Department for Environment Food & Rural Affairs

www.gov.uk/defra

Draft Evidence Annex

Assessment of the plans to improve air quality in the UK

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Contents

1. Introduction

1. This document assesses the impact of the national plan to help solve the problem of NO_2 exceedances in the UK. It has not been possible to quantify the impacts of all the local and national level measures on emissions and ambient concentrations within the national Pollution Climate Mapping (PCM) model. The implementation of example measures has therefore been assessed using a simplified approach based on a streamlined version of the PCM model (the SL-PCM).

2. The SL-PCM is used to assess the level of local fleet change and/or journey frequency that would be needed to deliver compliance in those zones that are otherwise projected to still have exceedances in 2020. The most straightforward approach to assess the possible impact of the plans was to model access controls within those zones.

3. This modelling indicates that it is possible to deliver the level of change required to reach compliance in all zones outside London by 2020. London has a particular set of issues due to the scale of its population and the level of challenge presented by current levels of NO_2 concentrations. However air quality will improve sufficiently to achieve compliance with the Directive in London before 2025 as a result of the implementation of these plans.

4. In reality, the most effective and efficient approach will depend on the local situation and therefore local authorities are best placed to design and implement the solutions in their areas. This requires local authorities to undertake a detailed assessment of their needs and select the combination of measures to deliver the local fleet and journey change necessary to reach compliance, which may or may not include access controls. Actions such as individual road improvements, other infrastructure changes and improvements to vehicle emissions performance, e.g. retrofitting, could in combination also bring forward compliance.

5. There are however practical limits on how quickly all measures could be introduced, e.g. due to capacity constraints such as supply of vehicles or equipment. Given this, there is not considered to be a combination of measures able to deliver compliance earlier than modelled in all zones outside London.

2. Background

6. A cleaner, healthier environment benefits people and the economy. Clean air is vital for people's health and the environment, essential for making sure our cities are welcoming places for people to live and work now and in the future, and to our prosperity. Our ambition is to make the UK a country with some of the very best air quality in the world.

7. Over recent decades, air quality has improved significantly thanks to concerted action at all levels. Emissions of NO_x alone have fallen by 62% since 1970. Even in our busiest cities we have seen falls in harmful emissions, for example a 15% reduction in average roadside concentrations of nitrogen dioxide (NO_2) since 2010, but there is more we can do.

8. In 2013 the UK did not meet NO_2 limit values as set out in the EU Ambient Air Quality Directive (EU AQD). This legislation sets health-based limit values for the concentration of air pollutants, including nitrogen dioxide (NO_2). NO_2 is associated with a range of health impacts and causes damage to the natural environment. As a result the European Commission commenced formal infraction proceedings in February 2014.

9. Recently, evidence on the health impact of exposure to NO_2 has strengthened significantly. It is well established that exposure to high concentrations of NO_2 causes inflammation of the airways, decreased lung function and causes respiratory symptoms. However more recently evidence has been released directly linking NO_2 exposure to mortality. Applying this evidence to the exposure levels across the UK suggests that exposure to NO_2 is increasing mortality by the equivalent of 23,500 deaths per year, within the range of 9,500 to 38,000 deaths.

10. Controls on NO_2 are primarily delivered through controls on emissions of oxides of nitrogen (NO_x). NO_x is used to describe the range of compounds of oxygen and nitrogen including NO_2, nitrogen monoxide (NO), and nitrous oxide (N_2O). This has a direct impact on NO_2 concentrations from primary emissions and second round impact as other oxides of nitrogen reacts in the atmosphere to produce NO_2.[1]

11. Road transport accounts for around 80% of roadside emissions of NO_X. Therefore to deliver health improvements it is necessary to control emissions from this source. As set out in the accompanying 'Draft UK Plans to Improve Air Quality in the UK', transport emissions can be controlled through combinations of many different measures. These actions will deliver progress towards compliance with the legal obligations for NO_2 concentrations.

[1] Emissions of different vehicle types are in main document: in 'Average NOx source apportionment on UK road links outside London exceeding an annual mean NO_2 concentration of 40µg/m3 in 2013' figure

12. The UK national measures will be influenced by the consultation responses. A technical report on the modelling and assessment methodology used in the preparation of the final plan will also be prepared for publication by 31 December 2015 alongside the plans.

13. This document will be reviewed and amended to summarise the final plan and take into consideration the outcome of the consultation and of the current Spending Review.

3. Clean air zones (CAZs)

14. A number of authorities are considering the use of access controls to tackle air pollution and several have already implemented them. Access controls can play a role both by directly reducing the number of polluting vehicles in an area and by encouraging the uptake of alternatives.

15. However, different approaches in different cities can lead to conflicting signals to consumers and businesses. Therefore a framework for the implementation of new Clean Air Zones (CAZ) by local authorities in England is proposed. CAZs are zones that can be defined in the priority towns and cities where a variety of complementary action needs to be taken to achieve compliance. These are likely to include access controls.

16. The CAZ framework will set a standard for vehicles to meet prior to entering any zone to ensure a consistent approach by local authorities, however it will be up to the local authority to decide what vehicle types are covered. Those not meeting the standard will be subject to a charge or other restriction appropriate to the type of vehicle.

17. The location and design of CAZs modelled in this document has been targeted towards those areas where further action is needed to achieve air quality limit values for NO_2.

4. Design of the CAZs modelled

18. Eight zones have been identified which without further action are predicted to exceed the legal maximum annual average NO_2 concentration of 40 µg/m^3 in 2020, based on the methodology outlined in section 3. Two of these zones (Eastern and South Wales) have been excluded from this modelling due to the specific location of the exceedances. For South Wales, it is expected that a targeted bus improvement scheme will bring this zone into compliance by 2020. The Eastern zone exceedences fall within Greater London CAZ and the effects from this will bring the Eastern zone into compliance in 2020. The locations of the remaining six zones and their baseline maximum concentrations are provided in table 4.1 below.

