, with greater effects through greater number of taxis affected	× Potential small, indirect impact likely to disproportionately affect poorer households / households with a disabled member through bus/taxi firms passing on costs.	× Potential small, indirect impact likely to disproportionately affect poorer households / households with a disabled member through bus/taxi firms passing on costs, with greater effects through greater number of taxis affected	× Potential small, indirect impact likely to disproportionately affect poorer households / households with a disabled member through bus/taxi firms passing on costs.
Affordability (businesses)	×× Largest area so greatest number of businesses potentially affected; places cost on large number of HGV and coach operators; Buses using depot but operating routes outside Soton affected; Taxis affected potentially not covered by incentive.	×× Largest area so greatest number of businesses potentially affected; places cost on large number of HGV operators	×× Smaller CAZ area so lower number of businesses affected; taxis affected potentially not covered by incentive; places cost on some HGV operators (accessing port/24 hour opportunities), but also delivers large benefits; places cost on some coach operators	× No CAZ charge area so fewer firms directly/indirectly affected; places cost on some HGV operators (accessing port/24 hour opportunities) but also delivers large benefits
Traffic impacts - *noise, accidents*	✓ Reduction in noise and accidents due to less HGVs, coaches and taxis on the road (those cancelling/avoiding).	✓ Reduction in noise and accidents due to less HGVs on the road (those cancelling/avoiding).	✓✓ Non-charging measures will reduce vehicle kilometres and/or shift them to a time when there are less other traffic – this will reduce noise and accidents. There could be a localised increase in noise around the distribution centre but this is expected to be small.	✓✓ Non-charging measures will reduce vehicle kilometres and/or shift them to a time when there are less other traffic – this will reduce noise and accidents. There could be a localised increase in noise around the distribution centre but this is expected to be small.
Traffic impacts - *congestion (accessibility)*	✓ Small reduction in HGV, coach and taxi traffic improving the accessibility for other road users	✓ Small reduction in HGV traffic improving the accessibility for other road users	✓✓ Improvement in congestion and therefore accessibility through a reduction vehicle kilometres and/or shifting them to a time when there are less other traffic. Some taxis/coaches cancel trips improving congestion for other traffic users but decreasing accessibility for those users who depend on these traffic modes.	✓✓ Improvement in congestion and therefore accessibility through a reduction vehicle kilometres and/or shifting them to a time when there are less other traffic. Some

3.6 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 27 and Table 28. 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.

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[21]. This is predominantly driven by Option 1 and 1a capturing HGVs within a charging CAZ, 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. This air pollution impact is likely to fall to a greater extent on poorer households as emissions reductions are likely to be greatest in and around the city centre, which tend to score lower on the IMD.

A key question feeding into the selection of a preferred option is the impact on air pollutant concentrations and achievement of legal limits – 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.

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

In addition, Options 1 and 1a also imply a higher **implementation cost** given they propose a much larger CAZ area than Option 2 (and Option 3 does not include a CAZ charging area at all). 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 many of these in the quantitative analysis and many are not deemed likely to be sufficiently large enough to change the ranking of options. That said, 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) 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 which have been

[21] 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.

explored through the distributional analysis. Assuming that the changes in traffic follow the same pattern as changes in concentration, these changes in noise, accidents and accessibility could also predominantly favour poorer households (although attention would have to be paid to the area immediately surrounding the SDC).

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.

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.

All options will have an impact on businesses through the costs of complying with the CAZ. But 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.

The key measure for mitigating the impacts of CAZ compliance on businesses is to exclude certain vehicle classes from a charging CAZ and instead incentivise them using non-charging measures. This is illustrated in the construction of the measures.

In fact, many of the non-charging measures could be implemented alongside the charging CAZ as mitigation measures themselves, for example:

- Freight drivers accessing the SDC would directly avoid the CAZ charge as the SDC is located outside the city-wide boundary
- Delivery and service plans (DSPs) can be used to reduce the number of trips entering the CAZ and to incentivise CAZ compliant vehicles for delivery
- 24-hour delivery could be combined with lower CAZ charges outside peak hours to further incentivise take up and mitigate part of the impact of the CAZ charge.

Doing so would also overcome some of the uncertainty associated with non-charging measures in terms of achieving the estimated savings.

Table 27 – Options summary

Option	Rationale
Option 1	• Positive NPV – delivers largest air pollutant emission reductions with largest costs • 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) – delivers large air pollutant emission reductions with large upgrade and implementation costs, but does not capture wider travel time benefits of HGV non-charging measures • Large impact on HGV operators, but mitigates negative impact on taxi and coach operators • 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 – 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 • Smaller implementation costs given smaller CAZ area, but not all costs of non-charging measures have been captured, in particular increased handling of freight through SDC • Smaller impact on HGV operators, 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 • Potential risk around deliverability of identifying taxis under charging CAZ in absence of national database
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 • Smallest implementation costs but not all costs of non-charging measures have been captured, in particular increased handling of freight through SDC • 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. Several barriers exist to implementing and delivering savings through these measures, creating high risk around achievement of air quality limits in shortest possible time

Table 28 – Summary assessment of options

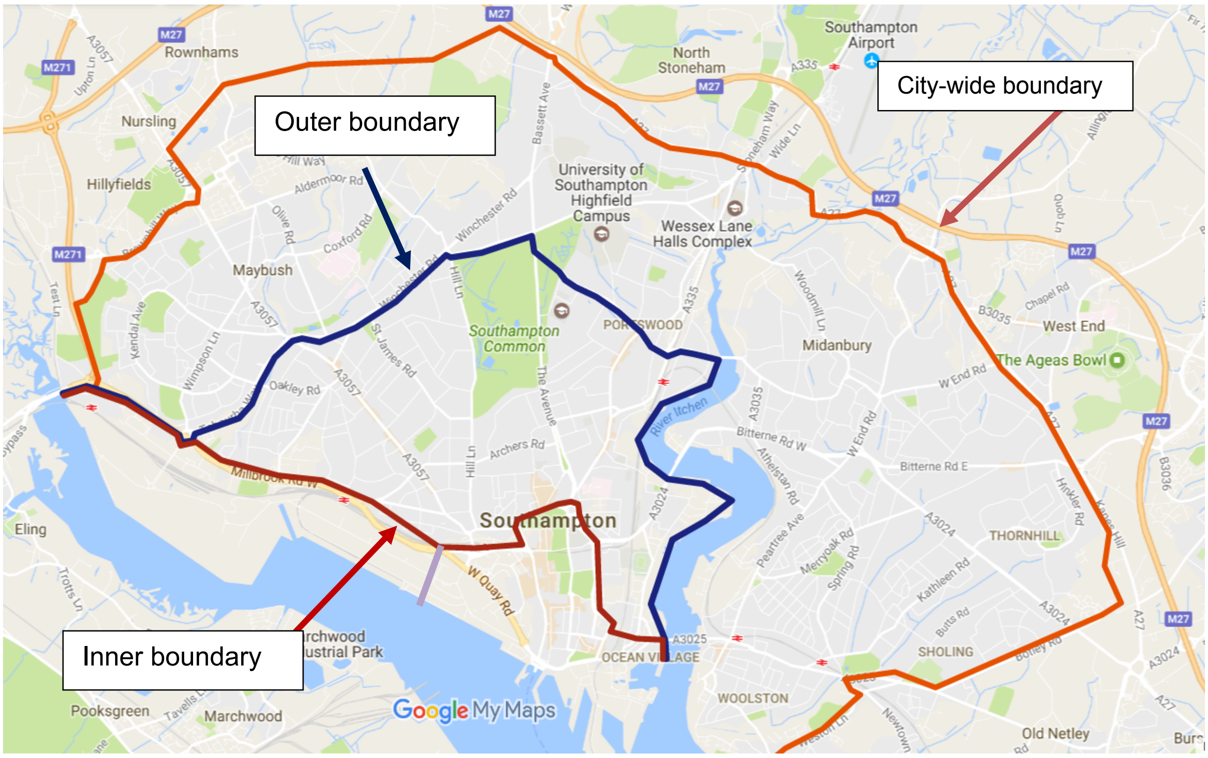
Option	Cost-benefit analysis				Delivery risk	Qualitative analysis	Distributional impacts
	Air quality impact	Costs		Other impacts			
		Vehicle upgrade	Implementation costs				
Option 1 (CW CAZ B)	✓✓ Larger reduction in Nox emissions (incl. impact on coaches)	×× Larger upgrade costs (4,500 vehicles upgraded)	×× High implementation costs associated with largest CAZ area	✓ Larger fuel/opex/GHG savings	✓ Lower risk as CAZ provides immediate incentive, although inertia may still delay take up. Plus potential issue identifying taxis	✓ Larger AQ emission reductions outside domain × Larger transaction costs from vehicle upgrades	×× Largest impact on businesses in absence of mitigation measures ✓ Smaller benefits in noise, accidents and congestions
Option 1a (CW CAZ B HGV only)	✓✓ Large reduction in Nox emissions	×× Moderate upgrade costs (3,500 vehicles upgraded)	×× High implementation costs associated with largest CAZ area	✓ Large fuel/opex/GHG savings	✓✓ Lowest risk as CAZ provides immediate incentive for HGVs (but inertia). Taxi / bus incentives could be timed pre 2020	✓ Larger AQ emission reductions outside domain × Larger transaction costs from vehicle upgrades	×× Large impact on businesses, but impacts on taxis and coach operators mitigated (relative to 1) ✓ Smaller benefits in noise, accidents and congestions
Option 2 (CC CAZ A)	✓ Moderate reduction in Nox emissions (incl. impact on coaches)	× Moderate upgrade costs (2,000 vehicles upgraded)	× Smaller (quantified) implementation costs associated with smaller CAZ area	✓✓ Smaller fuel/opex/GHG savings, but large congestion/time savings from SDC/24 hour delivery	×× Highest delivery risk – uncertainty around uptake / timing of non-charging measures, in particular HGV. CAZ A provides immediate incentive but inertia. Plus potential issue identifying taxis	✓ Smaller AQ emission reductions outside domain, but larger fuel/ opex/ GHG/ noise/ accident benefits through non-charging measures × Smaller transaction costs from vehicle upgrades, but additional costs of non-charging measures and noise through 24-hour delivery	×× Large impacts on businesses, including taxis and coaches. But some benefits for HGV operators ✓✓ Larger benefits in noise, accidents and congestions through HGV non-charging measures
Option 3 (non-charging)	✓ Smallest reduction in Nox emissions	× Smallest upgrade costs (1,500 vehicles upgraded)	× Smallest (quantified) implementation costs as no CAZ charging area	✓✓ Smaller fuel/opex/GHG savings, but large congestion/time savings from SDC/24 hour delivery	× High delivery risk – uncertainty around uptake / timing of non-charging measures, in particular HGV. Taxi / bus incentives could be timed pre 2020	✓ Smaller AQ emission reductions outside domain, but larger fuel/ opex/ GHG/ noise/ accident benefits through non-charging measures × Smaller transaction costs from vehicle upgrades, but additional costs of non-charging measures and noise through 24-hour delivery	× Fewer businesses directly affected, with benefits for some HGV operators ✓✓ Larger benefits in noise, accidents and congestions through HGV non-charging measures

