Triangular Cooperation Air Quality Improvement Project

Clean Air Zone Guidance Document

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DEUTSCHE ZUSAMMENARBEIT

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Glossary

Abbreviation	Definition
AADT	Annual average daily traffic
AirQ+	Health impact assessment tool developed by the World Health Organisation
ANPR	Automatic Number Plate Recognition
BEV	Battery electric vehicle
BS	Bharat Stage, Indian emissions standards for vehicles
CAAP	Clean Air Action Plan
CARB	California Air Resources Board
CAZ	Clean Air Zone
CBA	Cost-Benefit Analysis
CO	Carbon monoxide
CO_2	Carbon dioxide
CTM	Chemical Transport Model
DPF	Diesel particle filter
EcoSense	An integrated assessment model produced by REEEM, used for health impact assessment
ERP	Electronic Road Pricing
EV	Electric Vehicle
GAINS	A model that can estimate historic emissions in countries, and be used for health impact assessments
GGD	Health impact assessment tool developed by the Netherlands Public Health Services
GHG	Greenhouse gas
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GNSS	Global Navigation Satellite System
HC	Hydrocarbons
HEAT	Health Economic Assessment Tool, a health impact assessment tool developed by the World Health Organisation
HGV	Heavy goods vehicle
HIA	Health Impact Assessment
IAQM	Institute of Air Quality Management
ICE	Internal combustion engine
IIASA	International Institute for Applied Systems Analysis

Abbreviation	Definition
IOM	Institute of Occupational Medicine
IOMLIFET	A spreadsheet system for life-table calculations that can be used for health impact assessments
JRC	Joint Research Council of the European Commission
LAEI	London Atmospheric Emissions Inventory
LEZ	Low Emissions Zone
LGV	Light goods vehicle
LPG	Liquified petroleum gas
LTA	Land Transport Authority, Singapore
MER	Monitoring, Evaluation and Reporting
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
NRMM	Non-road mobile machinery
O_3	Ozone
PHV	Private hire vehicle
PM	Particulate matter
$PM_{2.5}$	Particulate matter 2.5 micrometres or less in diameter
PM_{10}	Particulate matter 10 micrometres or less in diameter
POM	Polycyclic organic matter
RFID	Radiofrequency identification
SCA	Smoke Control Area
SCR	Selective catalytic reduction
SO_2	Sulphur dioxide
SO_X	Sulphur oxides
SRO	Senior Responsible Owner
TM5-FASST	TM5-Fast Scenario Screening Tool, a health impact assessment tool produced by the Joint Research Council of the European Commission
ULEZ	Ultra-Low Emissions Zone
UN	United Nations
VOC	Volatile organic compound
WHO	World Health Organisation
WRF-Chem	Weather Research and Forecasting model coupled with chemistry

Abbreviation	Definition
WRF-CMAQ	Weather Research and Forecasting model coupled with the Community Multi-scale Air Quality model
WHO	World Health Organisation
ZEV	Zero-emissions vehicle
ZEZ	Zero Emissions Zone

1 Introduction

1.1 Project overview

The Triangular Cooperation Air Quality Improvement Project is being led by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and supported by Ricardo Energy & Environment. The project aims to facilitate the sharing of information and expertise on the management of air quality in urban environments, with a focus on transport emissions.

The cities partnering in this project include Cuttack and Bhubaneswar in Odisha state, India, and León, Salamanca, Celaya, and Irapuato, Mexico. Representatives of a selection of European cities are also being asked to contribute to the project, through the sharing of ideas, experiences and recommendations.

The project aims to strengthen capacities for the development of strategies, programs, and action plans to combat air pollution, with viable technical and financial solutions. The three fields of action for the project are:

- Knowledge Exchange – Development of technical capabilities for improving air quality through facilitating knowledge exchange.
- Technical Support – Planning and implementation of clean air measures through technical support.
- Capacity Building – Capacity building for replication in the Indian cities.

Ricardo Energy & Environment is supporting the project by:

- Sharing examples of best practice in air quality management;
- Developing guidelines and recommendations for strengthening the cities' Clean Air Action Plans (CAAPs); and
- Providing recommendations to Cuttack and Bhubaneswar for technical solutions to improve emissions from transport sources.

The project is being delivered in three packages:

- Package A: Air Quality Best Practice Review
- Package B: Analysis of air quality plans
- Package C: Systematization of the success stories implemented in India and Mexico

This report is part of Work Package B, which will provide detailed recommendations on how to improve air quality management in the Indian cities, and provide effective technical solutions for addressing air pollution problems linked to motor vehicles. The following document provides guidance on the process for implementing a Clean Air Zone to reduce emissions from road transport and improve air quality in a city.

1.2 Purpose of this document

This Clean Air Zone Guidance Document sets out recommended steps for implementing a Clean Air Zone in a city, covering the following:

- Determining the scope – including methodologies to determine boundaries, vehicle classes, emission sources, timescales, etc.
- Assessing the impacts – including approaches for determining the extent of impacts on air quality, the local economy and broader societal impacts.
- Implementation planning – including approaches to establishing the LEZ, including legislation, charging options, enforcement etc.
- Monitoring and evaluation – including recommendations for establishing a system of Monitoring, Evaluation and Reporting.

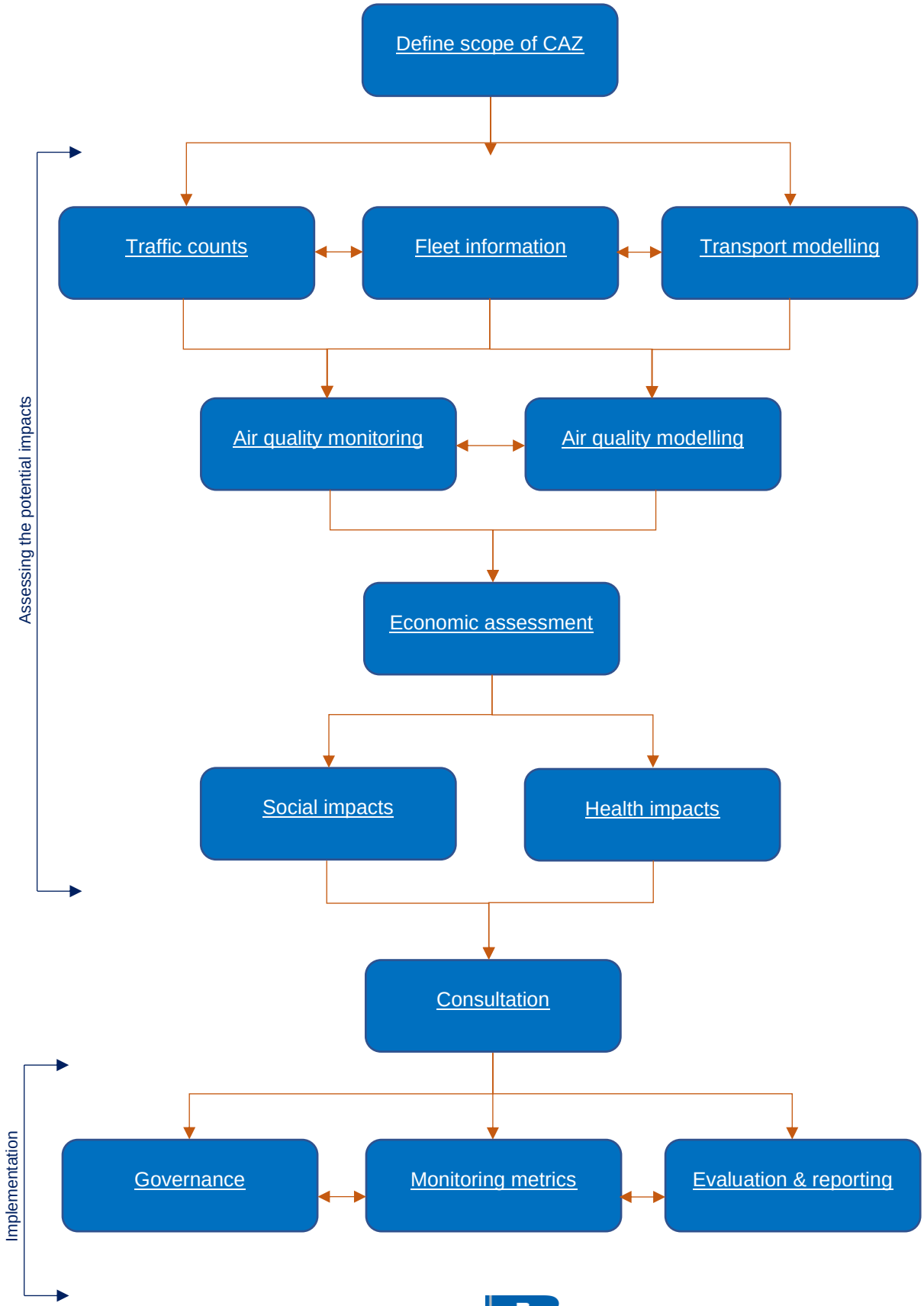
This guidance document can, in theory, be used by any city as an instruction manual on how to implement a Clean Air Zone. At each stage of the planning and implementation process, the different

options and decisions that can be taken are outlined. This enables the city to make an informed decision based on the local circumstances, data, time, and funding available.

Of particular importance are the ‘decision tree’ below, and the checklist in Section 7. Both of these resources should be used when completing the CAZ process as a way for cities to map out their projects and keep track of progress.

1.3 Decision tree

The decision tree below provides a summary of the process for implementing a CAZ. It can also be used to navigate through to the relevant sections of this document. Section 7 provides a detailed checklist of all the considerations under each of the aspects below.