Table 4.1: Prioritised locations for investigation of model Clean Air Zones

Zone/Agglomeration	Max concentration µg/m^3	
	2013	2020
Greater London Urban Area	126	71
West Midlands Urban Area	70	47
West Yorkshire Urban Area	74	47
East Midlands	64	43
Nottingham Urban Area	65	42
Southampton Urban Area	68	41

19. The difference in both the expected concentrations and the sources of the emissions in these different zones mean that different action may be required. Local authorities will decide whether all or a combination of the type of vehicles in these classes should be subject to control. For consistency four classes of CAZ are defined according to the types of vehicles included.
    - Type A – Buses, coaches and taxis only
    - Type B – Buses, coaches, taxis and heavy goods vehicles (HGVs)
    - Type C – Buses, coaches, taxis, HGVs and light goods vehicles (LGVs)
    - Type D – Buses, coaches, taxis, HGVs, LGVs and cars

20. In applying these restrictions standards will be set based on emissions level for each vehicle type. This is to ensure that only the cleanest vehicles are encouraged to enter the area, and where the option of retrofitting exists this can be effectively utilised. Box 4.1 provides further background on emission limits and the European vehicle emission standards (Euro standards) they are linked to. CAZs are not envisaged as absolute prohibitions, but it is expected that Local Authorities will set charges at levels which will have a deterrent effect.

21. CAZ perimeters for inclusion in the modelling have been estimated to include the majority of road links in the area in exceedance of the 40 ug/m^3 limit, especially the most persistent problems, following realistic boundaries where such existed and were easily identifiable from mapping. Where such boundaries would be set in practice are at the discretion of the local authority in question, and would need to be decided upon through a full feasibility study.

Box 4.1: Emissions limits and European vehicle emission standards

European vehicle emission standards set limits for exhaust emissions of vehicles sold in member states. Limits are set for the following pollutants:

- **Oxides of nitrogen (NO_x)**,
- Particulate matter (PM)
- Total hydrocarbon (THC),
- Non-methane hydrocarbons (NMHC),
- Carbon monoxide (CO)

Limits are specific to vehicle types (e.g. cars, HGVs, LGVs). Compliance is tested based on a standardised test cycle and all new vehicles must comply with set standards in order to be sold within the EU.

Euro standards year of first implementation[1,2]						
Vehicle Type	**Euro 1/I**	**Euro 2/II**	**Euro 3/III**	**Euro 4/IV**	**Euro 5/V**	**Euro 6/VI**
Car	1992	1996	2000	2005	2009	2014
Van	1994	1998	2000	2005	2009	2014
Bus and coach	1992	1996	2000	2005	2008	2013
HGV	1992	1996	2000	2005	2008	2013

[1] Arabic numerals refer to cars and vans while roman numerals correspond to heavy duty vehicles.
[2] The year from which new models have to comply with the standard; existing models generally have a grace period before their sale must stop.

The table below shows the NO_x emissions limits from Euro standards (from Euro 3 to Euro 6) for LGVs and cars for both petrol and diesel. There are no petrol Heavy Duty Vehicles (buses and HGVs). NO_2 is not directly regulated; manufacturers must simply ensure overall NO_x limits are met. The proportion of NO to NO_2 within this limit is not restricted.

	Euro standards			
Passenger car/ small LGV type (g NOx /km*)	**Euro 3/III**	**Euro 4/IV**	**Euro 5/V**	**Euro 6/VI**
Petrol	0.15	0.08	0.06	0.06
Diesel	0.5	0.25	0.18	0.08
Large LGV type (g NOx /km*)				
Petrol	0.18	0.10	0.075	0.075
Diesel	0.65	0.33	0.235	0.105
Heavy Duty Vehicles (g NOx/kWh)				
Rigid	5.0	3.5	2.0	0.4
Articulated	5.0	3.5	2.0	0.4
Buses and coaches	5.0	3.5	2.0	0.4

* Euro standards before Euro 3/III are not presented as by 2020 they are an insignificant proportion of the fleet.

Source: NAEI

22. The proposed emission rates that vehicles are assumed to meet within CAZs, and corresponding Euro standard, for each vehicle type are set out in Table 4.2. This design aligns the incentives for vehicle users to move towards cleaner vehicles at the lowest cost irrespective of their fuel type and supports the option of retrofit.

Table 4.2: Required emission limits and Euro standard by vehicle type

Vehicle type	Emission rate	Equivalent Euro standard
Cars (g NO_x/km)	0.08	Euro 6 diesel Euro 4 petrol
Light Goods Vehicles (g NO_x/km)	0.105	Euro 6 diesel Euro 4 petrol
Heavy Duty Vehicles (g NO_x/ kWh)	0.40	Euro VI

23. Combining the requirements in Table 4.2 with the 2020 compliance gaps set out in Table 4.1 results in the following designs of Clean Air Zones in order for each area excluding London listed to comply with EU NO_2 limit values by 2020[2]. This assumes they are using this measure alone.

Table 4.3 Zones in which CAZs are modelled

Zone/Agglomeration	Type	Vehicles affected
Greater London Urban Area	Type D	Buses, coaches, taxis, HGVs, LGVs and cars
West Midlands Urban Area	Type C	Buses, coaches, taxis, HGVs and LGVs
West Yorkshire Urban Area	Type C	Buses, coaches, taxis, HGVs and LGVs
East Midlands	Type A	Buses, coaches and taxis
Nottingham Urban Area	Type A	Buses, coaches and taxis
Southampton Urban Area	Type A	Buses, coaches and taxis

[2] The Greater London Urban Area would not reach compliance until 2025.