Note: *Compliance and local traffic effects are key considerations in comparison between options. These are not (directly) assessed in economic analysis (air quality impacts are assessed in terms of emissions, rather than concentrations and traffic effects are modelled in aggregate) and will feed in directly from SCC modelling

Appendices

Appendix 1 – Maps of proposed CAZ areas

Figure 4 – 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 – Mapping of impacts of Core CBA

	Pay charge	Cancel	Avoid	Mode shift	Upgrade	Upgrade	Non-charging measures
					Scrap & new	Sell & replace	
AQ	NA	✓	✓	✓	✓	✓	✓
CO2 emissions	NA	✗	✗	✗	✓	✓	✓/ ✗
Travel time / congestion	NA	✗ (?)	✗ (?)	✗ (?)	NA	NA	✓/ ✗
Upgrade costs	NA	NA	NA	NA	✓	✓	✓
Opex/maintenance	NA	✗ (?)	✗ (?)	✗ (?)	✓	✓	✓/ ✗
Fuel cost	NA	✗ (?)	✗ (?)	✗ (?)	✓	✓	✓/ ✗
Transaction cost	NA	NA	NA	NA	✗	✗	✗
Scrappage cost	NA	NA	NA	NA	✓	✓	✓
Welfare loss	NA	✓	✓	✓	✗	✗	NA
Charge cost	✓	NA	NA	NA	NA	NA	NA
Noise / accidents / infra	NA	✗	✗	✗	NA	NA	✗
Active travel	NA	NA	NA	NA	NA	NA	NA
Implementation costs	✓	✓	✓	✓	✓	✓	✓/ ✗

Note: Tick denotes impact modelled; NA denotes impact not applicable; cross denotes impact unable to be modelled; (?) denotes where impact may be captured (at least partially) through another impact – welfare effect; where both a tick and a cross are displayed, this shows that some impacts are captured, but some are not

Appendix 3 – Methodology summary (OBC)

Overview of approach and key assumptions

This section provides an overview of our approach to the economic analysis. A methodology paper is provided in the Annex of the OBC that provides a more detailed guide to the analysis.

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

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

The analysis is also underpinned by the following general assumptions:

- Each impact associated with each CAZ option is assessed relative to a 'do nothing' baseline
- 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 Green Book discount factor of 3.5%.

The methodology developed has been designed to be consistent with the JAQU guidance. However, in some cases we have sought alternative methods, additional steps, and assumptions where the study team felt that additional approaches were warranted.

Scenarios

The options assessed as part of the OBC are set out in Table 29.

Table 29 – Short-listed CAZ options assessed

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 • HGV action complemented with 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.
	• Charging CAZ complemented with non-charging measures for HGVs:
	  ○ 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

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

Scope of impacts assessed

A CAZ will impact various 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. The scope of impacts considered in this analysis are:

- **Upgrade costs** – the impact on those vehicle 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, or retrofitting an existing non-compliant vehicle so it achieves compliance. This encompasses the vehicle scrappage cost and the consumer welfare impact as described in the JAQU guidance.
- **Air quality emissions** – the impact on affected populations by a change in NOx and PM emissions as a result of CAZ implementation. Calculating the economic impact is dependent on the output of air quality and transport models which provide air quality outputs for the baseline and CAZ options for NOx and $PM_{2.5}$. The marginal impact on air pollution of each CAZ option has been calculated (in tonnes of pollutant) and combined with the air pollution damage costs provided by JAQU, which convert emission concentrations into monetised health impacts, to estimate the total benefit (in damage costs saved) for each CAZ option. Illustrative runs of the EfT have been undertaken to demonstrate the potential importance of impacts on coach emissions which are not included in the core modelling
- **Fuel savings / Greenhouse Gas impacts** - vehicle owners which upgrade vehicles will have an impact on fuel consumption and in turn on the emissions of GHG's. In addition, many of the non-charging measures will also impact on fuel consumption in different ways (e.g. through reduction in HGV vkm associated with the SDC). The marginal impact of CAZ options has been calculated for upgraded vehicles and valued using BEIS fuel costs and carbon prices as specified by JAQU.
- **Operating cost impacts** – those savings or additional costs that can result from CAZ implementation, associated with vehicle upgrades and the effects of non-charging measures.
- **Travel time /congestion impacts** – the impact of the CAZ on traffic flow and the subsequent costs or benefits experienced by affected populations. Where vehicle owners cancel journeys or avoid the zone, this can lead to changes in traffic and congestion within the zone. For charging CAZ options, trip and trip time data has been provided by the Transport modelling. In addition, many of the non-charging measures have a impact on travel time -e.g.the SDC will impact directly through reduction in driving time for freight drivers, and will have a wider indirect impact on other road users through a reduction in HGVs on city centre roads. DfT's WebTAG guidance has been applied to monetise any benefit from reduced congestion.
- **Welfare Costs** – Where vehicle users avoid the charging zone, cancel journeys or switch mode, 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. This is valued as half the charge to reflect the welfare loss associated with the CAZ.
- **Implementation costs** - Alongside costs to vehicle owners, there will also be costs for monitoring and enforcement for the implementing authority, and/or for businesses in and around Southampton (e.g. port booking system will require input from the port, and likewise uptake of the SDC will require scoping and implementation no behalf of delivery firms, freight recipients and the SDC).

The general approach to calculating economic impacts is as follows:

Total Economic Impact = Volume x Unit Economic Value

For example, in the case of air pollutant emissions, volume can be tonnes of NOx or Vehicle and associated economic values are Damage Costs per tonne of NOx or Values of Time.

A list of detailed assumptions and data sources is included in Table 30.

Table 30 – Key calculations and data sources

Impact	Volume	Unit economic values
Air Quality Emissions	Output of air quality modelling for each option, utilising the EfT toolkit	$PM_{2.5}$ and NOx damage costs provided by JAQU
GHG Emissions	Combining numbers of vehicles upgraded, average vkm travelled per annum with average emissions factors per km travelled For non-charging measures estimates of change in vkm are a direct input assumption to the modelling	BEIS Carbon Prices
Traffic Flow Improvements	Outputs from transport models for each option For non-charging measures estimates of change in vkm are a direct input assumption to the modelling	Values of time provided by WebTAG databook
Fuel/ maintenance cost	Change in vehicle fleet defined by SCC ANPR, taxi and bus fleet data combined with transport model outputs. Combined with average vkm travelled per annum and average fuel consumption per km	Fuel prices provided by BEIS Fuel consumption provided by WebTAG databook
Welfare loss	Analysis of ANPR data on number and frequency of unique vehicles accessing CAZ per week, scaled up to year	Half the CAZ charge as defined by JAQU
Costs associated with fleet change	SCC ANPR, taxi and bus fleet data and JAQU behavioural responses to define number of non-compliant vehicles upgraded	Vehicle Prices and depreciation rates from JAQU guidance
Implementation Costs	Labour and equipment required	Unit costs for labour, monitoring equipment etc

Appendix 4 – Qualitative distributional analysis

Introduction

The cost-benefit analysis described in this report provides insight on the aggregate impacts to society. However, it does not tell us how these impacts are distributed within the society. Distributional impact analysis seeks to explore whether any particular group is disproportionally affected by the proposed options. Following WebTAG guidance, distributional impact analysis is undertaken from the point of view of 'grouping variables' (the variable that is used to define different groups such as household income or business size) and impact variables (variables that changes as a result of the policy, such as air quality or affordability)[22].

Distributional impact analysis includes three key stages: screening, assessment and appraisal, which are discussed below. At this stage, it has not been possible to undertake detailed quantitative assessment of the distributional impacts. Instead, we have undertaken an initial qualitative assessment to explore the potential effects of the different CAZ options. The qualitative analysis follows the guidance and principles provided by the Joint Air Quality Unit (JAQU) Appraisal Guidance and DfT WebTAG Guidance on Distributional Impact Analysis[23]. The key deviation is that while the JAQU guidance suggests to include impacts on businesses, Web Tag Guidance A4.2 only considers distributional impacts between different socio-economic and demographic groups (income quintiles, children, elderly etc.).