2 What is a Clean Air Zone?

2.1 Clean Air Zones vs Low Emissions Zones

Clean Air Zones and Low Emissions Zones employ a similar approach to improving air quality: the use of a designated zone with stricter policies to reduce emissions of air pollutants. However, these two types of zone may differ in their objectives and the policies enacted within the zone.

Low Emissions Zones (LEZs) set the emission standards for vehicles that can access a particular area. More ambitious LEZs may be called an 'Ultra-Low Emissions Zone' (ULEZ, as in London), or a 'Zero Emissions Zone' (ZEZ, as in Oxford). All cities should ultimately aim to achieve a ZEZ, even if the route to zero emissions begins with a LEZ. The scope of an LEZ is narrower than for a Clean Air Zone – focussing on a reduction in emissions from road transport only. The associated benefits are usually for human and environmental health, including climate change.

Clean Air Zones (CAZs) primarily target the same emissions sources as an LEZ – traffic emissions – as well as other polluting sources. CAZs bring together local measures to improve air quality and health, support cities' local economies to thrive while delivering sustained reductions in pollution, and accelerating the transition to low emission transport, as shown in Figure 1. In areas with significant pollution problems, restrictions to encourage only the cleanest vehicles to operate in the city, similar to a LEZ, may be employed.

Figure 1: Key ambitions of a Clean Air Zone[1]

2.2 Emissions standards-based zones

Emissions from transport are often the main source of air pollution in urban environments, so managing the type of vehicles that can access city centres can be an important tool for improving air quality. One approach is to set restrictions on the types of vehicle that can access a particular zone, based on the emission standard of the vehicle. Often these zones are accompanied by an automatic or manual system for monitoring and enforcing which vehicles are entering the zone, and penalising those that do not meet the required standards. These restrictions can be reviewed and updated over time to achieve the desired impacts in terms of reduced emissions. Restrictions, or a complete ban, on internal

[1] Adapted from Clean Air Zone Framework, Principles for setting up Clean Air Zones in England, Defra, February 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863730/clean-air-zone-framework-feb2020.pdf

combustion engines (ICE) can also help to promote alternative forms of transport, including electric vehicles.

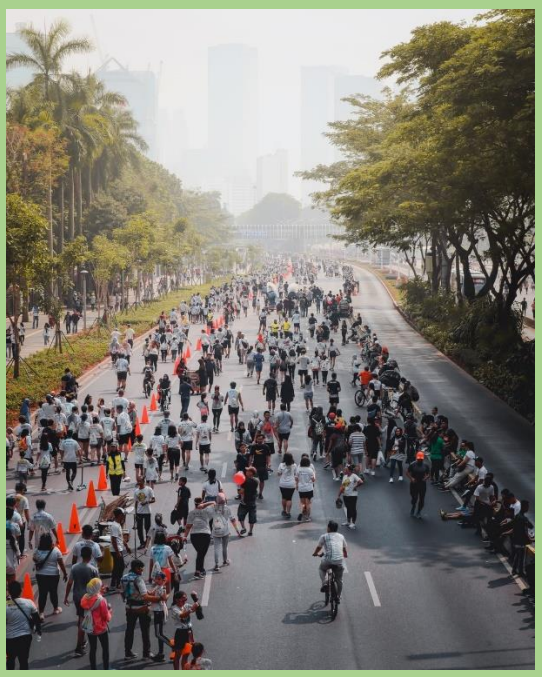
Emissions standards for the production and sale of vehicles are set in order to limit the amount of pollutants being released from a vehicle to an 'acceptable' level. Above this emission performance standard, other technologies are required to limit the vehicle emissions (although this is not the case for every CAZ). This regulatory technique initially had a focus on carbon monoxide (CO) and hydrocarbons (HC); however, many standards now include a range of other pollutants such as nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM_{10} and $PM_{2.5}$). There are three main sets of emissions standards: American (United States), Japanese, and European, although there are others too, such as the Indian Bharat Stage (BS) standards. Many countries outside of Europe, including Singapore, China, Bangladesh and others use European standards for all or part of their vehicle fleets.[2]

Example: In 2018, Madrid's LEZ banned the oldest and most polluting vehicles from the city centre, ahead of a planned total ban on private vehicles (except residents) by 2025.[3]

2.3 Access management

A CAZ that uses an access management approach controls what types of vehicles can access parts of the city, and when. This typically involves closing the zone, or some roads in the zone, to all vehicles (including electric vehicles) for example through pedestrianisation, or cycling and public transit access only.

Example: Copenhagen, Brussels, Milan, Madrid, and other cities have permanent car-free areas,[4] whilst Jakarta has arranged car free days every Sunday since 2012. [5]



Jakarta Car Free Sunday (Source: unsplash.com)

[2] Adoption of the EU Euro emissions standards for road vehicles in Asian countries, European Environment Agency, https://www.eea.europa.eu/data-and-maps/figures/number-of-international-environmental-agreements-adopted-1
[3] Madrid Central LEZ, Urban Access Regulations, https://urbanaccessregulations.eu/countries-mainmenu-147/spain/madrid
[4] 9 European Cities That Are Making Great Strides to Become Car Free, Goodnet, 2018, https://www.goodnet.org/articles/9-european-cities-that-are-making-great-strides-to-become-car-free
[5] Infocarfreeday (2021), available online at: https://www.infocarfreeday.net/

Access management is often present in small parts of a city centre, especially in tourist areas. A pedestrian zone can minimise traffic jams and congestion, improving the attractiveness of the areas and encourage increased foot traffic. Another approach is to establish car-free areas during events (see Section 3.5.1) or on certain days of the week / month.

2.4 Other emissions sources

Although the main focus of a CAZ is typically to reduce emissions from road transport, there are a number of other sources that may contribute to air pollution. With the wider scope of a CAZ compared to an LEZ, these additional sources of pollutants can also be targeted for restrictions. The following considers some of these emission sources, and approaches to managing them under a CAZ.

2.4.1 Off-road machinery

Off-road machinery or non-road mobile machinery (NRMM) includes mobile machines, transportable industrial equipment, and other vehicles fitted with an ICE, that are not intended for transportation of goods or passengers on roads. NRMM is particularly prevalent in the construction sector, for example: excavators, dumpers, mobile cranes, and more. Similar to road vehicles, it is possible to establish emission standards for NRMM, which requires the use of more modern, efficient and environmentally friendly equipment.

Case study: London NRMM LEZ

Exhaust emissions from NRMM can contribute significantly to pollution in a city; the London Atmospheric Emissions Inventory (LAEI) estimated in 2016 that NRMM exhaust emissions from construction alone were responsible for up to 10% of the pollution in London.[6] The Mayor of London implemented a NRMM LEZ that came into force on 1 September 2020, setting minimum emissions standards for NRMM operating in London that will become more stringent over time.

- From 1 September 2020 NRMM on all development sites within Greater London are required to meet emission Stage IIIB as the minimum; NRMM on all sites within the Central Activities Zone or Opportunity Areas are required to meet emission Stage IV as the minimum.
- From 1 January 2025 the standards will be Stage IV throughout London (with no difference between the standards set for the Central Activities Zone or Opportunity Areas).
- From 1 of January 2030 the standards will be Stage V throughout London.
- From 1 of January 2040 only zero emission machinery will be allowed.

More information, including retrofitting, exemptions, inspections, and management of non-compliant machines, can be found on the London Government's website[7] as well as in the Non-Road Mobile Machinery Practical Guide v.4.[8]

2.4.2 Diesel generator sets

Generator sets are typically used as a supplementary or back-up power source, and often have very high emission rates (particularly diesel generators, but also some gas generators), which can lead to heightened localised concentrations of NO_2 and particulate matter.

Generator sets can pose a challenge in terms of effective regulation, as they are often unregistered and can be widely used. However, it is possible to introduce restrictions on their use if this is believed to be contributing to local air quality issues. It is also possible to work with local stakeholders to encourage the incentivise the use of low or zero emission alternatives.

[6] Non-Road Mobile Machinery (NRMM) Practical Guide v.4, Cleaner Construction for London supported by mayor of London, September 2020, https://www.london.gov.uk/sites/default/files/nrmm_practical_guide_v4_sept20.pdf
[7] https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/nrmm
[8] Non-Road Mobile Machinery (NRMM) Practical Guide v.4, Cleaner Construction for London supported by mayor of London, September 2020, https://www.london.gov.uk/sites/default/files/nrmm_practical_guide_v4_sept20.pdf

The three main actions that can be taken to regulate diesel generator sets are:

- **Set emissions standards for in-use diesel generator sets.** Emissions standards are often set for new diesel generator sets, however, not the older generators already in use. Regulation will require defined standards based on the generator age, power, and fuel. Common standards include emission of various pollutants like carbon monoxide (CO), HC, NOx and PM in g/kWh, or smoke opacity. Regular testing should take place under defined conditions, for example, a specific cycle or duration, by authorised agencies.
- **Support the retrofitting of diesel generator sets.** Retrofitting may be used to lower the emissions of (in most cases) PM, but also to allow other fuels to be used alongside, diesel. Retrofitting with a dual fuel technology may require no modification to the internal components of the generator. A bi-fuel generator set can make use of natural gas as the main fuel component (natural gas hybrid), therefore significantly reducing the diesel fuel used, reducing emissions and fuel costs.[9]
- **Support the shift to cleaner fuels.** As well as retrofitting to give a dual fuel generator set, support could be provided to replace diesel generator sets with newer, gas-based generators. If generators are used only for backup power, replacing them with solar panels could even be an option.