5. Methodology

24. The assessment has been made in line with agreed best practice as set out in the HM Treasury Green Book Guidance.[3] In particular it follows:
    - Valuing impacts on air quality: Supplementary Green Book Guidance (2013)[4]
    - Transport analysis guidance: WebTAG (2014)[5]
    - Valuation of energy use and greenhouse gas emissions for appraisal (2014)[6]

25. The key development in this analysis is the recent evidence on the health impacts from exposure to nitrogen dioxide (NO_2). This assessment reflects an interim recommendation from a working group of the Committee on the Medical Effects of Air Pollutants (COMEAP)[7]. More information on this approach is provided in interim Defra appraisal guidance[8].

26. This document assesses the national impacts of measures, and as a result it has not been possible to consider a number of localised impacts in our modelling. In reality, CAZs may not be the most appropriate measure in all zones - the most effective and efficient approach will depend on the local situation and therefore local authorities are best placed to design and implement the solutions in their areas.

27. The remainder of this section provides an overview of this methodology. Figure 5.1 provides a flowchart of the methodology. More detail on each step is then provided.

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[3] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197893/pu1500-air-quality-greenbook-supp2013.pdf

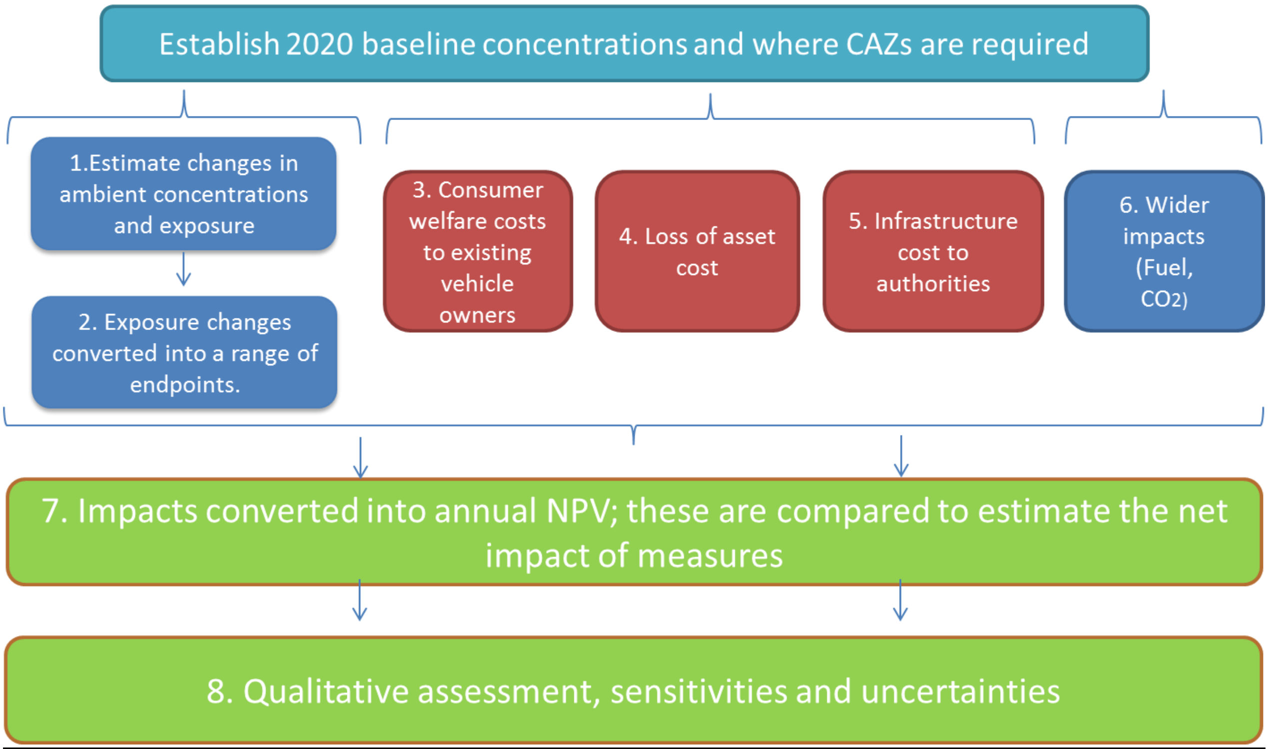
[5] https://www.gov.uk/transport-analysis-guidance-webtag

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360316/20141001_2014_DECC_HMT_Supplementary_Appraisal_Guidance.pdf

[7] COMEAP is an independent expert advisory committee of the Department of Health which advises the government on the impact of air pollution https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

[8] https://www.gov.uk/guidance/air-quality-economic-analysis

Figure 5.1: Air quality appraisal methodology



Step 0: Establish baseline concentrations and areas of exceedance where CAZs are required

28. The methodology employed for modelling the baseline concentrations across the UK is consistent with the UK's Ambient Air Quality Directive (AQD) annual compliance assessment[9]. It is based on NO_X emission projections from the National Atmospheric Emissions Inventory (NAEI)[10] mapped across the UK using geographical information system (GIS) methods. The mapped emissions are then coupled with meteorology and atmospheric chemistry within the Pollution Climate Mapping (PCM) model[11] to derive ambient NO_2 concentrations. The baseline emissions and concentrations are estimated for 2020.

29. The baseline projected concentrations of NO_2 for future years are based on 2013 data updated to reflect the latest emission factors.[12] The modelled NO_2 concentrations for the base year are calibrated using NO_2 measurements from Defra's compliance monitoring network, the Automatic Urban and Rural Network (AURN)[13]. As far as possible, the impacts of measures implemented and planned since Defra last submitted plans in 2011 are included in the baseline projections.

9 http://uk-air.defra.gov.uk/news?view=184

10 http://naei.defra.gov.uk/

11 http://uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling

12 This 2013 data will differ from data submitted to the European Commission in September 2014, and Defra will resubmit the data in due course.