The distributional analysis covers all options included in the short-list of options. In the absence of further quantitative data on income distribution and demographic data by Lower Level Super Output Area (LSOA), we provide a narrative on the likely distributional impacts focusing on the key outputs from the transport, air quality and economic modelling. It is important to note that the transport modelling was only completed for option 1 limiting the opportunities for detailed distributional impact analysis.

Step 1: Screening

An initial screening has been completed based on the list of impacts listed in the WebTAG A4.2 taking into account the likely local issues of the proposed options. A summary of the screening is included in Table 32 below.

The following effects have been 'scoped-in':

1. Air quality - changes in concentrations of NO_2
2. Affordability – including user benefits, considering both residents and local businesses
3. Traffic impacts – including changes noise and safety/accidents through changes in traffic flows; and accessibility impacts through changes in congestion/journey times.

Accessibility impacts have been included as part of a wider 'traffic impacts' category given:

- The key impact of charging CAZ will be financial, rather than placing physical barriers to travel. Hence, the majority of impacts will fall under affordability.
- There are no proposed changes to public transport provision (other than to upgrade vehicles), hence there will be no impacts as described in WebTAG A4.2 (mainly public transport accessibility aspect of accessing employment, services and social networks through changes in the provision of public transport services).
- Given the predominant response to CAZ is to upgrade or pay charge, and there is low number of 'cancelled journeys', there is likely to be low impact on provision of general services (such as shops, nurseries etc.) through changes in demand.
- The only additional accessibility impact (on top of those captured by affordability analysis) may be on travel time to particular amenities through congestion impacts.

[22] Joint Air Quality Committee: Guidance on Options Appraisal
[23] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/638644/TAG_unit_a4.2_distrib_imp_app_dec2015.pdf

Considering the points above, we propose a relatively light-touch approach to assess the accessibility impacts.

The feasibility study has also included a group of non-charging measures (bus traffic condition, taxi incentives, freight DSP and consolidation centre, preferred Port-booking system and 24-hour delivery). Again, these measures are not expected to change the provision of public transport or the availability of local taxis (because vehicles are expected to predominantly upgrade as a result) or to be designed in a way that mitigates any impact. Some of the measures that provide incentives to upgrade HGVs may have in impact on local noise (such as night time deliveries) but this will be covered in wider traffic impacts and do not warrant to be included as an impact of its own accord.

Step 2: Assessment

The assessment draws on qualitative analysis supported by limited amount of quantitative inputs. Additional data such as on demographic characteristics are not available to produce detailed spatial mapping of characteristics at this stage.

The spatial scope of this initial qualitative assessment of impacts focuses on Southampton city boundary and the domain of the air quality emissions modelling. However, the illustration of impacts could apply to areas outside this domain where a significant proportion of traffic travelling to the CAZ areas originates outside this boundary.

The CAZ is expected to be implemented in 2020, which will also be the first year of effects. The effects will then tail-off as the baseline fleet catches up with that under the CAZ scenario. For clarity, the reference period for the distributional effects is the same as that for the core CBA: i.e. a 10-year appraisal period from 2020-2030.

The coverage of impact categories and grouping characteristics is shown in Table 31 below.

Table 31 - Mapping of impact categories and grouping characteristics covered by distributional analysis

Group	Air quality	Affordability	Traffic impacts
Deprivation / income	✓	✓	✓
Children	✓		✓
Old people			✓
Disability			✓
Sex			✓
Ethnicity			✓
Businesses		✓	

Table 32 - Screening of distributional impacts

Impact	Description of impact	Screening assessment	Include in detailed analysis?
User benefits	• changes in travel time; • changes in user charges, including fares, tariffs and tolls; and • changes in vehicle operating costs met by the user (i.e. for private transport).	• There will be a distributional impact, (in some cases positive) • Given these are financial costs, there is an overlap with affordability	Yes – group under affordability
Noise	Changes in noise levels – move in line with traffic on roads	• Possible distributional impacts where large changes in traffic on individual links. • Night-time deliveries could increase noise levels locally	Yes – group under wider 'traffic impacts'
Accidents	Changes in accident rates – move in line with traffic / speed on roads	• Possible distributional impacts where large changes in traffic on individual links	Yes – group under wider 'traffic impacts'
Air quality	Change in emissions	• Will have varying impact between areas	Yes
Security	Any change in public transport waiting/interchange facilities including pedestrian access expected to affect user perceptions of personal security.	• Charging CAZ will not impact on security. Could be an impact if indirect impact on public transport provision. • Non-charging measures: Night-time deliveries could affect the security of the delivery personnel and those receiving the deliveries. However, the WebTAG description of the security impact focuses on public transport. Therefore, we will not include this in the distributional impact assessment but make a note that there may be an additional occupational risk that the companies need to consider.	No
Severance	Introduction or removal of barriers to pedestrian movement, either through changes to road crossing provision, or through introduction of new public transport or road corridors.	• CAZ will not impact on physical road crossings. The non-charging measures are not expected to introduce new road corridors.	No

Accessibility	• Changes in routings or timings of current public transport services, any changes to public transport provision, including routing, frequencies, waiting facilities (bus stops / rail stations) and rolling stock, or any indirect impacts on accessibility to services (e.g. demolition & re-location of a school).
	• Accessibility impacts should consider changes in services, routings or timings of current public transport services within the impact area.
		• Charging CAZ will not put up physical barriers which will impact on access to services
		• Charging CAZ does not plan to remove / change public transport services,
		  • Only placing additional costs on vehicle users – so any accessibility impacts of charging CAZ will overlap with affordability
		  • CAZ proposes no change to services / locations, only change is upgrade to buses,
		  • As long as same provision for wheelchairs / low floors
		• Only additional and significant impact could be through changes in congestion, which impact on travel time to amenities
			Yes – group congestion impact under 'traffic impacts'

Affordability		Charging CAZ will have significant impact on costs, which will vary by vehicle ownership. However, SCC is not considering CAZ D (i.e. inclusion of cars) which potentially has the greatest distributional impact for households.	Yes

Step 3: Appraisal

Air quality

The primary impact of the CAZ will be to reduce air pollutant emissions. Given there will be a spatial variation in where these emission reductions occur, there is the potential for a distributional effect between different groups. The distributional impact will depend on location of the emissions reductions and consequent changes in concentrations, and proximity to different groups, in particular, households at different points on the Index of Multiple Deprivation (IMD) and which have children.

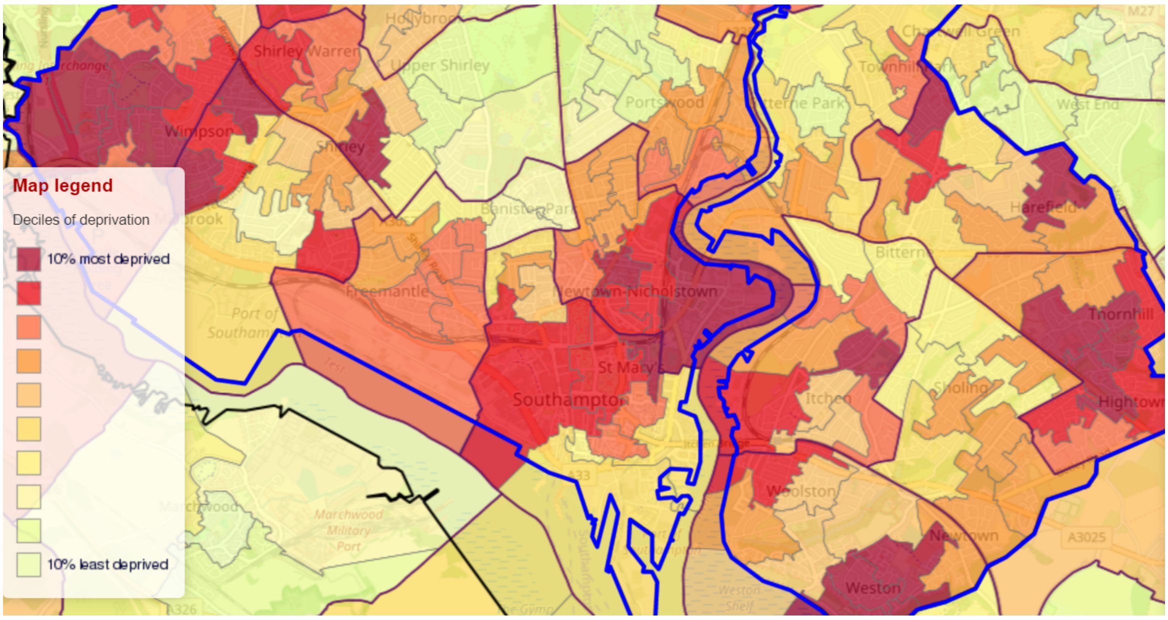
Figure 5 and Figure 6 show plots of the average IMD for Lower Super Output Areas (LSOA) in and around Southampton. These maps suggest that there is a high concentration of LSOA low on the IMD (i.e. with relative poorer households) around the centre of Southampton and out to the West/North-West and East of the centre.

The maps demonstrating the NOx concentrations as a result of different policy options suggest that Options 1 and 1a deliver the greatest reductions in concentrations compared to the baseline (an average 6% across the links) whereas options 2 and 3 deliver similar reduction, an average 3% across the links. Further the majority if not all links show decreases in concentrations, meaning it is likely that all households will benefit from the implementation of the CAZ through the general emissions reductions achieved.

Reductions in air pollution for all options are likely to be largest in the city centre. This is particularly the case for the city centre options and non-charging measures where the city centre (e.g. area bounded by the A3024) is the focus of the policies, but this is also where there will be high levels of traffic. Other areas of high impact will be on key links which also exhibit high traffic levels – in particular the Western Approach / port link (A33 and A35) and orbital motorway (M27). There will also be impacts on concentrations in other areas of the city, but potentially less so.