2.4.3 Open and solid fuel burning

Open burning for energy or waste disposal poses a significant human health risk, due to the potential for emissions of hazardous substances, including volatile organic compounds (VOCs) and polycyclic organic matter (POM). Open and solid fuel burning can be managed using smoke control areas (SCAs), for example where people cannot emit smoke from any chimney unless an authorised fuel is being burnt, or an 'exempt appliance' is being used. Fines can then be applied if these rules are broken within an SCA. Some outdoor burning equipment may be permitted in these areas, such as outdoor barbecues or fireplaces, as long as the appropriate rules are followed.

Example: In the UK, an extensive list of authorised fuels that can be burnt in SCAs, and information on these is available via a Government website.[1] In addition, anthracite, semi-anthracite, gas, and low volatile steam coal are all deemed 'smokeless' fuels and can be burnt within SCAs. A list of exempted appliances for each country in the UK is also available online.[10]

2.4.4 Dust from construction and other sources

Dust also poses a real challenge for air quality management in urban environments. Dust from construction, demolition, road works and other activities can be a visible nuisance, result in deposition on cars and buildings, and contribute to higher PM concentrations in ambient air, as well as creating a hazardous working environment.

Dust from construction and other sources can be mitigated via dust management practices, some of which may already be included as part of a city's CAAP. The four main construction activities from which dust can occur are: demolition (activities involved in the removal of an existing structure), earthworks (soil striping, ground levelling, excavation, or landscaping), construction (activities involved in the provision of a new structure), and trackout (transporting dust from a construction site onto the public road network). In a CAZ, there may be requirements for any construction activity to undergo a dust risk assessment, and if appropriate, employ suitable mitigation measures to reduce emissions of dust.

The Institute of Air Quality Management (IAQM) has published guidance on the assessment of dust from demolition and construction.[11] This guidance explains the potential impacts of dust emissions, as well as the steps to complete a dust assessment, and site-specific mitigation measures. The CPCB has

[9] The Diesel Generator: Pollution, Policies and Compliance, energeia, 2020, https://www.energeia.in/post/the-diesel-generator-pollution-policies-and-compliance
[10] Exempt Appliances, Defra, https://smokecontrol.defra.gov.uk/appliances.php
[11] Guidance on the assessment of dust from demolition and construction, Version 1.1, IAQM, 2014, https://iaqm.co.uk/text/guidance/construction-dust-2014.pdf

also published guidance on dust mitigation measures,[12] which highlights major dust generating activities within the construction sector and a number of mitigation measures.

It may also be possible to employ additional dust control measures within a CAZ to minimise impacts on local residents and businesses, including regular street sweeping and sprinkler systems.

2.5 Regulatory approaches

There are two approaches to regulating a CAZ:

1. Prescriptive; and
2. Market-based.

Depending on which type of regulation the CAZ uses, different methods of enforcement will be required (see Section 3.4).

2.5.1 Prescriptive

The prescriptive regulatory approach can be summarised with the message "You must not". In prescriptive CAZs, the following might be applied:

- Road closures for all vehicles within the zone (a form of access management).
- Direct bans for certain vehicle types or industries (e.g. no construction allowed within the zone).
- Emissions standards for vehicles or other machinery (only vehicles / machinery that meets the minimum standard is allowed to operate within the zone).

In a prescriptive CAZ, the above restrictions are binding, i.e. there is no compensation that can be paid, or agreement to be made to allow the activities to take place in the CAZ (aside from pre-agreed exemptions).

2.5.2 Market-based

The market-based regulatory approach can be summarised with the message "We encourage you not to". In market-based CAZs, the following may allow access to the zone:

- A payable access charge may be introduced to allow the more polluting vehicles / activities to take place in the zone, as long as a compensatory payment is made .
- The pricing of parking might be increased to discourage people driving into the CAZ, or be preferential towards certain vehicle types.
- There may be the option to purchase permits in order to drive more polluting vehicles / carry out polluting activities within the CAZ.
- There may be other incentives to not taking a polluting vehicle / doing a polluting activity within the CAZ, for example: subsidised / free public transport within the CAZ, subsidised / free bike hire within the CAZ, free parking for electric vehicles within the CAZ.

In a market-based CAZ, polluting activities are unlikely to be stopped immediately or entirely, but the introduction of penalties and incentives can help to encourage a shift away from the more polluting options.

[12] Guidelines on Dust mitigation measures in handling Construction material and C&D wastes, CPCB, MoEFCC, 2017, https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvNTYxXzE1MTE5MzMzNzJfbWVkaWFwaG90bzEyNjcxLnBkZg==

Case study: Singapore's Electronic Road Pricing System

Singapore's Electronic Road Pricing (ERP) system is run by the Land Transport Authority (LTA), a statutory board under the Ministry of Transport Singapore which spearheads transport developments across the city. The ERP system first launched in 1998, using smart cards and radiofrequency identification (RFID) to collect toll charges as vehicles drive through automatic, electronic barriers ('gantries') on frequently congested roads in the city.[13] All vehicles driving within Singapore, except for a few exemptions, are required to have in-vehicle units from which the toll is deducted from.

The ERP system aims to manage congestion in Singapore, as well as reduce air pollution on the busiest roads and highways. Motorists are charged higher rates when they use specific priced roads during peak (congested) times. The automated system varies the rates charged depending on the route, time, and local travel conditions.

In 2021, work is set to begin on the ERP's new Global Navigation Satellite System (GNSS)-based network that will remove the need for the charging gantries, but involve installation of a new type of in-vehicle unit for toll charges.

[13] https://www.zdnet.com/article/singapore-readies-satellite-road-toll-system-for-2021-rollout/

3 Defining the scope of a Clean Air Zone

The following sections outline the main considerations when defining the scope of a CAZ, as well as the options that are available within each category.

3.1 Pollutant(s) targeted

CAZs should be implemented in response to a clearly defined air quality problem, seek to address and continually improve it, and ensure the actions within the CAZ are understood locally. Therefore, it is vital to understand which pollutant or pollutants the CAZ is targeting, and ensure the scope of the CAZ will help reduce the levels of those pollutants.

3.1.1 Particulate Matter

Particulate matter has been identified as the main pollutant of concern for cities in India and Mexico. Particles with a diameter of 10 microns or less can penetrate deep into the lungs, and particles with a diameter of 2.5 microns or less can even penetrate the barrier of the lungs and enter the bloodstream; both pollutants can cause serious health issues. The World Health Organisation (WHO) has stated that for PM_{10} and $PM_{2.5}$ no threshold has been identified below which no damage to health is observed.[14]

The main sources of PM pollution in a city are likely to be:

- Diesel vehicle exhaust emissions
- Poor vehicle maintenance / oil burning
- Non-exhaust emissions from brake pads, tyres, and road dust
- Dust from construction and/or demolition processes
- Solid fuel burning (e.g. heating and cooking)

3.1.2 Nitrogen oxides

Nitrogen oxides (NOx and/or nitrogen dioxide, NO_2) are the major pollutants of concern in many cities in Europe. NO_2 can contribute to serious inflammation of the airways, bronchitis, and reduced lung function growth.

The main sources of NOx / NO_2 pollution in a city are likely to be:

- Diesel vehicle exhaust emissions
- Power generation
- Heating

3.1.3 Other pollutants

Although PM, NOx and NO_2 are the main pollutants of concern from road transport, other pollutants may also be targeted within a CAZ.

Sulphur dioxide (SO_2) is produced via the burning of sulphur-containing fossil fuels for domestic heating, power generation and motor vehicles. SO_2 can adversely affect the respiratory system and lung function, as well as causing inflammation of the eyes. According to the WHO,[15] hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels, and evidence shows health effects at much lower concentrations of SO_2 than was previously thought. The combination of SO_2 and water gives sulphuric acid, which is the main component of acid rain.

Ozone (O_3) is formed via a photochemical reaction of pollutants such as NOx, and VOCs, that are often emitted from vehicles, solvents and industry.[16] High concentrations of O_3 are associated with sunny

[14] Ambient (outdoor) air pollution fact sheet, WHO, 2018, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
[15] Ambient (outdoor) air pollution fact sheet, WHO, 2018, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
[16] Ambient (outdoor) air pollution fact sheet, WHO, 2018, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

weather due to the photochemical nature of the reaction. O_3 may cause breathing problems including lung diseases, reduced lung function, and triggering of asthma, at higher concentrations.

3.2 Scope of restrictions

To have the greatest impact, a CAZ should target high activity, high pollution, and/or high population density areas where exposure to pollutants is most serious. The scope of restrictions in a CAZ should be logical and evidence-based. The following aspects should be taken into consideration when setting out the scope of the CAZ restrictions.