13 http://uk-air.defra.gov.uk/networks/network-info?view=aurn

<u>Step 1:</u> Estimate changes in ambient concentrations

30. For modelling purposes illustrative perimeters were drawn for each of the CAZs. In practice, these will be established via local authority feasibility studies. The Streamlined PCM (SL-PCM) model has been used to estimate changes in ambient concentrations of NO_2 inside each of these CAZs. More information on the SL-PCM is provided in Box 5.1.

Box 5.1: The Streamlined PCM

The SL-PCM model is a tool developed for Defra by Ricardo Energy and Environment that quantifies the effect of changes in road traffic on emissions of oxides of nitrogen (NO_x) and annual mean concentration of nitrogen dioxide (NO_2) across the United Kingdom.

Changes in road traffic composition and flow are defined by the user, in terms of vehicle type (passenger cars, all types of light goods vehicles (LGVs), urban buses, articulated and rigid heavy goods vehicles, coaches, mopeds and motorcycles), fuel type (petrol or diesel), and Euro Standard. The model takes into account the age and composition of the fleet, the size of the vehicle, the emission standards the vehicles complied with when sold new, abatement technologies used to reduce emissions, the type of fuel used and trip characteristics. It can then calculate changes in emissions for 18,346 road links in 406 local authorities of the United Kingdom and NO_2 annual mean concentrations for all of the modelled links.

The Streamlined PCM models the projections for NO_x emissions (tonnes of NO_x) and NO_2 concentrations in 2020 based on modelling the effect of changes in fleet composition and vehicle flow. The baseline scenario in the SL-PCM was derived from a run of the full PCM model.[14]

31. The introduction of controls on certain vehicles is likely to lead to changes in behaviour of owners of these vehicles. These changes in the fleet composition and use are fed into the Streamlined PCM. In this modelling, assumptions on behavioural responses have been based on evidence from similar transport schemes. However in practice the proportion of drivers making each of these choices will depend on the design of the measure including level of charge, the penalty fees, enforcement regime and location.

32. Users of vehicles which do not meet the specified standards will broadly have the following options:

- **Replace existing vehicle with a vehicle which meets the standards**
- **Redeploy existing fleet**
- **Pay charge for entering restricted zone**
- **Shift mode of transport**
- **Divert, delay or alter journey**
- **Avoid journeys**

[14] Details of the PCM can be found here: http://uk-air.defra.gov.uk/assets/documents/reports/cat09/1312231525_AQD_DD4_2012mapsrepv0.pdf

33. The national modelling used in this assessment makes assumptions about the first three of these reactions based on evidence from similar transport measures, however there is a key uncertainty surrounding responses which is outlined in Table 6.7. It has not been possible to reflect the other reactions without an integrated transport model at a national level but is viable for a more localised assessment.

34. Where the existing fleet is redeployed emission reductions experienced within the zones result in emissions increases outside the zone. This is driven by the reallocation of less polluting vehicles within the zones and more polluting vehicles being used outside the zones.

Step 2: Concentrations converted into relevant outcomes

35. To value the impacts of changes in air quality it is necessary to convert them into outcomes which can be valued. This is done by:
    - Converting ambient concentrations (estimated in step 1) to public exposure;
    - Public exposure is used to calculate health outcomes based on the advice from the Committee on the Medical Effects of Air Pollutants;
    - Health outcomes are then valued.[15]

36. The impacts on health of both particulate matter (PM) and NO_x can be valued. Given the focus of this plan, only the impacts of changes in exposure to NO_X have been quantified and valued. This is to avoid any risk of double counting the benefits associated with reductions in public exposure to NO_2 and PM.

37. Evidence on the link between NO_2 and health is rapidly developing. Therefore a sensitivity assessment has been undertaken in section 6.

Step 3: Fleet adjustment costs incurred by existing vehicle owners

38. The majority of drivers entering the zones (over 90% according to the DfT National Transport Model fleet composition projections) would not be directly impacted by the introduction of CAZs. This is because either: they do not drive in an area where a CAZ has been modelled; the restrictions in the CAZs they enter do not cover their vehicle type; or their vehicle already meets the emission standard required. However, those drivers operating restricted vehicles will have to change their behaviour, which will impose a social cost.

39. The different responses to the introduction of a CAZ are outlined in Step 1. Of these responses, we expect the most significant impact on welfare to be associated with consumers that choose to upgrade their current vehicle. Only a limited number of reactions could be modelled. This is not a major concern as the other reactions are expected to have a smaller impact on consumers. This is reflected in the uncertainties in Section 6.

[15] https://www.gov.uk/guidance/air-quality-economic-analysis

40. The fleet adjustment cost is estimated assuming the value a consumer derives from owning or purchasing a vehicle is equal to the total value they derive from that vehicle over the market price (known as consumer surplus). For example, if an individual were to value their current car at £5,000 and the market value was £4,500, the consumer surplus for the individual owning that vehicle would be £500.

41. In addition there are transaction costs associated with the inconvenience of searching for and procuring a new vehicle and risk around quality when buying a second hand vehicle. It is assumed the implementation of any restriction on vehicle usage will be announced with sufficient time for users to adjust within their usual replacement process. Therefore, these are not quantified in the analysis.

42. The estimate of consumer surplus is quantified based on three assumptions:
    - Owners of restricted vehicles must value them above the market price (when also considering transaction costs) otherwise they would sell them or not purchase them, even without a CAZ.
    - The maximum value placed on a vehicle is the value of a similar vehicle one Euro band above (as newer vehicles are generally more fuel efficient and often provide greater comfort).
    - Owners of vehicles can value them differently, depending for example on how much they drive them. It is assumed that the levels at which the vehicles are valued is equally distributed between the maximum (i.e. price of a newer vehicle) and minimum value (i.e. market price). (This is a practical assumption because the distribution of consumers' valuations is not readily available).