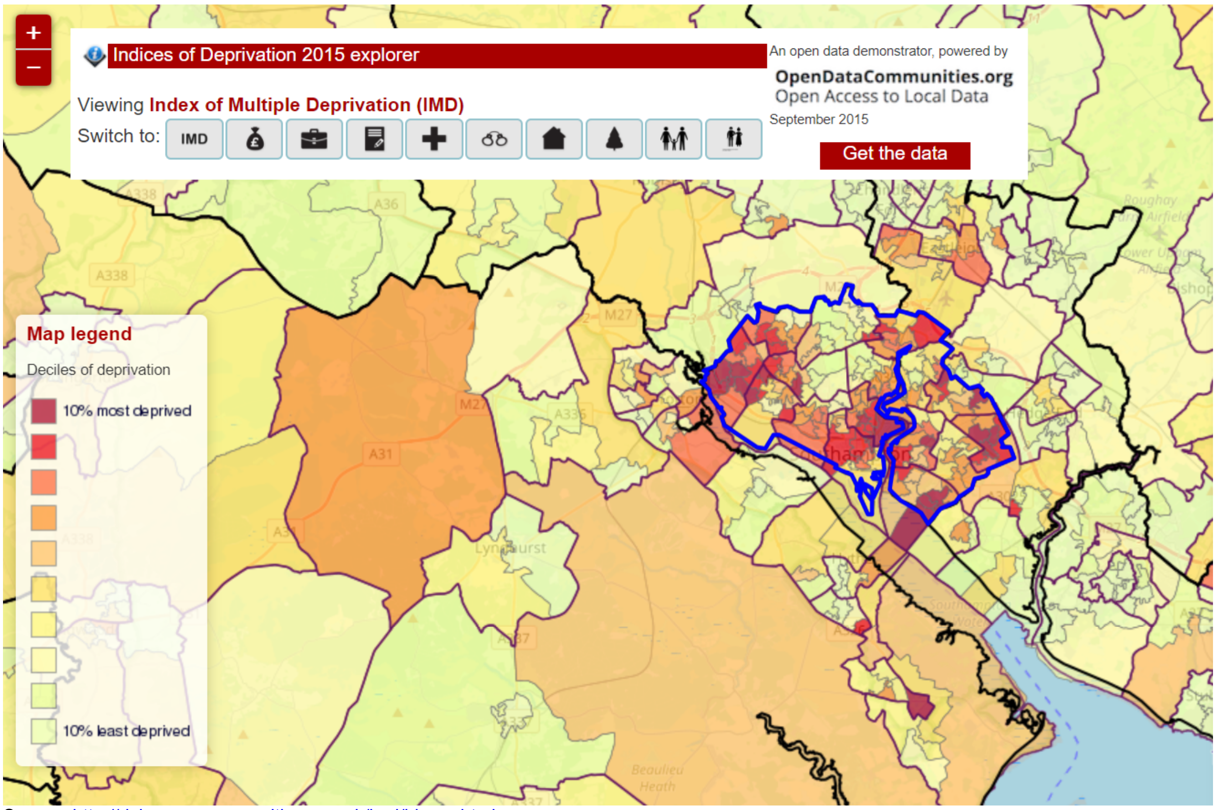
This is demonstrated by the maps presented in Figure 7, Figure 8, Figure 9, and Figure 10 which show that greater reductions (and corresponding concentration reductions) are achieved in the centre. The emission reductions are strong around the Southampton Central Station, Hoglands Park and A3024 Roundabout north-east of East Park, and on/around the Redbridge road roundabout. Further Options 1 and 1a also deliver large reductions around the M27 junction to the north of the city. Comparing these locations to the IMD plots, these tend to be associated with households lower on the IMD. Therefore all options could also have a bigger benefit for poorer households. However, it is difficult to conclude whether any option will be more progressive than any other in this respect, as impacts for these key links across different LSOA appear to move in step between the options.

Figure 5 - Plot of IMD at LSOA scale in Southampton city centre



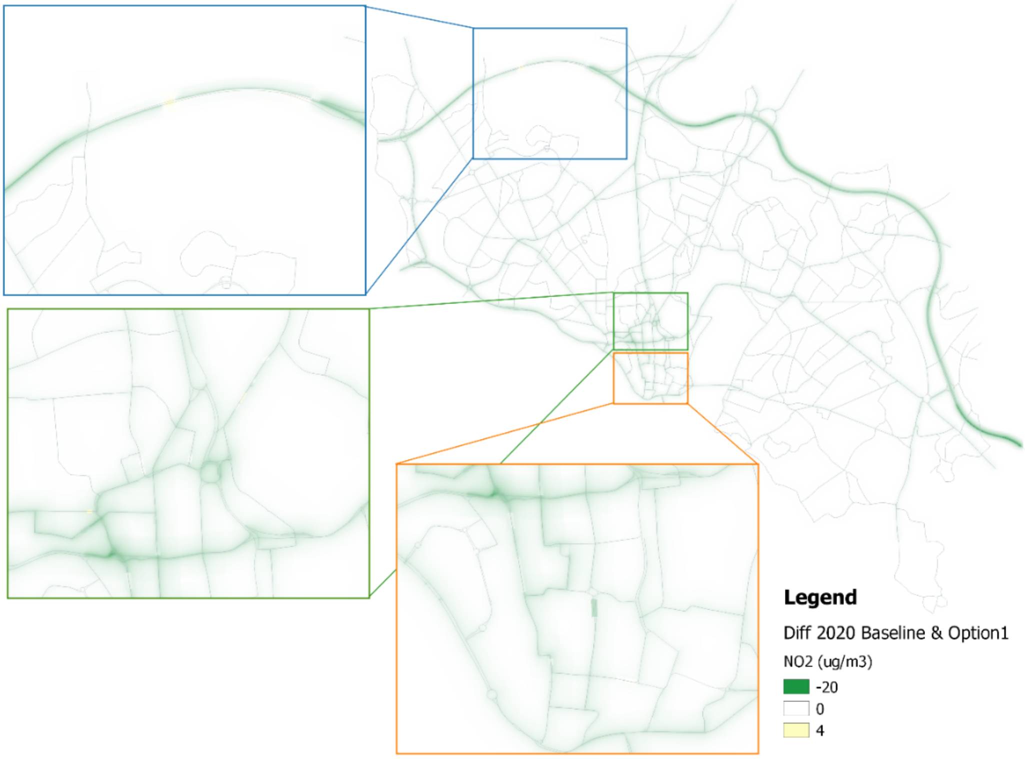
Source: http://dclgapps.communities.gov.uk/imd/idmap.html

Figure 6 - Plot of IMD at LSOA level for Southampton area



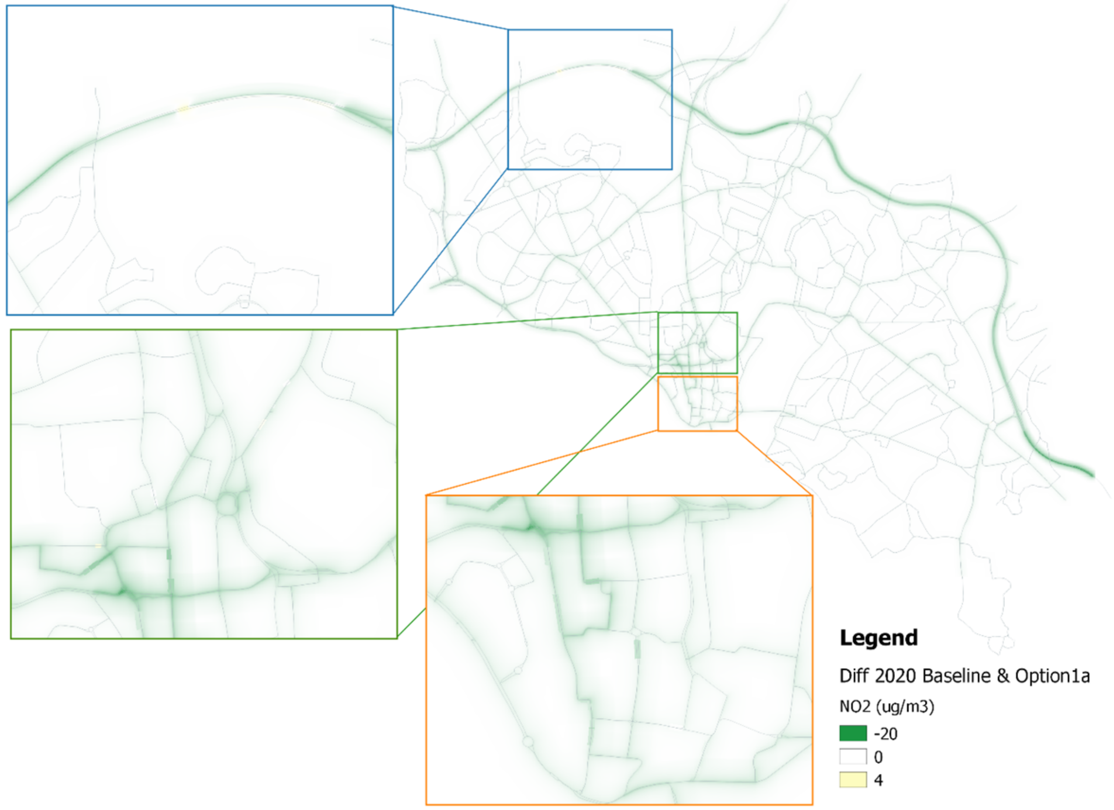
Source: http://dclgapps.communities.gov.uk/imd/idmap.html