3.2.1 Types of vehicles

When considering the types of vehicles that will be restricted in the CAZ, there is a balance between restricting a great enough proportion of the vehicle fleet to have a significant impact on pollution levels, but not restricting an unnecessarily high amount of vehicles from operating within the CAZ, which may have knock-on effects for the community and local economy. The following questions may help determine which types of vehicles should be restricted from entering the CAZ:

- ***Which types of vehicles make up the greatest proportion of the vehicle fleet operating within the city, and within the CAZ area?***
  To answer this question, data on the vehicle fleet will be required – for more information, see Section 4.1. The type(s) of vehicles being restricted from entering the CAZ must make up a large enough proportion of the fleet so that removing them from the CAZ area has an impact on pollution levels. For example, restricting heavy goods vehicles (HGVs) from entering the zone will not have a large impact on air pollution if the majority of the fleet comprises private cars.
- ***Which types of vehicle contribute the most to pollutant levels in the city, and in the CAZ area?***
  Different types of vehicle tend to contribute more pollution, although this will also vary by the age of the vehicle, fuel type, and the pollutant of consideration. In general, larger, heavier, diesel-powered vehicles like HGVs, buses, or other machinery (NRMM, waste collection vehicles, etc.) contribute more pollution per vehicle than other vehicle types.
- ***Which types of vehicle will it be feasible to restrict from entering the CAZ?***
  Although the desire may be to restrict all vehicles from entering the CAZ, it may not be practical or feasible to do so. Depending on the type of enforcement being considered (see Section 3.4) certain vehicle types may not be able to be restricted (e.g. physical enforcement via bollards would still allow motorcycles to enter the zone). The feasibility of restricting vehicles with important roles within the zone, for example delivery vehicles, emergency services, also needs to be taken into account – this can be considered within ‘exemptions’ (see below).

There are many examples of CAZ/LEZ that have only been applied to one, or a few, types of vehicle. In Oxford, a bus-based LEZ was in operation from 2014,[17] in London there is now a LEZ specifically for NRMM (see Section 2.4), Singapore plans to have an environmental zone specifically for motorcycles,[18] and other LEZs may only restrict HGVs.

Example: In Helsinki, the capital of Finland, the environmental zone only applies to buses and waste management HGVs (dustbin lorries / garbage trucks). These vehicle types must be at least Euro 5 standard or cannot enter the zone.[19]

[17] https://www.oxford.gov.uk/info/20299/air_quality_projects/208/oxfords_low_emission_zone_lez
[18] https://www.green-zones.eu/en/blog-news/singapore-introduces-environmental-zone
[19] Helsinki Low Emissions Zone, Urban Access Regulations https://urbanaccessregulations.eu/countries-mainmenu-147/finland/helsinki-ar

3.2.2 Emissions standards

Setting emissions standards for vehicles entering the CAZ is a common alternative to a blanket ban on all vehicles from entering the zone. If this type of restriction is to be implemented, the standards for every type of vehicle must be clearly set out, so those attempting to enter the zone know exactly what is expected of them. The consequences for not meeting the required emissions standards must also be set out.

There are a number of factors to consider when setting emissions standards for a variety of vehicle types:

- **Type of vehicle** – car, HGV, light goods vehicle (LGV), bus, coach, taxi, private hire vehicle (PHV), etc.
- **Fuel type** – petrol, diesel, hybrid (of which there are many forms), battery electric vehicle (BEV), hydrogen, liquified petroleum gas (LPG), biofuel, etc.
- **Retrofitting** – how the vehicle standards apply where a diesel particle filter (DPF) or selective catalytic reduction (SCR) has been installed.
- **Type of emissions standards** – there are a number of different types of emissions standards worldwide, including Bharat Stage (India), Euro standards (Europe and others), California Air Resources Board (CARB, United States of America). It is important to set the same type of emissions standard for all vehicles in the CAZ, so the standards are comparable between vehicle types.
- **Emissions standard currently available / in circulation** – the highest standard of vehicle available, and the most common standard of vehicle in circulation in the city and within the CAZ should be considered. Different vehicle types have different standards available, for example the highest Euro standard for a motorbike is currently Euro 5, but for a petrol car the highest available standard is Euro 6(d). It may not be feasible to set the requirement for entering the CAZ to the highest possible emissions standard for every vehicle type in the first instance, but higher vehicle standards should be introduced over time.

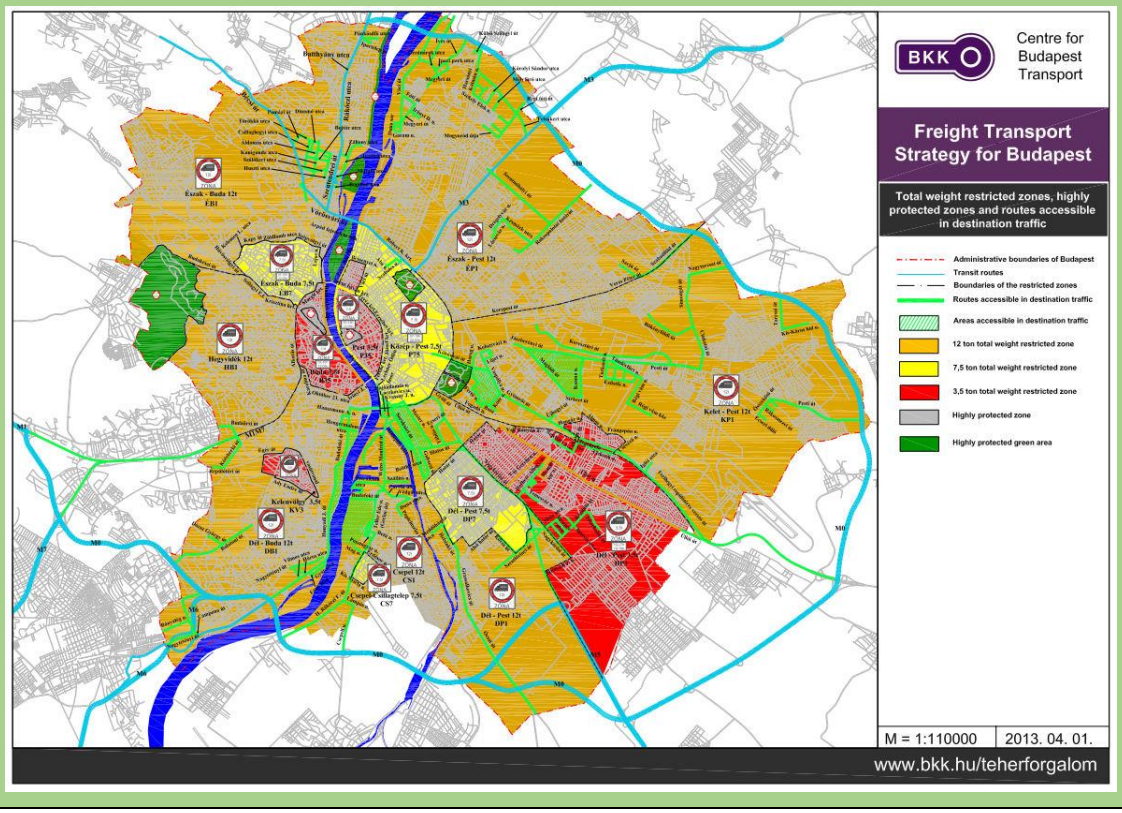
3.2.3 Boundary/ies of the zone

The CAZ boundary will signify the point at which the restrictions come into force. A CAZ could be made up of multiple smaller areas, with different restrictions, or be one large area. Often, city centres, ports, dense residential areas, shopping areas, or tourist sites might be targeted for a CAZ. Highly congested areas, or densely populated areas where the safety, environmental, and/or health risks are highest, should be considered to have the maximum impact on air pollution and human health.

The boundary of the CAZ should be clearly defined, making it easier for people to comply with the rules. It is often helpful to make use of clear and recognisable markers for the boundary of the zone that are already present in the city – these could include ring roads, rivers, green spaces, or pedestrianised areas. Evidence must be provided to support the proposed boundary; this might include land use, the number of residents, the number of businesses, the current road network, schools present, hospitals present, heritage or tourist sites.

There is value in mapping out a number of potential boundaries for the CAZ. The initial boundary should be the smallest, and may be used as a trial while people get used to the requirements, enforcement and supporting measures offered alongside the CAZ. As the CAZ becomes more accepted over time, the boundary could be expanded, enabling the air quality benefits from the CAZ to expand with it. Further information on this is provided below under ‘introduction’.

Example: There are 11 'protected zones' and 15 'restricted zones' in the city of Budapest (Hungary). The protected zones consist of historical sites, or recreational green sites, with no vehicular traffic at all. The restricted zones are certain parts of the city where HGVs need an entry permit to enter. The cost of the permit depends on their total weight and vehicle emissions. The zones also operate at varying times of day.[20] The map of these boundaries is shown below:



3.2.4 Time of day

Many CAZs operate 24 hours a day, seven days a week. However, there is also the option to employ restrictions only at certain times of the day. As with the other considerations in this section, the evidence base behind choosing the time for restrictions to apply is vital. Useful evidence might include: hourly concentrations of pollutants, diurnal profile of footfall (people walking in and around the zone, i.e. level of human exposure), diurnal traffic profile in and around the zone, and the type of enforcement that is planned for the zone.

If there is strong evidence to suggest that air pollution is only high at certain times during a 24-hour period, and these coincide with high vehicular traffic and high footfall, then it may be appropriate to only restrict access to the zone during these periods. Applying restrictions to a certain time of day also allows for those on lower incomes to access the CAZ outside of the charging hours, thereby avoiding charges or penalties. However, having a shorter time period during which restrictions are active also reduces the impact of the CAZ on air pollution.

Example: The city of Sofia, in Bulgaria, operates access restriction in two zones: the 'Central Zone' and 'Zone 1' (surrounding the Central Zone). Both zones restrict heavy vehicles from entering during the day, every day of the year:

- Vehicles over 4 tonnes cannot enter the Central Zone from 07:00 – 21:00.
- Vehicles over 15 tonnes cannot enter Zone 1 from 07:00 – 22:00.[21]

[20] Budapest Access Restrictions, Urban Access Regulations https://urbanaccessregulations.eu/countries-mainmenu-147/hungary/budapest
[21] Sofia Access Restriction, Urban Access Regulations https://urbanaccessregulations.eu/countries-mainmenu-147/bulgaria/sofia-ar

3.2.5 Levels of charging

If the CAZ is to involve charging, the city should set the levels of charge for vehicles entering the zone that are appropriate to the local circumstances. In setting the level of charge, the behaviour change needed to deliver the ambitions for the zone; the local economic and social factors of the zone and surrounding areas; and the operational costs of running a scheme, must be considered.