43. It should also be noted that there will be a shift in demand from vehicles which don't meet the emissions standards to those which do. This would increase the supply of the former vehicles in the market while demand for them will be reduced, leading to a decrease in the value of such vehicles, negatively impacting other owners of vehicles which don't meet the standards. It is not possible to forecast this change in the market price and therefore this impact is not valued for all vehicles, however the loss of value for the oldest vehicles is valued as in step 4.

44. Estimating adjustment costs is challenging therefore a second approach has also been applied. This approach is set out in section 5 and in practise the calculations underpinning the two approaches are very similar.

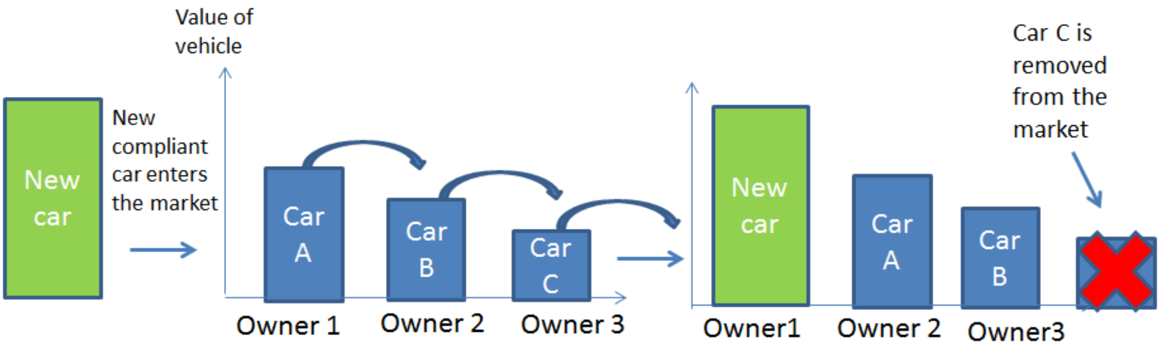
<u>Step 4:</u> Loss of asset value

45. The introduction of CAZs will trigger fleet turnover across the UK, as the owners affected upgrade to vehicles which meet the specified standards.

46. Owners of vehicles which do not meet the necessary standards who choose to upgrade can either purchase a second hand vehicle or a new vehicle. As total fleet in operation is not expected to change, it is assumed that a number of the oldest, most polluting vehicles will exit the market and be scrapped, as demand for such vehicles falls to zero. It is assumed the number of these vehicles will equal the number of new vehicles being purchased as total vehicle numbers in the fleet will not change. The lost value of these scrapped vehicles incurs a cost to society.[16]

47. This entrance of new cars into the nationwide car market, and subsequent knock-on effects on the rest of the vehicles in the market can be demonstrated in Figure 5.2 below. For example, if car A is a Euro 5 diesel, owner 1 can sell this to owner 2, who does not travel frequently into the restricted area and owns car B, a Euro 4 diesel. Owner 2 in turn will sell on car B to owner 3, and car C (a Euro 2 diesel) will be scrapped.

Figure 5.2: Fleet turnover process



48. However, if the CAZs had not been introduced, all cars in the market would have a value greater than zero, and would have remained in the market. The introduction means that this value is lost, and there is hence a cost to society.

[16] It is also recognised that there will be a benefit to users of these vehicle who do not use them in the restricted areas as the price falls. This additional benefit is not assessed within this annex.

Step 5: Infrastructure costs to authorities

49. It is at the discretion of the Local Authority whether and how they implement any CAZs. If this measure is pursued, costs of setting up and enforcement of vehicle emission standards will be incurred. Such costs could include the following:
    - General infrastructure costs (e.g. signage)
    - Automatic Number Plate Recognition system (e.g. ANPR camera and installation costs, running costs, IT equipment) or other technological solution;
    - Ongoing communication, enforcement and staff costs

50. TfL have provided detailed data on the uptake of vehicles which reach the specified standards, and associated costs. To estimate the costs that will be incurred within the restricted areas considered here, the costs for London were scaled up depending on the total population and perimeter lengths of these zones to obtain the costs for each zone under assessment.

Step 6: Wider impacts

51. There are also other impacts from implementing CAZs. It is not possible to assess all the possible impacts but the two most significant wider impacts are around:

- **Greenhouse Gases (GHGs)** – As consumers will be expected to move towards cleaner vehicles, the overall GHG emissions would be expected to fall as a result of this change in the fleet composition. To assess this impact, CO_2 emissions by Euro standard for the different vehicle types are obtained from the NAEI Road Transport Emission Projections for 2020. Changes in CO_2 emissions are calculated by reference to the expected fleet change occurring as a result of implementing CAZs. Although there may be a rebound effect if these are more efficient cars and there is a cheaper marginal mileage cost, the distance travelled is assumed not to change over this period. The total change in CO_2 emissions in tonnes per year is then multiplied to obtain the lifetime emissions[17]. This figure is valued at the cost per tonne to get the monetised impact of the change in CO_2 emissions.
- **Fuel savings** – As the measure will lead to a shift from older vehicles to newer, more fuel efficient vehicles, consumers are likely to experience a fall in running costs due to savings on fuel purchases. The final value for savings is based on the resource cost of fuel, which excludes duty and VAT. Average fuel efficiency is obtained based on Euro standards. The total distance travelled is assumed to remain unchanged. The annual distance travelled is divided by the fuel efficiency for each vehicle type, to arrive at the annual litres of fuel consumed. The fuel consumed is multiplied by the average residual life remaining for each vehicle type to get the total change. This is multiplied by the projected 2020 fuel (resource) price, in order to calculate the total savings. The figures are then adjusted to 2015 price base year.

52. Neither the CO_2 nor fuel costs reflect the impact of changes from HGVs or buses. This is primarily a result of the different way in which this data is collected and means that the benefits will be underestimated.