Figure 7 - NO_2 emission reductions compared to the baseline, Option 1



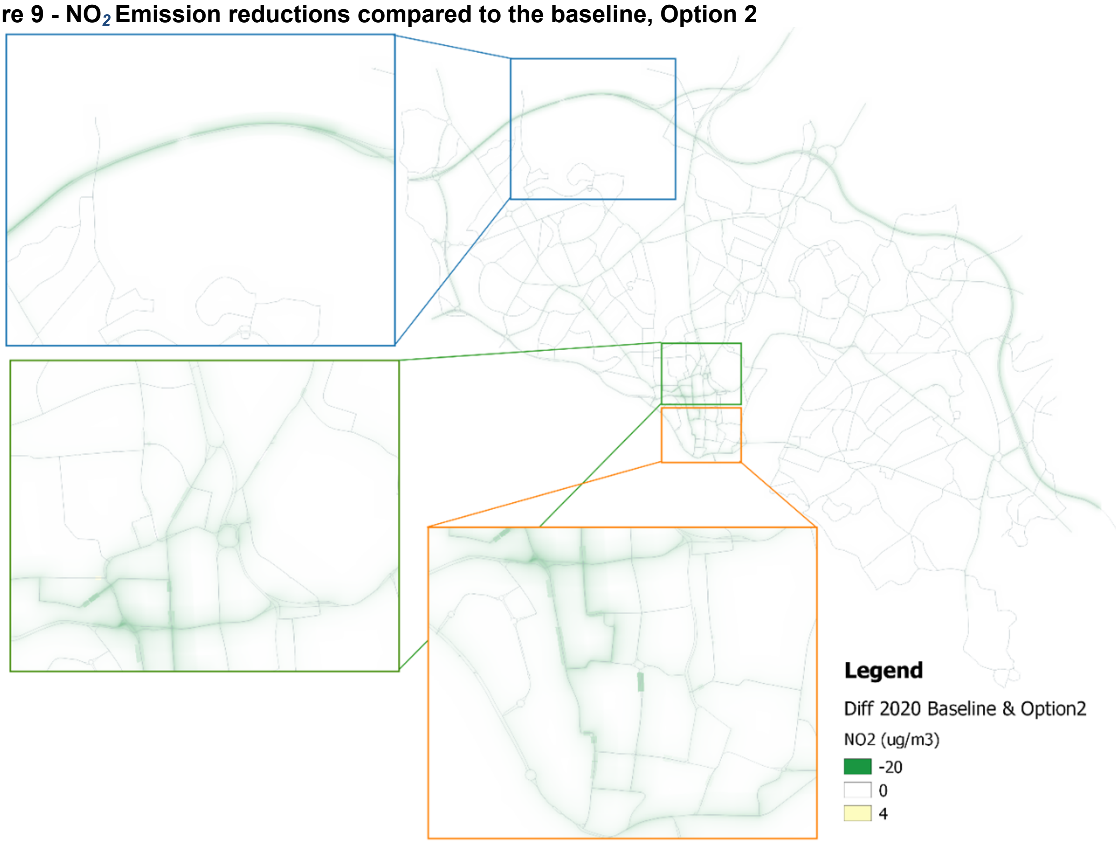
Source: Ricardo modelling

Figure 8 - NO2 emission reductions compared to the baseline, Option 1a



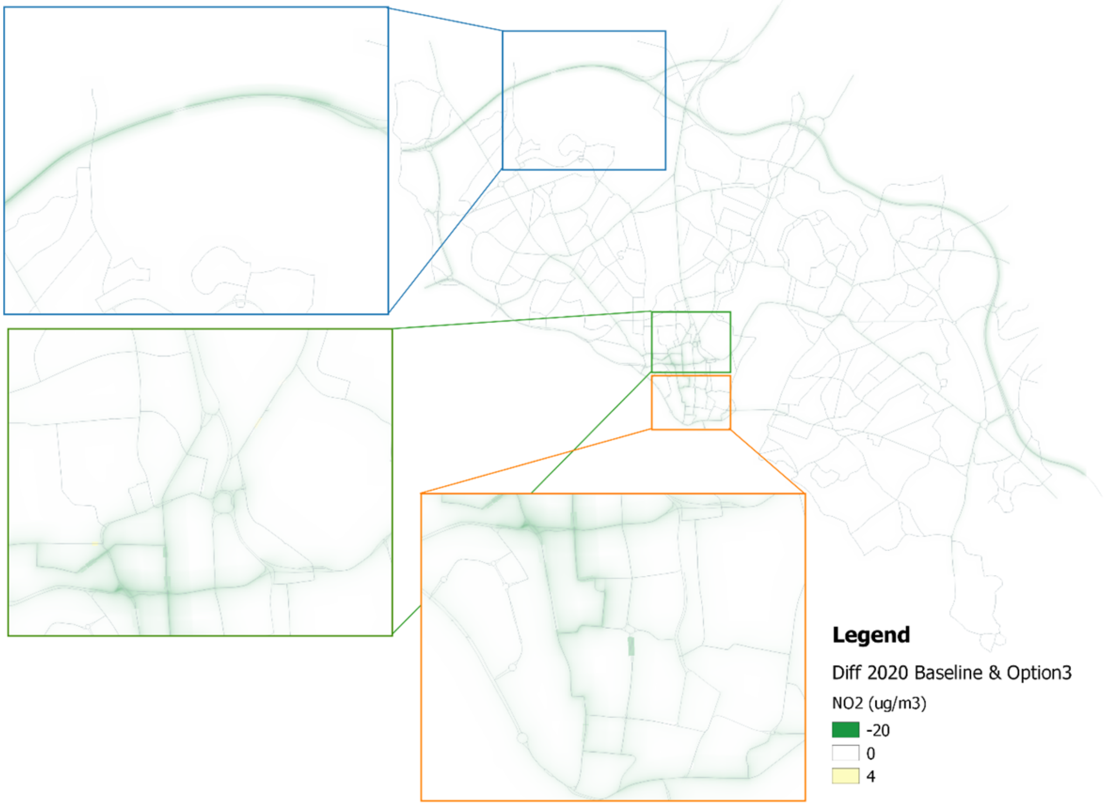
Source: Ricardo modelling

Figure 9 - NO_2 Emission reductions compared to the baseline, Option 2



Source: Ricardo modelling

Figure 10 - NO_2 Emission reductions compared to the baseline, Option 3



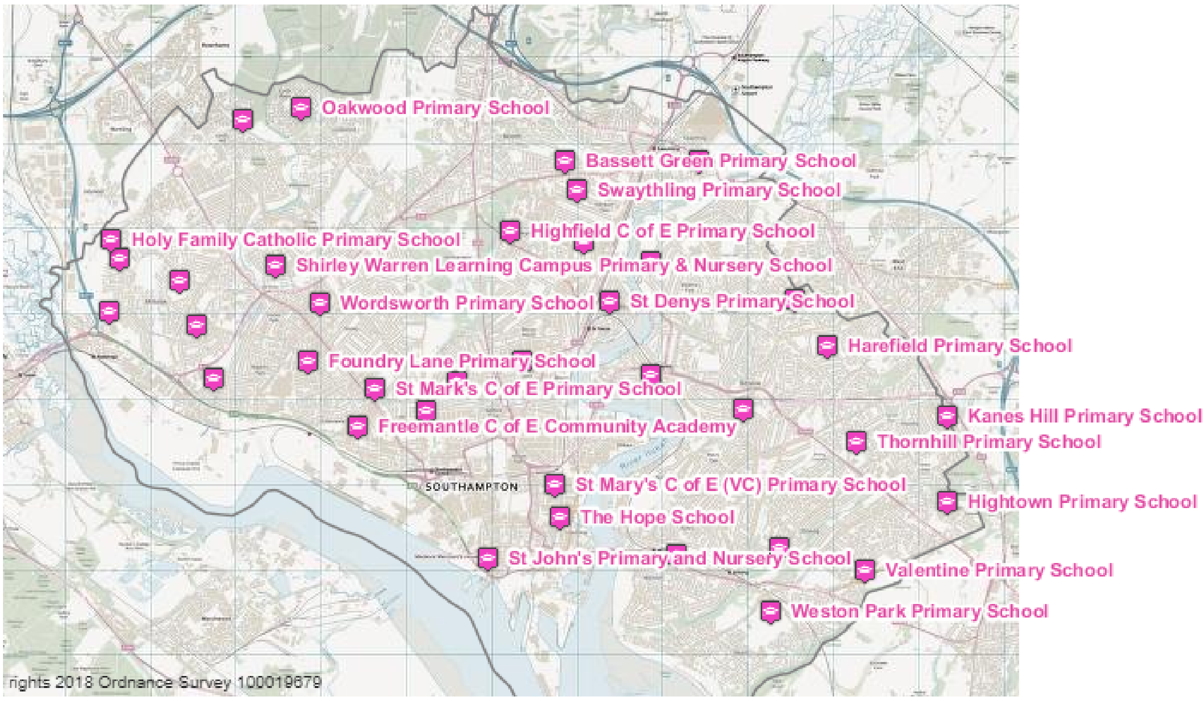
Source: Ricardo modelling

Less data is available with which to assess the impacts on households with children.

A map of the location of primary schools in Southampton in Figure 11 suggests that primary schools are relatively evenly scattered around the city without any particular concentration in the centre. Therefore, it is reasonable to assume that families with children are likely to benefit the most from options that deliver the highest emission reductions, alongside households without children. However, any distributional impact in favour of households with children will critically depend on where children reside, which can only be fully explored with quantitative data, but looks unlikely from this qualitative assessment.