Example: In the UK, the Transport Act 2000 requires any excess revenue that may arise from CAZ charges to be re-invested in local transport policies. These policies should aim to improve air quality and support the delivery of the ambitions of the CAZ. The charges must not be used as a form of taxation to raise revenue generally.

Case study: Oxford ZEZ

The city of Oxford in the UK is implementing a ZEZ. The ZEZ will be based on a road user charging scheme, similar to many other CAZs in the UK.

In the Oxford ZEZ, different charges apply to different categories of vehicle, depending on the emissions.[22] When the scheme launches, the lesser polluting vehicles will pay a smaller charge than the more polluting vehicles. The first (2021 to 2025) and second (2025 onwards) stages of the scheme can be seen below, along with the charging time (7am to 7pm, daily).

Band	**Emissions**	**Daily charges (applies 7am - 7pm)**	
		Up to July 2025	**from August 2025**
Zero emission vehicle	0 g/km CO2	£0	£0
Ultra-low emission vehicle	Emits less than 75 g/km CO2 National ULEZ standard will be adopted for HGVs when defined	£2	£4
Clean Air Zone compliant vehicle	Euro 4 petrol Euro 6 diesel	£4	£8
Others	Any vehicle not meeting any of above standards	£10	£20

As well as Zero Emission Vehicles (ZEVs) being exempt from paying the ZEZ charge, residents and businesses within the ZEZ, and disabled Blue Badge holders are set to have partial exemptions from the above charges.

3.2.6 Exemptions

There are a variety of exemptions to consider for a CAZ, which will depend on the scope of the restrictions being imposed. Exemptions provide a degree of flexibility in the restrictions to ensure certain vehicle types can continue to operate partially or completely as normal.

In general, there are three categories of exemption:

- **Complete exemption** – these exemptions would be granted full access to the CAZ, with no charge or penalty to pay for accessing the zone.
- **Partial exemption** – this type of exemption might include some form of penalty for entering the zone, but a penalty that is discounted from the standard restrictions of the CAZ. For example, there might still be a charge to pay for entering the CAZ, but at a cheaper rate.

[22] https://urbanaccessregulations.eu/countries-mainmenu-147/united-kingdom-mainmenu-205/oxford-zez

- **Temporary / transitional exemption** – this type of exemption could be full or partial, but it only applies for a temporary or transition period. Temporary exemptions are common for businesses and residents in the zone because they are unlikely to have the option of avoiding driving into the CAZ altogether. Temporary exemption allows these groups time to plan for and adjust to the CAZ restrictions.

Common exemptions include:

- Zero-emission vehicles (e.g. BEVs)
- Emergency service vehicles (e.g. police, ambulance, fire engine)
- Vehicles for the transport of people with a disability
- Vintage vehicles
- Fairground or market vehicles
- Municipal vehicles (e.g. waste collection, vehicles specially equipped for maintenance and inspection of public installations / infrastructures)
- Motor homes (as these may be classed as a dwelling)

When considering exemptions, it is important not to undermine the effectiveness of the CAZ. Exemptions for certain groups, or types of vehicles should be granted carefully and follow a strict timeline. Otherwise, there is the risk of these exemptions being exploited and causing the CAZ to not have the maximum impact on air pollution.

3.2.7 Introducing a CAZ

It is recommended that CAZs are introduced incrementally and grown progressively over time, either by increasing the strictness of restrictions or by increasing the geographic coverage of the zone. In theory, this should reduce resistance to adoption of the CAZ, and may even be more affordable for the city. Most LEZs or CAZs have at least two stages; this allows temporary exemptions during the first stage, and removal of these exemptions (along with potential strengthening of restrictions and expansion of the CAZ area) during the second and subsequent stages.

In developing a zone it is important to recognise that the longer businesses and individuals have to make these changes the easier it will be for them to do so, and therefore more likely they will, but this needs to be balanced by the ongoing health impacts of pollution.

For users of the CAZ to adapt their behaviour and switch to cleaner vehicles or other forms of mobility, a clear and predictable calendar of the changing restrictions must be established and communicated. Such calendars are also relevant for tourists, for whom the lack of information and transparency is a problem, even in places like Europe where a database on LEZs exists.

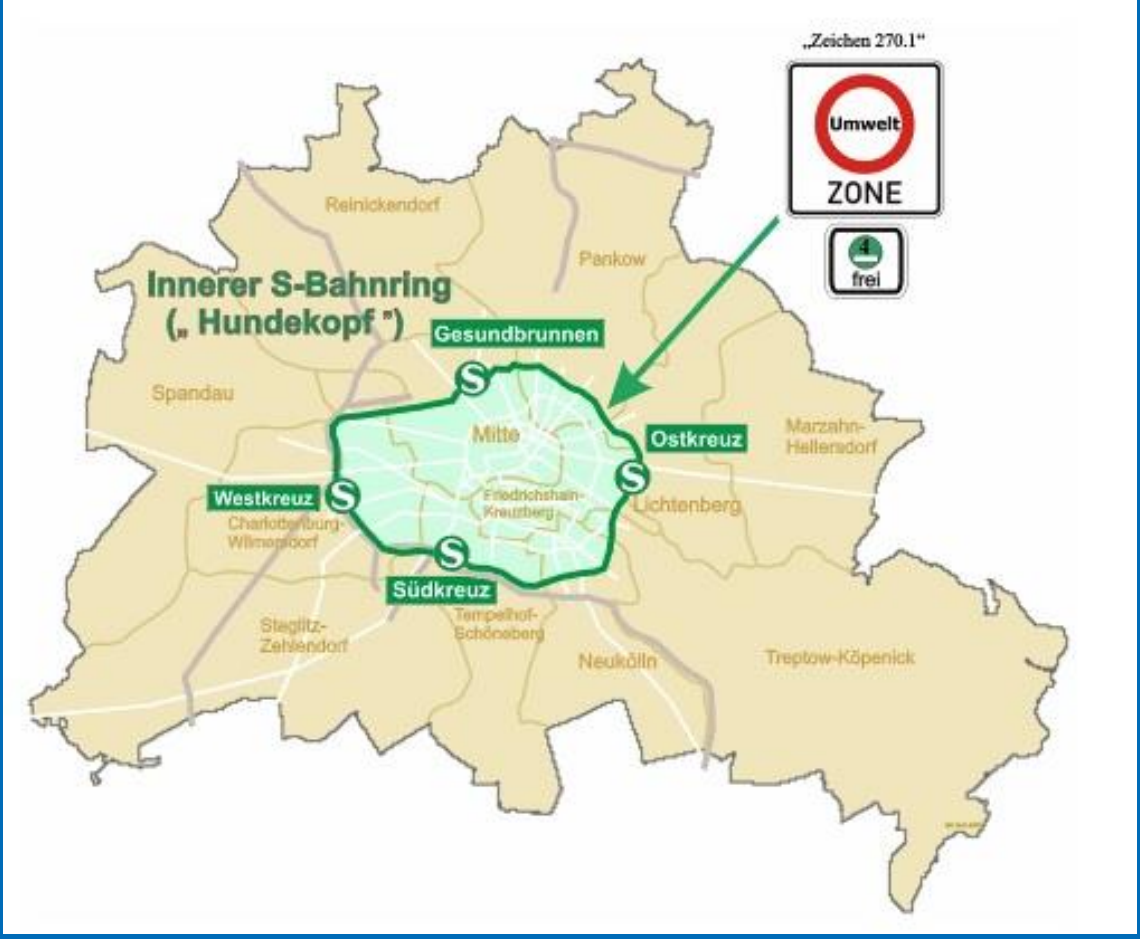
Case study: Berlin's LEZ

The Berlin City LEZ or 'Umweltzone' covers approximately one tenth of the total area of Berlin and is situated in the city centre.

The LEZ was implemented in two stages:

1. From 1 January 2008, all diesel vehicles were required to be at least Euro 2 to enter the zone, and all petrol vehicles had the requirement of Euro 1 or above.
2. From 1 January 2010, the diesel vehicle standard was raised to Euro 4, and the petrol vehicle standard remained at Euro 1.

The boundary of the Berlin City LEZ, which is shown below,[23] did not change when moving from Stage 1 to Stage 2.



There is also a 'Diesel Euro 6 LEZ' that came into place on eight streets in Berlin from July 2019. All diesel vehicles travelling on those streets must be at least Euro 6. As of June 2021, the improvement in air quality was such that four out of the eight streets had their LEZ requirement removed.

3.3 Legal basis

There are two basic approaches to the legal basis for a LEZ:

- ***Prescriptive or regulatory* mechanisms** – this is a direct ban or restriction on certain types of vehicles accessing and area. These types of powers are typically used for defining pedestrian areas, bus lanes or weight and size limits. However, that can also be used to ban vehicles based on the emissions performance. These powers many be set at the national or state level and may need adjustment to allow there use for restricting vehicles by emissions performance.

[23] https://urbanaccessregulations.eu/countries-mainmenu-147/germany-mainmenu-61/berlin

- ***Financial or charging mechanisms*** – this is an alternative approach where rather than directly restricting vehicles financial penalties or even incentives are used to strongly discourage the post polluting vehicles from entering an area. This may be based on more general road user charging powers or could be related to parking charges. Again, they may be set at the national or state level and may need adjusting to allow use in respect of vehicle emissions.