[17] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360316/20141001_2014_DECC_HMT_Supplementary_Appraisal_Guidance.pdf

Step 7: Impacts converted into annual net present value (NPV)

53. To facilitate the comparison of different impacts as far as possible all impacts have been quantified and valued in monetary terms. Where impacts are spread over time the values have been converted to present values based on the recommended Green Book discount rate (which is 3.5% per annum).

54. For ongoing costs and benefits, a 10 year appraisal period is used from 2020 (when the policy is assumed to be fully implemented) and upfront costs are assumed to be incurred in 2017 (when the infrastructure is implemented). The present value of the differences between the streams of costs and benefits is calculated to provide the NPV discounted to 2015 prices.

55. This allows the present value of the costs to be compared to the estimated benefits to calculate the net present value and the benefit cost ratio. In this way it is possible both to assess the public value of the measure and for this to be compared with the impact of measures in other policy areas.

Step 8: Qualitative Assessment, sensitivities and uncertainties

56. While the modelling set out above provides a detailed assessment of the main impacts of implementing CAZs, it is not possible to quantitatively reflect all the potential impacts. Therefore these gaps have been supplemented with a qualitative description and where possible an indication of the potential significance.

57. Throughout the modelling a range of assumptions and models have been used. As with any modelling there are a range of uncertainties around the underpinning design.

58. The three main uncertainties are around the performance of vehicle emissions standards, health impacts of NO_2, and the valuation of fleet adjustment costs. The impact of these uncertainties is presented in section 6.

59. There remain a number of other uncertainties where such an analysis is not possible or is not proportionate to undertake quantitatively. These uncertainties have been provided with a brief description of the potential significance in Table 6.7 at the end of this document.

6. Results

60. The results show the impact of implementing CAZs in areas otherwise projected to be in exceedance in 2020. In reality, the most effective and efficient approach will depend on the local situation and therefore local authorities are best placed to design and implement the solutions in their areas, which may or may not include CAZs.

6.1. Impact on Concentrations

61. The model described in Section 4 is run for each of the identified CAZs individually, according to zone type and vehicles restricted, to calculate the concentration of NO_X in each zone, both with and without the implementation of the restrictions.

62. Table 6.1 shows the original maximum concentration of NO_x and the resulting concentration once the CAZ has been introduced.

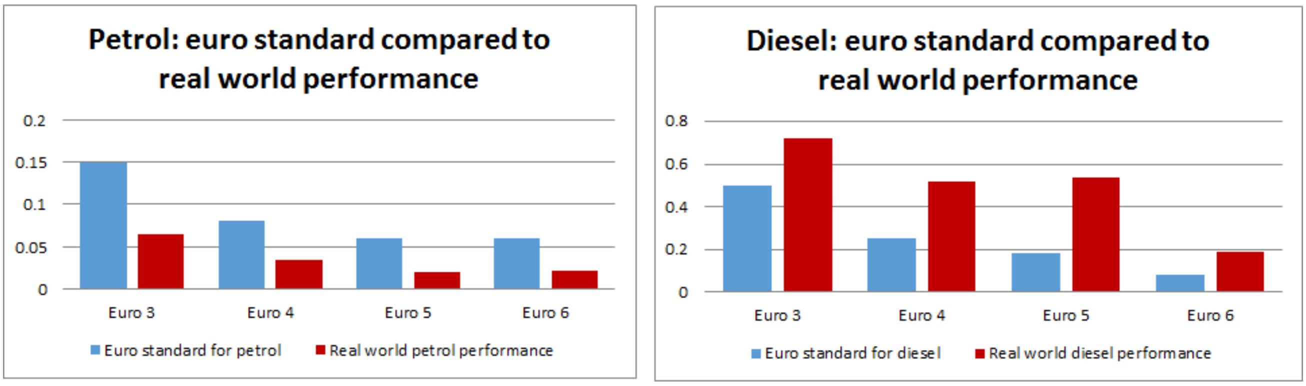
Table 6.1: Change in concentration in priority areas in 2020

Zone/Agglomeration	Original[18] max concentration $\mu g /m^3$	Remaining max concentration $\mu g /m^3$
Greater London Urban Area	71	49
West Midlands Urban Area	47	37
West Yorkshire Urban Area	47	36
East Midlands	43	37
Nottingham Urban Area	42	37
Southampton Urban Area	41	36

63. The road transport emissions modelled in this document are based on the latest evidence of vehicle NO_x emissions. However, there have been issues with the European test cycles not accurately reflecting real world performance and emissions. This has resulted in NO_x emissions of diesel cars in actual driving conditions being significantly higher than the European standards would otherwise suggest, as demonstrated in Figure 6.1.

[18] Also in 'Summary of 2013 exceedance of NO2 limit values and projected dates of compliance' table in main text where projection years are presented.

Figure 6.1: Car Euro Standard Compared to Real World Performance



Source: COPERT 4v11 (2014)

64. While emerging data indicates that the European test cycle results are becoming closer to real world performance, there is still disparity. In order to reflect the current issues in road transport emission factors for Euro 6 diesel vehicles, an alternative scenario is modelled assuming that the actual emissions are higher than currently predicted. This is based on recent evidence from Portable Emissions Measurement System (PEMS) data on Euro 6 diesel passenger cars.

65. The results of this are presented in Table 6.2. This shows that should Euro 6 emissions standards not perform as modelled, it could result in up to 22 additional zones being non-compliant in 2020. Given this, it is clear that the performance of emissions standards going forward will have a significant impact on the efforts to reduce NO_2 concentrations.

Table 6.2: Compliant zones with different emissions standards performance

	Central estimate of Euro 6 emission standards	If Euro 6 emissions standards do not perform as modelled[1]	Difference
Number of compliant zones in 2020	**35**	**13**	**22**
Number of non-compliant zones in 2020	**8**	**30**	
Total number of zones	**43**		

[1] Not performing is modelled here with real world emissions 5 times the estimated test emissions.