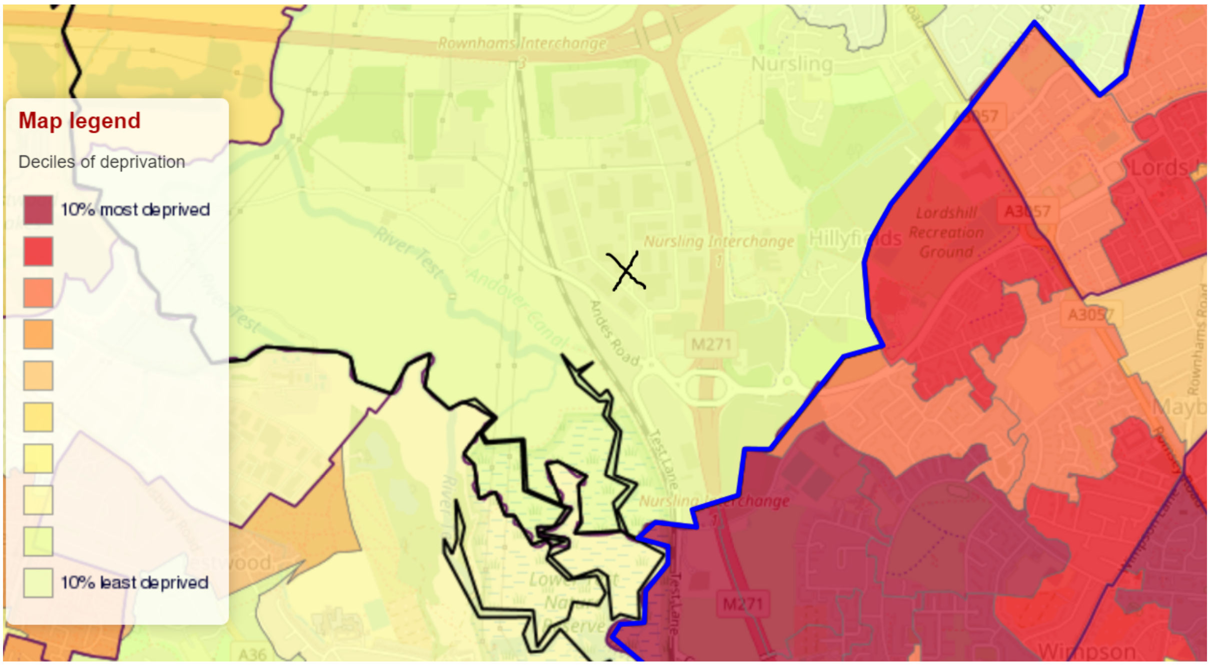
One non-charging measure requiring further consideration is the increased use of the SDC (included in Options 2 and 3). The SDC is located in Nursling Industrial Estate is just north of a LSOA with households low on the IMD (see Figure 12 below). Therefore, any increase in traffic locally in this area (i.e. through increased inbound freight dropping off at the SDC or outbound SDC operated vehicles) could disproportionally affect poorer households. However, this impact will be limited to the extent re-routing freight elects to use the motorway as the key means of accessing the SDC, and likewise SDC operated freight using the motorway and western approach to access the city which will reduce somewhat the impact on air quality in the area.

Figure 11 - Location of primary schools in Southampton



Source: https://www.southampton.gov.uk/whereilive/mapsouthampton.aspx

Figure 12 - Plot of IMD at LSOA around the consolidation centre at the Nursling Industrial Estate (see the X on figure represents the location of the centre).



Affordability, households

The charging CAZ options proposed for Southampton are unlikely to affect households directly given cars are not included in the scope of the CAZ options.

The selected options may still have indirect effects on households through:

1. Impacts on businesses – e.g. affected businesses, such as freight/delivery operators, may tend to employ more low-wage workers

2. Impacts on other transport modes used by households – i.e. taxis / buses.

It is difficult to anticipate the likelihood and size of these impacts at this stage. These impacts will depend on:

(a) what costs will fall on businesses (e.g. this will also depend on what wider support and finance is made available and accessed by these firms) and
(b) how businesses will respond to any costs (e.g. to what extent will these be internalised and how, or passed on to consumers).

However, to the extent that businesses do pass on any additional costs to consumers, there may be a disproportionate impact on poorer households:

- Buses, as a cheaper mode of transport, are used more so by poorer households[24]. Hence these households will shoulder a greater proportion of any pass-through costs.
- Taxis are often relied upon by disabled persons who are unable to drive, and hence also could face a disproportionate share of any costs passed through.

For buses, these potential impacts are likely to be similar for the city wide CAZ options and the city centre options because the majority of buses are assumed to travel to the centre at some point and therefore similar numbers of vehicle upgrades are expected. For taxis, the options including a CAZ charging option could have a slightly higher impact given more vehicles are assumed to affected by the charging zones than simply the non-charging incentive.

Affordability – businesses

All options include vehicles which are likely to be owned and/or operated by businesses. Hence, all options have the potential to impact on businesses.

Businesses can be affected by the CAZ and/or non-charging measures through a number of pathways:

a. Direct effects where they own non-compliant vehicles and travel within/into the CAZ
b. Indirect effects on deliveries and delivery costs
c. Indirect impacts via commuting employees
d. Indirect effect on their supply chains, either upstream or downstream.
e. Indirect effect via impacts on customers and footfall.

It is likely therefore that all businesses located in and around the CAZ will be affected to some extent, many indirectly. That extent will be determined by a number of parameters, in particular by the location and type of the business, and also by what complementary funding and support is made available to affected businesses to mitigate any negative effects.

The focus of the qualitative analysis at this stage is on those directly effected.

Bus operators: Bus companies operating scheduled services within Southampton will be directly affected by the inclusion of buses as part of the charging CAZ or through non-charging measures. With respect to these vehicles the impacts are unlikely to vary significantly between options as it is assumed that all buses travelling within the city are likely to travel to the city centre at some point. Hence, the impacts of the city centre and city wide options are likely to be similar on bus operators as the same number of vehicles will be affected, they will just be captured in a different way.

In addition, there is a bus depot located close to the city centre which is used to store and service buses, many of which operate on routes outside Southampton. Buses using the depot are unlikely to be affected by a bus condition, and are assumed able to avoid the effects of the city-centre CAZ, but would be implicated by the city-wide charging CAZ under Option 1[25]. However, these buses undertake limited mileage within the city area and hence are unlikely to contribute significantly to achieving concentration limits within the city.

There are around four bus operators operating in Southampton (First, Bluestar, Wheelers and Xelabus) which vary in size of operations within Soton (e.g. Bluestar operate a fleet of 143 and Xelabus of 4) and size of compant (e.g. First is part of the wider First group operating in multiple cities across the UK). Hence their propensity to absorb any additional costs, to meet any immediate upfront costs, and indeed the options they have to respond to the CAZ (e.g. larger firms could switch around

[24] https://www.ucl.ac.uk/transport-institute/pdfs/transport-poverty
[25] In fact, in the development of options, Option 1a only including HGVs in a city-wide CAZ was developed in part in response to this issue.

fleet with other non-CAZ cities) will vary. It is assumed that the smaller firms will have greater difficulty meeting any immediate upfront costs of complying with the CAZ.

That said, as noted above the impact on businesses will also depend on whether additional support is available to assist compliance. In this case, it has been confirmed that Southampton will receive funding to support the retro-fit of all non-compliant scheduled buses operating on routes within Southampton, covering the full cost. Hence, a large part of the impact on bus operators will be mitigated through this funding.

The only remaining issue will be under Option 1 on the owners of buses using the depot but servicing routes outside Southampton. They will either be directly affected, or may even shift their servicing regime where alternative options are available, which will deliver additional emissions savings within Southampton but could have wider impacts on the local economy and employment at the depot in Southampton. One mitigation option considered (as presented as part of the alternative options) is not to use non-charging measures to capture buses operating in Soton, and exclude buses from a charging CAZ.

Taxis companies and operators: Under all options, the intention is to make available some level of incentives to help taxis to upgrade their vehicles. This will help mitigate the burden on taxi companies somewhat of complying with the CAZ. However, it is uncertain at this stage how much funding will be available, for what and the terms of this funding, all of which could influence the size of effects on taxi firms.

In addition, there will be a further (and potentially larger) effect on taxi companies under charging options - i.e. Options 1, and 2. A greater number of vehicles are captured by the charging framework, leading to a greater cost overall, and the CAZ charges place the costs on the taxis operators to comply (although some of these will be mitigated by the incentive scheme above). Option 1 is anticipated to have slightly larger impact than Option 2 given most taxis are assumed to travel to Southampton city centre at some point, but not all may do.

Taxis undertake a large amount of mileage in the city boundary and hence they contribute not insignificantly to air quality issues. Furthermore, given annual mileage for taxis is much larger than other vehicle owners (e.g. cars), there is a stronger financial case for upgrading these vehicles – this will deliver much larger fuel (and opex) cost savings, which themselves will be gained by the taxi operators.

But it is important to recognise that many taxi owners and operators will be classified as small firms, with many drivers simply owning and operating their vehicle on an individual basis. Hence taxi owners may be more restricted in terms of their ability to cover the upfront costs of upgrading their vehicle. This will depend on the individual finances of the taxi owner, and cannot be spread across a wider fleet or company operations.

One mitigation option considered (as presented as part of the alternative options) is not to use non-charging measures to capture taxis operating in Soton, and exclude taxis from a charging CAZ. However, given current uncertainty in the funding available and the reliance on behavioural response, engagement and uptake on behalf of the taxi firms, the modelling reflects that fewer taxis would be upgraded in the absence of a charging CAZ.

Where taxis are included in the charging CAZ, there may be greater indirect effects on businesses as taxis cancel journeys to the centre, potentially impacting on commuters and/or footfall.