An alternative approach focusing on specific vehicle types rather than areas is the use of ***vehicle licensing powers***. The classic example here is taxi licencing powers that could be used to set age limits or emission standards for taxis operating in a city. These overall powers are often defined at the national or state level but implemented locally by the city. Bus are another class of vehicle that may be managed specifically as they may be owned and operated by the city or regulated by the city.

Case study: Clean Air Zones in England and Low Emission Zones in Scotland

In the UK both a charging approach, in relation to Clean Air Zones in England, and a regulatory approach, with regards to Low Emission Zones in Scotland, have been used.

In England they have opted to user road charging powers as the basis for Clean Air Zones (and the London LEZ/ULEZ). These powers were set out in the Transport Act 2000,[24] a piece of national government legislation in the UK. Part III of the Act focuses on road user charges and workplace parking levies. This section empowers local authorities (as "charging authorities") to make a local charging scheme in respect of the use or keeping of motor vehicles on roads.

Matters to be dealt with in charging schemes by charging authorities include:

- Designating the roads and classes of vehicles (type and emissions standard) subject to a charge.
- The charges imposed.
- The manner in which charges are to be made, collected, recorded and paid.
- The period for which a scheme is in force.
- Exemptions and reduced rates from charges.
- Enforcement regimes and penalties for non-payment of charges.

The Clean Air Zone Framework[25] was published in 2017, guiding authorities on how to implement a CAZ using the above powers.

In Scotland they opted for a regulatory approach based on Traffic Regulation Orders defined under the Road Traffic Regulation Act 1984[26] to directly restrict vehicles not meeting specific standards. This basic legislation was then adjusted to set common standards and enforcement powers through the Transport (Scotland) Act 2019.[27]

3.4 Enforcement

Enforcement of CAZ requirements is vital in ensuring that those entering the zone comply with restrictions, and that the impact of the CAZ is fulfilled. There are three main types of enforcement, each with a variety of options; each city will have a preference for the best way for them to enforce their CAZ.

3.4.1 Physical

Physical enforcement of a CAZ could include barriers, bollards, road closures, and signage. For CAZs that are permanent (operating 24 hours a day, seven days a week) and those that operate for all types (e.g. access management and/or a pedestrian-only area) physical enforcement could be the simplest way to ensure the restrictions of a CAZ are adhered to. However, physical enforcement can also take into account restrictions that only apply to certain vehicle types, as well as exemptions. For example,

[24] Transport Act 2000, UK Government, https://www.legislation.gov.uk/ukpga/2000/38/contents
[25] Clean Air Zone Framework, Principles for setting up Clean Air Zones in England, Defra, February 2020, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863730/clean-air-zone-framework-feb2020.pdf
[26] Road Traffic Regulations Action 1984, https://www.legislation.gov.uk/ukpga/1984/27/contents
[27] Low Emission Zone provision in the Transport (Scotland) Act 2019, https://www.transport.gov.scot/our-approach/transport-scotland-act-2019/low-emission-zones-and-the-transport-scotland-bill/

some bollards can be raised or lowered depending on who is being allowed into the zone, and roads can be closed for certain vehicle types, with this explained via clear signage.

3.4.2 Manual

Manual enforcement is perhaps the most common type of enforcement in Europe, often in the form of permits, sticker systems, and manual vehicle checks. Where permits or sticker systems are concerned, it is vital that there are clear instructions on how to obtain permission to enter the CAZ, and how long this process is likely to take so drivers can prepare before their journey. In particular, visitors to the city who are unfamiliar with the CAZ must have access to this information, and there must be a suitable way to demonstrate exemptions.

3.4.3 Automatic

Automatic enforcement is likely to give the highest rate of enforcement and therefore potentially the greatest success for the CAZ. Automatic Number Plate Recognition (ANPR) cameras, or tags on vehicles can be used to automatically determine whether a vehicle meets CAZ restrictions or contravenes. Automatic enforcement systems tend to be a more expensive investment than manual or physical enforcement, however, if the CAZ is likely to be in place for a number of years then the investment may be worthwhile.

3.5 Supporting measures

The restrictions imposed within a CAZ must be complemented by the introduction of supporting measures to ensure that those impacted by the restrictions can manage the changes, and that benefits are equitable. ‘Supporting measures’ covers a wider range of actions, including financial support for citizens and small businesses switching to cleaner vehicles (e.g. scrappage schemes), ensuring bus routes and cycle paths reach low income areas, and community outreach to allow a smooth transition into the CAZ restrictions as they are implemented, among many others.

The sections below describe some of the most impactful supporting measures that could be implemented alongside a CAZ.

3.5.1 Informative measures

Informative measures are perhaps the most important type of supporting measure, as this category covers all the methods by which the CAZ’s purpose, and restrictions by which this purpose will be achieved, are communicated to the public. CAZs are likely to receive resistance from the public; clear communication should be used to inform, educate, and minimise resistance where possible.

Signage

Effective signage is critical for the successful implementation of the CAZ. Signage should be particularly clear at all possible entrances and exits along the boundary of the CAZ to ensure that anyone entering or leaving the zone is aware that they are doing so.

Other important information that could be displayed on CAZ signage includes:

- What vehicle types the restrictions apply to.
- Hours the CAZ restrictions are in operation (even if only to confirm the CAZ is constant).
- The type of enforcement in place (e.g. traffic officers, sticker system, ANPR cameras).
- Where to go to get all the information that is not on the sign.
- How drivers can avoid entering the zone.

A balance must be struck between including enough useful information and ensuring drivers can take in all the relevant information from the sign(s) whilst driving safely.

Example: CAZ and other supporting measures signage prepared for various locations in the UK:[28]

Communication and educational strategies

It is recommended CAZs are accompanied by a strategy for engaging and informing the community, to ensure they understand the importance of good air quality, the choices available to them, the impacts they make and how these contribute to a successful CAZ. People are more likely to become engaged with and support the CAZ measures if they have first-hand experience of the problem, if the actions to address air pollution are visible, and have clear results. It's vital to present the problem and the solution(s) together – this will enable people to feel empowered to take action to improve air quality, rather than feel anxious about it.

Examples of communication and educational strategies could include:

- Interactive applications and/or websites, using real time air pollution monitoring.
- Advertisements in and around the proposed CAZ area, as well as on public transport.
- Educational activities in schools.
- Educational leaflets / posters / activities in community groups, health centres and doctors surgeries.
- Providing advice and alerts during high air pollution episodes.
- Working with local businesses to help raise awareness among employees.

[28] Details of non-standard traffic signs approved in England since 1 January 2011, Department for Transport, https://www.dft.gov.uk/traffic-auths/

- Engaging the public through citizen science projects, such as low-cost air quality monitors.

Demonstrating progress and maintaining engagement throughout and beyond the lifetime of the CAZ is also important. Air pollution can be substantially improved if decisive action is taken on emission sources. If pollution sources are removed then air quality will improve, and will stay that way so long as the emissions do not return to their original levels.

Events

Events in and around the CAZ are a great way to promote the importance of clean air, whilst informing residents and visitors about the restrictions.

- A launch event for the CAZ can serve as a promotional event, as well as being very clear on when the restrictions begin.
- 'Car-Free' Days could be used as a trial for the CAZ during the planning process (if this is feasible). As well as demonstrating what life in the new CAZ could look like, 'Car-Free' Days provide an opportunity to test the reaction of the general public to the restrictions.
- Other social events (which should be combined with the communication and educational campaigns above) could take place involving local schools, universities, societies, businesses, health centres, and clubs.

Example: Birmingham in the UK launched its CAZ on 1 June 2021 with a public event. Harmless smoke was released from the top of the Library of Birmingham, demonstrating the average amount of NOx the CAZ will save every ten seconds in the city. The publicity campaign for the CAZ uses the hashtag #brumbreathes. A video compilation of some of the highlights of the launch can be viewed at https://www.youtube.com/watch?v=30Bg9XK-jzU

In the months leading up to the launch, Birmingham City Council provided a series of webinars to help residents, commuters to the city centre, and local businesses, to prepare for the CAZ restrictions. There were at least two dates and times for each webinar, as well as a monthly series of webinars aimed specifically at providing support to businesses.[29] The webinars were in addition to all the relevant information being available online at www.brumbreathes.co.uk

3.5.2 Management measures

Management measures support the smooth operation of the CAZ restrictions throughout its lifetime. These types of measures may make it more likely that people comply with the restrictions of the CAZ, make enforcement easier, or similar. Other restrictions provide incentives for people to transition to less polluting forms of transport or go beyond the minimum requirements of the CAZ restrictions (see Section 3.5.3).

Increased emissions testing

It's vital for citizens to have access to a way of determining the emissions standard of their vehicles, and increasing emissions testing in a CAZ city will allow for greater compliance with the CAZ requirements. Emissions testing for private and commercial vehicles should be convenient and affordable, therefore increasing testing uptake.

Depending on the type of enforcement of restrictions in the zone, increased emissions testing may make a huge difference to the easiness of this enforcement. For example, greater emissions testing would make issuing permits or stickers for vehicles simpler, or could be used to have an up-to-date database for ANPR cameras.

A co-benefit of increasing emissions testing in a city is that it may generate new jobs for residents, which may be more important depending on how businesses operating within the CAZ are affected by the restrictions.