6.2. Impact on Society

66. In addition to the assessment of the measures on compliance with air quality limits, an assessment of the costs and benefits to society has been undertaken, comparing improvements in air quality against the associated costs of implementation. The results of this are presented in Table 6.3.

Table 6.3: Estimated impacts of CAZs (£m)

Impact	Central	Low	High
Monetised impacts of NOx reduction inside zone	1,913	765	3,061
Monetised impacts of NOx reduction outside zone	582	215	1,019
Fuel	145	145	145
Carbon	38	38	38
Total Benefits (NPV)	**2,678**	**1,163**	**4,263**
Cost of fleet adjustment	1,005	1,453	1,005
Infrastructure costs	24	24	24
Loss of asset cost	194	194	194
Total Cost (NPV)	**1,223**	**1,671**	**1,223**
Net Present Value	**1,455**	**-508**	**3,040**

67. Table 6.3 suggests that the health benefits of introducing CAZs in the zones predicted to exceed limit values in 2020 would deliver a social benefit of £2.7 billion. This action would also impose a cost on the users of those vehicles of around £1.2 billion.

68. The NPV range for the modelled results can vary significantly based on the assumptions applied. This is shown in Table 6.3 which demonstrates the effect in varying assumptions on the cost of fleet adjustment vehicles and the health impact of NO_2. There is a range of other factors, detailed in Table 6.7, which are not reflected in the analysis here.

6.3. Direct costs and benefits to business

69. The enforcement of higher vehicle emission standards will lead to additional costs to businesses. Primarily, the key cost to businesses is the cost of adjusting their fleet to meet the higher emission standards.

70. Some businesses may be able to meet the higher emission requirements by redeploying their existing fleet. However, where redeployment is not an option, the biggest impact on businesses will materialise through the need for businesses to replace vehicles which do not meet the standards with those which do.

71. The specific impact on individual businesses will depend on fleet composition, in terms of the age and type of vehicles. The overall business costs have been assessed, based on replacing each vehicle type as follows:

- Cars: Company registered cars represent 8.6% of the total car fleet. It is therefore assumed that an equal proportion of the total fleet adjustment cost will fall on businesses, which is around £86m. This is likely to be an overestimate, as businesses tend to own newer vehicles (54% of all car first registrations were made by companies in 2014[19]). They are therefore less likely to incur costs of upgrading. Businesses are also likely to redeploy cars, which would lower the costs, however this has not been considered here.

- LGVs: DfT data shows LGV ownership is closely split between privately owned (52%) and company-registered vans (47%). However, the data also shows that the majority of privately owned vans are chiefly used for business purposes[20]. Given this, it is assumed that the full fleet adjustment of non-compliant LGVs falls on businesses. However, this approach may lead to a slight overestimation of the costs to businesses.
- HGVs: It is assumed all HGVs are owned by businesses and the full fleet adjustment cost of this category of vehicle is therefore included in the fleet adjustment cost for businesses.

72. The cost businesses are expected to incur as a result of the assessed measure has been calculated and is presented in Table 6.4 below. The primary source of cost is LGVs (£397m). Overall, businesses are expected to incur approximately 56% (£565m) of the total fleet adjustment cost (£1bn) – the remainder of this cost will fall on households.

Table 6.4 Fleet adjustment cost for businesses (£m)

Fleet adjustment cost for businesses (£m)	
Cars	£36
LGVs	£397
HGVs	£132
Total cost to businesses	**£565**

6.4. Uncertainties and sensitivities

Mortality impact of NO_2

73. Evidence on the health impacts associated with ambient NO_2 concentrations has strengthened significantly over the past few years. While uncertainties remain, there is now stronger evidence of effects and that NO_2 plays a causal role. To reflect the current evidence, the analysis has been based on recent advice from COMEAP, which has provided interim guidance to Defra on how the latest NO_2 evidence should be reflected in policy analysis[21].

74. Evidence on the health impacts is still being assessed and it is subject to a number uncertainties. Three key uncertainties are:

- The figure assumes that there is no overlap in mortality impacts of PM and NO_2. This is unlikely to be the case; however, as the impacts of PM are not

[19] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/421337/vls-2014.pdf

[20] http://www.racfoundation.org/assets/rac_foundation/content/downloadables/van_report_aecom_100414.pdf

[21] On 24 July 2015 a COMEAP working group on NO_2 wrote to Defra recommending that a coefficient of 1.025 per 10 µg/m^3 exposure to NO_2 (within the range 1.01 – 1.04) should be used to assess the link between long term exposure to NO_2 and all-cause mortality.

valued in this assessment, the overall health impacts are likely to be an underestimate.

- Any potential threshold effect for impacts of NO_2 is not considered. There is no clear evidence for a threshold of effect at the population level, so no cut-off for quantification has been applied in the calculations.
- Importantly, because of the uncertainty in the extent to which the association between long-term average concentrations of NO_2 and mortality is causal, there is likely to be more uncertainty in applying the coefficient to assess the health benefit of measures that are specific for a reduction in NO_2 compared to interventions that reduce the whole mixture of air pollutants.

75. To reflect the range of the current evidence, the central coefficient (2.5%) has been compared against the range of coefficients as recommended by COMEAP (1% and 4%). Table 6.5 shows the results of this comparison. Using COMEAP's lowest coefficient of 1%, the benefits of reducing NO_2 are 60% lower than the central estimate. The maximum coefficient leads to estimated benefits that are 65% higher than the central estimate.