HGV operators and freight recipients: Across all options, action on HGVs will impact on freight companies. Furthermore, unlike other vehicle categories, impacts on HGVs will likely have greater indirect business effects on those who rely on their deliveries and other firms in the supply chains of the primary firms affected, and on other firms in the freight supply chain (e.g. the port).

The owners of HGVs affected will likely represent a diverse group. This will include large national operators of coach fleets (e.g. Stobart), to small firms operating defined services within Southampton and the local area (perhaps operating just one HGV). This will include HGVs based and operating the majority of their time within Southampton. But there will also be many only visiting Southampton regularly but every so often (e.g. servicing the port), or visiting Southampton as a one off.

The greatest impact on HGVs will likely be associated with Options 1 and 1a which capture HGVs in a city-wide charging scheme. This will affect the greater quantity of vehicles and places the costs of compliance on HGV operators. Fewer vehicles are anticipated to upgrade under Options 2 and 3, with targeted action targeting those servicing the port or in order to access 24 hour delivery opportunities. There will be other costs for HGV operators associated with non-charging options under Options 2 and 3, such as scoping and implementing delivery contracts through the SDC, or payment of out-of-hours wages for freight drivers delivering 24 hours. However, there will also be significant benefits for the freight operators associated with some of these non-charging measures (some of which are captured and illustrated in the core CBA), including:

- Driver time, fuel and operating cost savings through dropping deliveries off ‘early’ at the SDC
- Driver time and fuel savings through use of 24 hour delivery opportunities
- Fuel cost savings through implementation of fleet recognition scheme/driver training.

Furthermore, measures will also deliver some costs (e.g. out-of-hours staff time to receive 24 hour deliveries and costs of implementing a DSP) for recipient firms, but will also provide benefits (e.g. greater co-ordination of deliveries and reduction in need for on site storage associated with SDC).

One way of mitigating the impacts on HGV operators (as presented as part of the alternative options) is not to incentivise them using non-charging measures, and exclude HGVs from a charging CAZ. In fact, many of the non-charging measures could be implemented alongside the charging CAZ as mitigation measures themselves, for example:

- Freight drivers accessing the SDC would directly avoid the CAZ charge as the SDC is located outside the city-wide boundary
- 24 hour delivery could be combined with lower CAZ charges outside peak hours to further incentivise take up and mitigate part of the impact of the CAZ charge.

Coach owners/operators: No non-charging provision for coaches has been included in the CAZ options considered. Hence where these are not included in the charging CAZ classification (Options 1a and 3), there will be no impacts on coaches or their owners/operators.

Option 1 is likely to have a larger impact on coach operators than Option 2 given the greater CAZ area will likely capture a greater number of vehicles.

Like HGVs, the owners of coaches affected will likely represent a diverse group. This will include large national operators of coach fleets (e.g. stage coach), to small firms operating defined services within Southampton and the local area (perhaps operating just one coach). This will include coaches based and operating the majority of their time within Southampton, and those only visiting the Southampton area regularly but undertaking only small mileage in the city (e.g. servicing the port), or visiting Southampton as a one off (e.g. servicing the football stadium and other visitor attractions).

As with other vehicle categories, there will be concerns around the extent to which smaller firms can afford any additional upfront costs of complying with a CAZ charging area. Indeed many of the smaller firms are likely those based in and serving Southampton and the surrounding local area specifically.

Furthermore, unlike taxis, coaches are assumed not to undertake a significant proportion of their mileage in Southampton. On this basis, coaches were not included as a separate category in the air quality modelling given their assumed low impact.

In addition, unlike HGVs and the SDC, it is not clear that there is an obvious alternative that would appeal to coach operators that they could use to mitigate the impacts of a charging CAZ. To a certain extent operators could use the rail network running into the centre but this is limited in terms of destinations covered and there is no established park and ride system. It is uncertain to what extent such options could appeal to coach users, whether for practicality (e.g. those going to the port) or security (e.g. those going to football) reasons.

Where coaches are included in the charging CAZ, there may be greater indirect effects on businesses as coaches cancel journeys to the centre, potentially impacting on commuters and/or footfall.

One mitigation option considered (as presented as part of the alternative options) is to simply exclude coaches from a charging CAZ.

Summary: In summary, the adverse impacts on businesses (both in terms of size of impacts and number of businesses affected) are likely to be highest under Option 1 given this captures the greatest number of vehicles and places the costs on vehicle owners to upgrade. This is followed by Option 1a given a large number of HGV operators will be affected, and potentially those relying on their deliveries. Option 2 will deliver the next greatest impact as it captures taxi and coach firms in a charging CAZ, but could deliver net benefits for freight operators, and lastly Option 3 will deliver the lowest impact on businesses as it is expected to deliver a net benefit for freight operators, will provide incentives for taxi companies to upgrade and does not make provision for coaches. Note: it is difficult to fully anticipate the likelihood and size of these impacts at this stage without as the details of the supporting policy is unknown.

Traffic impacts – noise and accidents

The predominant behavioural response to a charging CAZ is anticipated to be to 'upgrade vehicles' or 'pay the charge', each of which has no direct impact on traffic movements. However, where vehicle users opt to 'avoid the zone', 'cancel journey' or 'mode shift', this will impact on the volume and location of traffic travelling around the network, on individual links and the speed of travel.

Furthermore, many of the non-charging measures considered will also have a direct impact on the number of vehicles travelling round the network (e.g. SDC), or the time of travel (e.g. 24 hour delivery). Hence, the CAZ options have the propensity to impact on noise levels and accident rates, which are associated with the volume of traffic and speed. Any distributional impact will of course depend on the location and specific links where significant changes occur.

With respect to the charging options, the traffic impacts have only been modelled for one option: 1a. As noted above, given the majority of non-compliant HGVs are assumed to upgrade or pay the charge, only a small reduction in HGV traffic is observed on links in the CAZ. Furthermore, a rebound effect is also seen as car traffic increases reflecting individuals taking advantage of reduction in HGV traffic. Hence the net reduction on traffic is even smaller, meaning any positive impact on noise or accident rates is also likely to be marginal. Option 1 will likely have a slightly greater effect as taxis, buses and coaches are also included, but this could only serve to increase the rebound effect further which will curtail any additional benefit. Option 2 considering a city-centre charging CAZ will likely have smaller effects on traffic in the centre as even fewer vehicles are affected.

Under all options the greatest impacts are likely to be strongest in the city centre (mimicking those observed in the air quality distributional analysis set out above) but it is challenging to provide any further analysis on the potential distributional impacts.

The non-charging measures affecting freight under Options 2 and 3 will have a mixed impact on noise and accidents:

- **SDC:** By removing vkm from city-centre roads, the SDC will generally reduce noise and accidents. Further, given the reduction in vkm could be significant, these additional benefits could also be sizeable. However it could increase noise levels locally; the consolidation centre will reduce traffic by HGVs in general but may increase traffic around the consolidation centre. Therefore, they may be an adverse impact on households residing close to the consolidation centre. As discussed earlier there are households low on the IMD just south of the consolidation centre that could be adversely affected.
- **24-hour deliveries:** Also, there have been some discussion that 24-hour deliveries could have an adverse impact on noise: reducing vkm at peak times will also reduce noise at these times, but will shift these effects to non-peak times where people may be more susceptible to large changes in noise (e.g. during night-time hours).

Generally, by removing vehicle kilometers or shifting it to a time when there are fewer pedestrians / road users, the non-charging measures will reduce the likelihood for accidents.

Traffic impacts – congestion (accessibility), charging measures

As defined by WebTAG A4.2, there is the potential for accessibility impacts where the policy option:

1. Changes public transport provision, including routing, frequencies, waiting facilities (bus stops / rail stations) and rolling stock, or any indirect impacts on accessibility to services (e.g. demolition & re-location of a school).
2. Impacts on provision of services/amenities through indirect impact on demand
3. Places physical barriers which limits travel across the network.

On the basis of these points, the CAZ options are expected to have minimal accessibility impact in Southampton. The bus condition (Options 1a and 3) could in theory have an impact on service routing and hence accessibility but in practise the impact is expected to be small and it is reasonable assume that the policy will be designed and delivered to minimise the impact on accessibility.

In addition to the examples above, the only additional and significant accessibility impact could be through general changes in congestion, which will impact on the travel time to amenities. This is the focus of the analysis undertaken here.

Detailed modelling of the impacts on the transport network of a charging CAZ has been undertaken by Systra for the Option 1a. The key finding is that the overall travel time and congestion reduce due to the reduction in travel time of the HGVs. In addition, the travel time of cars increases and this could be seen a response to the increased space in roads: car travel is more attractive now, leading to a switch from other modes e.g. public transport. Despite this small increase in the travel time by cars the net effect on congestion is still negative (i.e. less congestion). This reduction in congestion, combined with the observed rebound effect of increase in car trips, indicates that accessibility improves as a result of the CAZ. However, these effects are small relative to overall travel time and congestion on the network given the majority of non-compliant HGVs choose to upgrade or pay the charge in response to the CAZ.

These impacts are expected to be marginally higher under Option 1 as some taxis and coaches will also re-route or avoid the zone, improving the congestion in the centre. This potentially also increases the car rebound effect described above. The charging area is much smaller for Option 2 and does not capture HGVs. It is therefore assumed that the option is likely to deliver much smaller benefits in terms of reduced congestion.

Alongside the charging CAZ, non-charging measures under consideration could also have an effect on accessibility measured as congestion, but the mechanisms are generally different compared to the charging CAZ. In particular the use of the DSPs (reducing HGV traffic overall) and the reduction in freight at peak times through the use of 24-hour delivery both benefit other road users.