[29] Birmingham City Council launches a series of Clean Air Zone webinars, February 2021, https://www.birmingham.gov.uk/news/article/806/birmingham_city_council_launches_a_series_of_clean_air_zone_webinars

Amending the road network

It may be necessary or beneficial to amend the road network surrounding the CAZ, depending on the type of restrictions being implemented:

- If the CAZ is prescriptive (i.e., "you must not" / complete bans on certain types or standards of vehicle), it may be necessary to have permanent changes to the road network, or diversions on the roads in the vicinity of the zone, as some vehicles will not be allowed to enter the zone at all.
- Even if the CAZ is market-based (i.e., "we encourage you not to" / charge or penalty-based entrance to the zone) there will still be a proportion of non-compliant vehicles that choose not to enter the zone, to avoid paying the penalty or charge. Therefore, the roads and routes that drivers can take to bypass the zone must be able to cope with additional traffic, especially without transferring the air quality problem from within the CAZ to outside it.

In both of these cases, the road network may require amendments (e.g. widening of lanes) to accommodate greater volumes of traffic, diversions, and also an increase in pedestrian and bicycle traffic.

Additional parking near the Clean Air Zone

Creating additional parking facilities near to the CAZ can be useful in a number of ways:

- If the CAZ is already located at a tourism / heritage area, or the aim is to establish the zone as a social hub, then additional parking will be required to accommodate visitors to the zone, without having to drive into the zone.
- If the CAZ is prescriptive (i.e., features a ban where some vehicles cannot enter the zone at all) then parking outside of the zone is vital to allow people to access the zone, even if they cannot drive into it.
- To encourage active travel or mode shift (e.g. to public transport), park & ride or bike & ride services could be established away from the CAZ, with the opportunity for people to walk, cycle, or catch the bus into the zone.

As with parking inside the CAZ, there is the potential to generate significant revenue from charging for the use of parking spaces near the zone. This revenue could be used for improvements to the CAZ and the surrounding area. However, as with other measures that extend outside the CAZ, the impact on air quality (and ensuring the air pollution does not move from within the CAZ, to elsewhere in the city) must be considered and quantified.

3.5.3 Support for vehicles / alternative transport

The final set of supporting measures for a CAZ are those measures that encourage people to make changes to their travel habits, either by increasing the number of choices available, making these options more convenient and affordable, or providing incentives.

It's particularly important to provide residents and businesses with attractive low-impact alternatives to receive the same level of service. Ensure that the LEZ supports walkability and public transit for residents, and that businesses have access to cost-competitive low-emitting safer last-mile delivery solutions.

Support for Electric Vehicles

Support for EVs falls under two categories: infrastructure, and incentives. When considering the combination of infrastructure requirements and incentives, the balance must be struck between the cost of the action, and the impact it is likely to have on the uptake of EVs.

Adequate EV infrastructure ensures that the CAZ can cope with an uptake in EVs. Considerations include:

- Power supply and connection to the grid (continuous electricity supply, voltage, appropriate cabling)

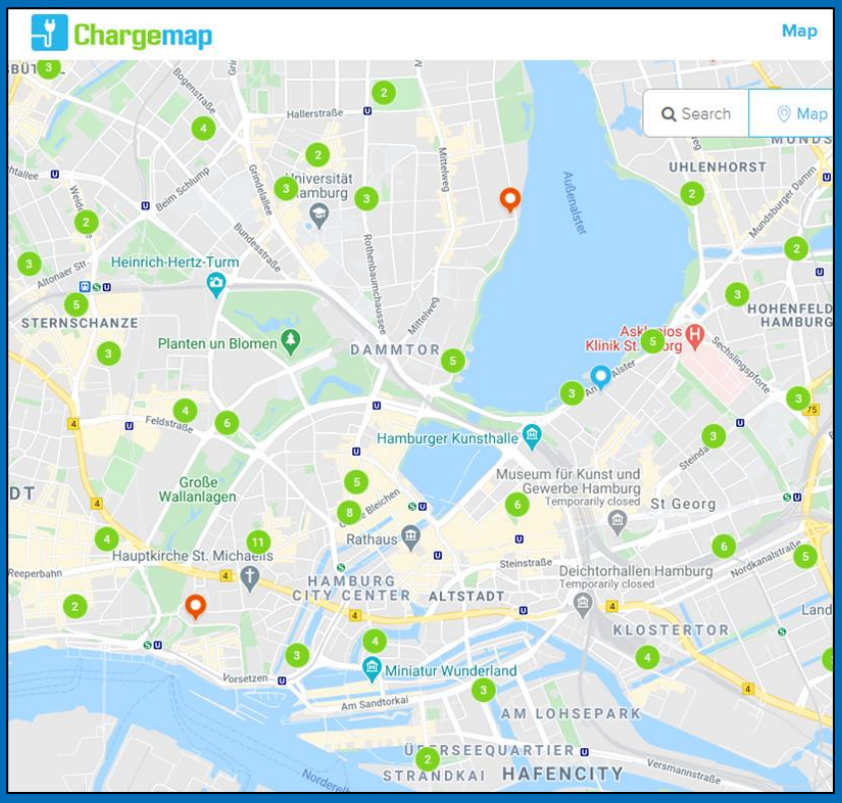
- Current network of EV chargers and parking spaces (including location of chargers and types of chargers – slow, medium, fast, rapid)
- Demand for public, workplace, and residential chargers
- Current provision of EVs in the city (cars, buses, taxis, e-bikes, etc.)
- Estimated uptake of EVs in the city (same as above)

Incentivisation for uptake in EVs can come in many forms:

- Funding or grants for purchasing an EV
- Tax breaks
- Free, discounted, or priority parking inside the CAZ
- Free or discounted entry to the CAZ (if applicable)
- EV-only road access / lanes (similar to bus lanes)
- Ensuring charging an EV is cheaper than fuelling a vehicle powered by an ICE

Case study: EV infrastructure and incentives in Hamburg, Germany

Hamburg in Germany has been incorporating EV infrastructure into the city for over ten years. EV charge points in Hamburg can be located using the mapping service ChargeMap, as shown in the figure below.[30]



Another example of the continuously expanding charging infrastructure is the number of payment options available to those who wish to charge their EV at a public charge point in the city. Spontaneous access (charging via SMS or app) was introduced at all charging stations in 2015.[31] The E-charging Hamburg website explains how to use each of the four payment options: SMS, app (both Direct Pay), charging card (RFID) and billing.

A dedicated website to electromobility in Hamburg provides a number of useful webpages detailing the subsidies available to those wishing to purchase an EV, explains other incentives such as tax breaks, and also provides information about public and commercial charging infrastructure.[32]

[30] Chargemap, 2021, available online at: https://chargemap.com/map
[31] E-charging in Hamburg, https://www.e-charging-hamburg.de/so-funktionierts/
[32] Electromobility in Hamburg, https://elektromobilitaethamburg.de/

Increased public transport

Comprehensive public transport infrastructure is required to ensure that the public transport system is an attractive alternative to travelling via private vehicle – especially in and around the CAZ. The key characteristics of a good public transport service are:

- Needs-based – the network should ideally cover the entire city, especially public points of interest such as supermarkets, shopping centres, major workplaces, and tourism hotspots. Central traffic hubs in the travel hotspots should be used as mobility stations, enabling users to switch to bus, rail, or active travel.
- Competitive pricing – travelling via public transport should have a comparable, if not more affordable, cost when compared to travelling via private vehicle. Reasonable pricing and discounts for daily, weekly, monthly, or even annual tickets are likely to increase the use of public transport systems due to value for money and ease of use.
- Simple payment system – different modes of public transport might have a common ticket provider, and/or a single way to pay for all types of transport in the city. As many modes of transport as possible should be included under one ticketing and tariff system, making it simpler for travellers to transfer between modes, especially at short notice.
- Accessible – public transport should be accessible to people of any age, level of income, or those with disabilities. For example, ramps allow access for those with mobility issues, as well as parents with prams, and people who wish to take their bicycle with them on their journey.
- Reliable – the public transport service must be on time and have an adequate level of service to accommodate the expected number of passengers. Users should be able to rely on the services to be safe.
- Comfortable – vehicles should have adequate room for the number of passengers, comfortable seating, temperature control, and maybe other benefits such as Wi-Fi or places to charge phones / laptops (e.g. for commuters).

Improvements to footpaths / cycle paths / other active travel options

Along with public transport, active travel is the other major transport option when moving away from private vehicles. As with encouraging EV uptake, and public transport usage, increasing active travel also revolves around two themes: infrastructure, and incentivisation.

Firstly, a strong cycle network creates good foundations for a culture of safe and comfortable cycling. A city's cycle network may consist of cycle-only routes, as well as shared spaces between cyclists and motor vehicles, and cyclists and pedestrians. In all cases, it is important that the routes have good quality surfaces, clear signage, and are safe for all users. A cycle network should be complemented by secure cycle parking facilities in and around the CAZ, as well as at transport hubs (such as bus or train stations). There may also be options to rent bicycles – this could be especially popular at tourist locations.

Improved footpath networks enable walking to become a viable option for travelling to work or school, and encourage walking for leisure. If the CAZ is to be a pedestrian-only zone, and social hub for the city, then the quality of footpaths is even more important. The ideal characteristics of a footpath network are largely similar to those of a cycle network:

- Footpaths should be wide enough to overtake others, or pass those going in the opposite direction.
- They should have a smooth surface that is easy to walk on.
- Roads and other obstacles should be easy to cross – for example pedestrian crossings with short waiting times.
- Pedestrians should be separate from bicycle traffic, as well as motor traffic.
- Noise pollution, odours and air pollution should be minimised for an attractive and healthy experience.
- Depending on the climate, there may be requirements for shade and/or shelter as well as places to rest (e.g. benches).
- Footpaths should feel safe – be constant (no gaps where one has to walk in the road), be well lit, away from roadsides and sharp drops, and may have barriers in place to protect users.