Table 6.5: NO_2 Impact Sensitivities

	Monetised health impact of NO_2 (£m)
Central (2.5%)	£2,495
Min (1%)	£980
Max (4%)	£4,080

Fleet adjustment costs

76. The alternative approach attempts to assess the impact on the owner's utility of upgrading from a vehicle that doesn't meet the standard to one that does. Under this approach, it is assumed that:

- the maximum cost to the owner is equal to the difference in the depreciation costs associated with owning a car which meets the standards;
- owners do not benefit from any reduction in depreciation cost. This is on the basis that there are fuel savings and comfort benefits to owning a newer car which offset the difference[22]; and
- the costs to owners upgrading to a vehicle which meets the standards is evenly distributed between the maximum and minimum values.

77. The results of this methodology are outlined in Table 6.6. This approach does not estimate the positive impact on owners who operate outside the CAZs. These owners will be able to purchase vehicles which do not meet zone standards at a lower price, and sell vehicles which do for a higher price to those drivers who do enter such zones.

[22] These benefits can't more than outweigh the difference in depreciation costs or the owner would not choose a non-compliant vehicle in the absence of the restriction.

Table 6.6: Consumer Fleet Adjustment Cost Valuation Sensitivity

	Fleet adjustment cost (£m)	Overall NPV
Central	£1,004	£1,455.9
Alternative Model	£1,454	£1,006.9

78. Table 6.7 provides a brief overview of a range of relevant other uncertainties and sensitivities not covered above.

Table 6.7: Summary of Assumptions and Associated Uncertainties

Assumption	Associated uncertainty
The analysis assumes that Local Authorities choose to undertake CAZs. In practice Local Authorities will define the most effective and efficient approach to compliance, based upon their local need.	The final costs and benefits of compliance depend upon the package of measures that Local Authorities choose to take forwards. A different package of measures will result in different costs and benefits of compliance.
Vehicle numbers outside London are based on Trafficmaster data. This tracks a sample of around 160,000 vehicles travelling around the UK and identifies those entering multiple CAZs. This reduces double counting of vehicles entering different CAZs. This dataset has been combined with data from the London LEZ.	The sample of vehicles is not derived statistically, and may be biased towards newer vehicles, which usually drive longer distances. There is a significant amount of uncertainty as to the actual vehicle numbers entering the cities. However, this is the best available data set to identify vehicle numbers.
The costs have been estimated based on the loss of utility to consumers of upgrading to a newer vehicle.	Given limited data on maintenance and insurance costs, changes in these factors have not been considered in the calculations. However, these factors influence consumer fleet adjustment cost, and therefore may have an impact on economic costs.
Wider costs to those within zones (e.g. those incurred by businesses due to redeployment or journey cancellations or adverse impacts on consumer welfare from making fewer and shorter trips) are not quantified in the analysis. They are assumed negligible.	It is not necessarily the case that the wider costs would be negligible, however given particular local conditions they have not been assessed here. Such costs will be appropriately considered by local authorities during the feasibility assessment of the local package of measures.
The modelling is based on the assumption that consumers are economically rational, that their utility from a vehicle is based on its economic cost and that vehicle owners always prefer newer vehicles. It is also assumed that consumers on average replace their vehicles every 4 years, and the introduction of CAZs is announced 4 years before implementation, therefore consumers will not experience any additional transaction costs.	In reality this may not be the case, as there are a number of motivations for owning particular vehicles besides economic (i.e. preference for a certain model, or particular vehicle). This may mean costs of upgrading may be greater than it is assumed that for such vehicle owners. The assumption also ignores the potential transaction cost impacts on consumers who replace their vehicles less frequently than every four years.
In the model, it is assumed that the upgrade to higher Euro standards will lead to the most polluting 25% of vehicles being scrapped. This would lead to an upgrade in the UK fleet, as these vehicles also drive outside zones as well as inside.	There is potential that the introduction of access controls would encourage drivers of the least polluting vehicles outside the zones to sell these to frequent zone users, given the increased demand for such vehicles. This may encourage a rise in mileage of the more polluting vehicles outside of zones. This is accounted for as it is assumed that 75% of the emissions inside zones are diverted out. However, estimating how driving patterns would change and the roads affected is complex and dependent on a number of factors. Given it is expected that a significant proportion of the most polluting vehicles would be removed from the road, nationally,

	emissions are likely to fall as has been have modelled. However some road links may experience an increase in concentrations. In such cases, other policies such as local transport schemes would be appropriate.
The CAZ perimeters have been estimated to include all areas in exceedance of the 40 ug/m^3 limit, and following realistic boundaries where such existed and were easily identifiable.	However, where the access restriction boundaries fall is at the discretion of the local authority in question, and should be decided upon via full feasibility studies. This has not been undertaken for the purposes of this assessment; Local Authorities are best placed to determine where the perimeters should lie. This may mean the perimeters change significantly, which would have an impact on infrastructure costs, and also number of vehicles, and population affected.
In the model, it is assumed that of the affected diesel owners who upgrade to a vehicle in line with emissions standards, the majority purchase a compliant petrol vehicle and the rest a Euro 6 diesel vehicle.	Lack of robust studies on actual behavioural responses means this assumption is based on assessment of the number of vehicles available and expert judgement on responses.
There are uncertainties surrounding the assumed behavioural responses of consumers to the policy. How consumers respond will depend on the exact design of the CAZs (e.g. level of fine, enforcement regime) and what other policies are implemented simultaneously.	These behavioural responses will be appropriately considered by local authorities during the feasibility assessment of the local package of measures depending on the specific design of the CAZs and accompanying policies.
The second hand value of vehicles is estimated based upon estimated depreciation rates.	There is uncertainty around the actual depreciation rates of vehicles, which generates uncertainty on the cost of purchasing second hand vehicles.
The analysis produced here is based on a new model produced to assess the costs and benefits of Clean Air Zones.	There is uncertainty around the final cost and benefit results, as the model inputs and calculations are quality assured and refined these estimates may change.