These measures will have a positive impact on accessibility for other road users without any negative impact, such as through journey cancellations as under the charging CAZ measures.

Putting together the impacts on accessibility of both charging and non-charging measures we can conclude that, accessibility benefits are likely to be greatest for Option 2 (non-charging measures plus CAZ A) and Option 3 (non-charging measures) and then Option 1 and 1a. It is challenging to differentiate between Options 2 and 3 because under Option 2 some taxis and coaches cancel their journeys improving the overall congestion. But if taxes/coaches cancel journeys this could in theory also have a negative impact on accessibility, in particular, as disabled people may tend to use taxis to travel to hospital appointments and similar activities. The net impact is however unknown.

Appendix 5 – 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[26]. 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)

b) AQ impacts 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).

c) 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 associated with the retrofit of buses funded through the CBTF). 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 predominantly anticipated to occur in terms of time to design and deliver the measures, many of which could fall on SCC:

    - Policy costs of designing / developing / implementing the bus control order and taxi incentives (all options)
    - Costs of handling / co-ordinating a greater volume of freight through the SDC that will accrue to the SDC in the first instance, but may be passed onto clients (Options 2 and 3)
        - It is assumed that given the SDC is already up and running, increasing the volume of freight will incur any upfront costs. Further, given the SDC currently has a large amount of spare capacity, we also assume that some of the variable costs which scale with level of freight handled will also not be incurred, such as the need for warehouse space or freight vehicles. Hence the only additional costs (not captured) will be additional administrative, labour and handling costs within the warehouse.

          These costs could still be significant – a study by Transport Catapult into the benefits of the University Hospital suggested that the costs of warehousing (including rental space) and administrative and labour costs are much greater than running the fleet of delivery vehicles, in the range of 5.7:1[27].

          Furthermore, should additional warehouse space or vehicles be required, the costs of increasing freight through the SDC could increase substantially.

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

[27] Figures provided in direct discussion with Transport Catapult

- Policy and operating costs of encouraging / adopting / implementing HGV Fleet recognition scheme that will affect the council and operators (Options 2 and 3)
- Policy costs of designing / implementing a 24-hour freight delivery scheme (Options 2 and 3), and the design/delivery of responses from freight operators and businesses.

d) 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 – 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. Further transport modelling is only available for one option.

  Looking at the aggregate impacts of the transport modelling, 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 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.
- Efficiency savings from fleet recognition scheme: implementation of a recognition scheme on a businesses fleet typically involves consultation with experts to identify efficiency savings within the fleet and its operation. This could include recommendations around upgrading fleet, adopting driving aids or driver efficiency training. At this stage, no impact is included in the quantitative CBA given it is uncertain what measures will result from such analysis, and also relies on the take up by fleet owners. However, all actions could transpose into fuel and GHG emission savings (and also opex savings). The extent of such effects will depend on the number of firms and size of fleet covered by such schemes, and the action undertaken (e.g. upgrading vehicles has the potential to make much greater savings than driver aids). Further the effects of some measures may erode over time (e.g. driver training needs to be repeated periodically to be effective).
- 24 hour delivery: Relaxing freight delivery rules to allow off-peak drop-offs will ease congestion and improve the flow of traffic at peak times. This will have a direct impact on the fuel consumption and GHG emissions of the freight vehicles switching to off-peak, but also an indirect impact on other road users from these vehicles being removed from the roads at peak times. These savings may not just accrue to non-compliant vehicles switching, but may also be achieved by already compliant vehicles taking advantage of this incentive. It has not been possible to quantitatively assess this impact given it is uncertain how many vehicles will take up such an incentive and the

length / current speed of their delivery routes, and how much this would be improved off peak. 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.

e) 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. Some have 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', b) direct benefit of reduction in driver time for freight re-routing through the SDC, and c) indirect effect of SDC reducing HGV vkm in city area on other road users (although this is only included in sensitivity analysis given methodology available).

   - 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. It has not been possible to include this impact in the core analysis given transport modelling is only available for one option (1a – where this is the case a quantification is included in the sensitivity analysis around the core results). Looking at the transport modelling outputs for the available scenario, 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.
   - 24 hour delivery: Relaxing freight delivery rules to allow off-peak drop-offs will ease congestion and improve the flow of traffic at peak times. This will have a direct impact on the speed and journey time of the freight vehicles switching to off-peak, but also an indirect impact on other road users from these vehicles being removed from the roads at peak times. These savings may not just accrue to non-compliant vehicles switching, but may also be achieved by already compliant vehicles taking advantage of this incentive. It has not been possible to quantitatively assess this impact given it is uncertain how many vehicles will take up such an incentive and the length / current speed of their delivery routes, and how much this would be improved off peak.

f) 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. Given restrictions in the availability of transport impacts for all options, these could not be captured using the 'Marginal External Costs' from WebTAG. However, 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.
   - 24 hour delivery: shifting HGV vkm to off-peak times could reduce accidents as traffic occurs where there are fewer pedestrians. However the impact on noise could be negative where deliveries are shifted to off-peak times which are quieter (hence people

are more perceptive of big changes in noise) and when the health impacts may be much greater (e.g. through disturbed sleep). Given this is a shift in vkm, not a change, there will be no impact on infrastructure requirements.

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 33.

A full mapping of the impacts captured and not captured by the core analysis is included in: Appendix 2 – Mapping of impacts of Core CBA.

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:

- 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, in particular 24-hour delivery, fleet recognition and SDC costs for handling greater freight volumes 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).

Table 33 – Qualitative analysis of CAZ options against impacts not covered by core CBA

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)	✓✓ HGVs upgraded in response to the CAZ will travel outside the zone, delivering additional emissions benefits. Also potential impact on buses using depot but not operating on routes in Soton. 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.	✓✓ 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.	✓ Fewer HGVs upgrade in response to non-charging measures, hence smaller effect relative to Options 1 and 1a (but still positive and same impact as Option 3)	✓ Fewer HGVs upgrade in response to non-charging measures, hence smaller effect relative to Options 1 and 1a (but still positive and same impact as Option 2)
AQ impacts associated with alternative responses of coaches and taxis in response to charging CAZ	✓/✗ 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	- No additional impact given coaches / taxis are not captured as part of the charging CAZ	✓/✗ Coaches/ taxis which avoid zone could increase emissions (in this case potentially within the city area around the city centre), but vehicles which cancel could reduce emissions overall. Hence overall impact is uncertain	- No additional impact given coaches / taxis are not captured as part of the charging CAZ
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 higher for this option (~3,500 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 lower for this option (~2,000 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 (~1,500 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	✓/✗ 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	✗	✗	✗✗ Large additional costs associated with design/delivery of bus/taxi incentives	✗✗ Large additional costs associated with design/delivery of bus/taxi incentives

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)
	Small additional costs associated with design/delivery of bus/taxi incentives	Small additional costs associated with design/delivery of bus/taxi incentives	(falling on SCC), plus design/delivery and response to 24-hour delivery (SCC, freight operators, freight recipients), design/delivery and response to fleet recognition scheme (SCC, freight operators), and arrangement/handling of additional freight through the SDC (SDC)	(falling on SCC), plus design/delivery and response to 24-hour delivery (SCC, freight operators, freight recipients), design/delivery and response to fleet recognition scheme (SCC, freight operators), and arrangement/handling of additional freight through the SDC (SDC)
Wider fuel/opex/GHG impacts	✓/✗ No significant effects from avoid/cancel responses to charging CAZ – HGVs/taxis/coaches avoiding increase emissions but those cancelling decrease. 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	✓/✗ No significant effects from avoid/cancel responses to charging CAZ - HGVs avoiding increase emissions but those cancelling decrease. Removal of HGVs 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	✓ No significant effects from avoid/cancel responses to charging CAZ – taxis/coaches avoiding increase emissions but those cancelling decrease. Removal of 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 from driver efficiency training; small benefit on other road users from greater use of SDC; net benefit from 24 delivery shifting peak time HGV traffic to off-peak periods	✓ Small benefit from driver efficiency training; small benefit on other road users from greater use of SDC; net benefit from 24 delivery shifting peak time HGV traffic to off-peak periods
Wider congestion/travel time effects	✓/✗ Very marginal improvement in speed for other road users from avoid/cancel responses to charging CAZ – greater than 1a as some taxis/coaches also cancel/avoid but greater rebound effect	✓/✗ Very marginal improvement in speed for other road users from avoid/cancel responses to charging CAZ (shown in sensitivity analysis)	✓ Very marginal improvement in speed for other road users from avoid/cancel responses to charging CAZ – smaller than 1a as some taxis/coaches cancel/avoid city centre CAZ, but no impact from HGVs and fewer vehicles affected overall Benefit for freight drivers and other road users from 24 hour delivery shifting HGV traffic to off-peak periods	✓ Benefit for freight drivers and other road users from 24 hour delivery shifting HGV traffic to off-peak periods
Noise / accidents / infrastructure	✓/✗ No significant effects from taxi/HGV/coach avoid/cancel responses to charging CAZ as	✓/✗ No significant effects from taxi/HGV/coach avoid/cancel responses to charging CAZ as	✓(/✗) No significant effects from taxi/HGV/coach avoid/cancel responses to charging CAZ as	✓(/✗) DSP/SDC could have large benefit through reduction in noise, accidents and infrastructure.

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)
	modelled impacts small and countered by car rebound	modelled impacts small and countered by car rebound	modelled impacts small and countered by car rebound DSP/SDC could have large benefit through reduction in noise, accidents and infrastructure. 24 hour delivery could reduce accident rates, but may carry with it noise pollution issues at off-peak times	24 hour delivery could reduce accident rates, but may carry with it noise pollution issues at off-peak times

Appendix 6 - 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.

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