Co-benefits from uptake of active travel include reduced congestion, improved safety, improved air quality, increased exercise, and improved health (mental and physical) of citizens. In particular, showing that cyclists and pedestrians are a priority in the city will make these groups feel safe and valued, therefore, active travel is likely to increase further.

4 Assessing the potential impacts of a proposed Clean Air Zone

Once the proposed scope of the CAZ has been decided upon, an assessment must be made as to the impacts, positive and negative, that the chosen CAZ is likely to have on the city. The core impacts to assess are those on air quality, traffic, and the economy. Wider considerations that may be taken into account include health, social and political impacts, and wider environmental benefits (such as climate change).

The sections below briefly describe the considerations to be taken for these types of assessments (in the order they are likely to be completed in), including the data required, and what the results of the assessment can be used for.

4.1 Implications for traffic

The first assessment to be completed should be the impact on traffic as a result of the CAZ. At this stage, it should be established whether or not the road network can cope with the proposed restrictions of the CAZ. If not, then the scope of the CAZ must be revisited. Providing the road network can cope with the proposed changes, the results of the traffic assessment will then feed into subsequent assessments for air quality and other impacts.

4.1.1 Traffic counts

Traffic count data is the most basic form of traffic data and the easiest to collect. The options for traffic count data include:

- **Manual / automatic** – Manual traffic count data may be taken by a person counting and recording vehicles on a certain stretch of road. Automatic traffic count data can be collected using cameras, pneumatic road tubes or other sensors. Automatic traffic counts are likely to be more accurate and reliable, however, are also likely to cost more.
- **Location(s)** – The number and location of traffic count sites should be carefully considered. The greater the number of traffic count sites, the greater the resources and costs required to collect data. Placement of these sites should be strategic, in order to capture traffic on the routes most vital to the CAZ. These could include routes in and out of the zone, any roads that may act as a diversion to avoid entering the zone, and junctions or routes that are expected to experience an increase in road traffic as a result of the zone.
- **Duration** – The duration of the traffic count study should be representative of traffic on the road(s), not only on a single day, but on the 'average' day in order to inform the CAZ. Ideally, count data needs to be collected multiple times throughout the year to account for seasonal change (especially in tourist areas). Weekdays and weekends should be considered, as should the time of day – it is vital to collect traffic count data over at least a 24 hour period to account for changes in traffic during this time.
- **Level of detail** – There are many characteristics of vehicle traffic that can be collected, however, collecting all of them is likely to be more cost and resource intensive. Some characteristics can only realistically be recorded via automatic traffic counts.
    - Traffic volume is often collected as the Annual Average Daily Traffic (AADT).
    - Directional or two-way flows can be collected, depending on if the direction of travel is of importance.
    - Vehicle types and the categories that vehicles fall into must be clearly set out prior to the traffic count study. This is especially important to define if manual traffic counts are being taken. It must also be determined whether bicycle and pedestrian traffic is to be counted as part of the study.
    - Speed is a useful metric and may be possible to attain, although for manual and automatic counts a tool will be required.
    - Number plate information may be recorded – in some cases this might be linked to a database which provides more information about the vehicle (for example age, fuel type, emission standard).

Although traffic count data may be the most basic form of traffic data, it still provides valuable information that can inform the CAZ assessment:

- The information collected, especially AADT, is a vital input for transport and emissions modelling. If modelling cannot be completed, estimates of changes to traffic flows can still be obtained.
- Traffic count information from a variety of count points can be used to identify hotspots. It may also be sensible to complete more detailed traffic count studies in a specific area, depending on the results of the initial study or studies.
- Traffic count studies can be valuable tools for monitoring and evaluation. Prior to the implementation of any CAZ restrictions, traffic counts provide a useful baseline from which to assess the impact of changes to the road network. Subsequent traffic studies can be performed relatively quickly, at regular intervals, to gauge the impact on traffic at those locations once restrictions have been imposed.

4.1.2 Fleet information

Understanding the state of the current fleet within the CAZ and wider city road network is vital for the following tasks:

- **Determining the scope of the CAZ restrictions** – As described in section 3.2, the types of vehicles being restricted in the CAZ will depend on what types of vehicles are present in the city, and their contribution to air pollution (if known). There is not much point in restricting vehicle types that have little presence in the city, or those that do not contribute much to air pollution.
- **Estimating the emissions from the fleet** – The proportion of each vehicle type, age profile, and emissions standards profile are all important in calculating the predicted emissions from the vehicle fleet. This information can be used to determine which vehicle types contribute most to air pollution (source apportionment).
- **Predicting how the fleet may / will change over time** – The current fleet may be used, along with projections at the national level, or from other similar cities and/or countries, to estimate how the fleet might improve over time. This improvement may incorporate the natural progression of the fleet to newer, less polluting vehicles, as well as the CAZ actions that encourage faster uptake of low emission vehicles. If historical fleet data is available, it may also be possible to use this to help predict how the fleet will change in the future.
- **Emissions and air quality modelling** – Future fleet projections can be used to estimate transport emissions, and therefore air quality concentrations, in the future. A variety of fleet scenarios can be used to determine how much the fleet needs to improve in order for the required reduction in pollution to be achieved.
- **Monitoring and evaluation** – As with traffic count data, information gathered about the current state of the vehicle fleet can be used as a baseline from which to measure the impact of CAZ restrictions.

4.1.3 Transport modelling

Transport modelling uses mathematical relationships to model the choices that people might make when travelling around a (road) network, for example in a city. Transport models can be useful for the following tasks for assessment of CAZ impacts:

- Forecasting the number of trips on each road (with and without the CAZ).
- Projecting growth in traffic over time, e.g. for the year the CAZ is to be implemented.
- Testing out how different scenarios (for example with or without a CAZ, or with different scopes of CAZ restrictions) will impact traffic on the road network.
- Identify measures that could be taken to alleviate congested areas or traffic hotspots – and then test these out.
- The outputs from transport modelling can be entered into an emissions model, before being used in air quality dispersion modelling to predict how pollutant concentrations may change as a result of CAZ restrictions.

Setting up a transport model requires three main datasets in order to forecast accurately:

- Socioeconomic data – e.g. population, households, employment, etc.
- Network data – an accurate representation of the current transport network, as well as any planned changes.
- Validation data – information to check the validity of the transport modelling, e.g. Geographical Information System (GIS) files to compare the road network to, traffic counts to compare trip generation to, surveys to compare socioeconomic data to.

Transport modelling is the more accurate and flexible approach to assessing the potential impacts of CAZ restrictions on the (road) traffic network. However, this approach is likely to cost more, and be more time consuming than making predictions from traffic count data.

4.2 Air quality impacts

Following the traffic assessment, the air quality impact assessment will assess how the CAZ restrictions are likely to change air quality in and around the CAZ, but also importantly the wider city. As the purpose of the CAZ is to improve air quality, this is the most important assessment of impacts that will be made during the planning for the CAZ.

As well as being vital for demonstrating the potential positive effect the CAZ will have on air pollution, the results of the air quality assessment will also feed into subsequent assessments for other impacts such as economics, or health.

4.2.1 Air Quality monitoring

Most, if not all, cities will already have an established air quality monitoring network in place. However, additional monitoring may be necessary in order to adequately assess the impact of the CAZ restrictions on air quality. For example, there may not be enough monitoring stations, or any at all, in the vicinity of the proposed zone – in this case, it's worth considering adding additional stations to the monitoring network and/or a temporary, dense network of sensors to capture the impacts at the local scale.

There are, in general, three types of air quality monitoring network to consider:

- **Automatic / continuous** – These monitoring stations collect data continuously and automatically produce pollutant concentrations on a short timescale, for example hourly or even more often. They may also collect information on other parameters such as wind speed, temperature, or humidity. Continuous monitoring stations are expensive to install and maintain, but provide extremely valuable air quality information.
- **Non-automatic / manual** – Non-automatic networks measure less frequently compared to automatic networks (e.g. daily, weekly or monthly). In some cases, such as in India, manual monitoring stations are operated twice per week for 24 hours at a time, collecting data including pollutant concentrations and meteorological parameters. With non-automatic monitoring, samples are collected by a physical means before being subjected to chemical analysis, and final pollutant concentrations calculated from these results. With manual monitoring, there is more likely to be variation or bias in the data compared to continuous monitoring, but the costs are much lower.
- **Low-cost sensors** – These air quality sensors are a relatively new and rapidly improving technology that measure air pollutants, and cost much less than traditional air quality monitors. Low-cost sensors are increasingly used to help track air quality conditions in local areas without monitoring or to supplement existing monitoring. The challenge is the interpretation of sensor data; as these sensors are compact and inexpensively built, the data may vary from regulatory monitors.

It is important that baseline information about pollution levels in and around the CAZ, as well as the wider city, is collected for up to one year prior to implementation of the CAZ restrictions. With a baseline established, subsequent data collected once the CAZ restrictions are imposed can be used to estimate the impact the restrictions have had on air pollution. In this way, air quality monitoring is an excellent tool for monitoring and evaluation of the success of the CAZ.

As well as (hopefully) seeing an improvement in air quality in and around the CAZ, it's vital to monitor pollution elsewhere in the city to ensure that the restrictions have not caused pollution to be displaced

to other parts of the city and create a problem there instead. This is especially relevant if there is a total ban on any vehicles entering the zone, as more vehicles are likely to be rerouted to other roads in the city.

4.2.2 Air quality modelling

Air quality modelling is perhaps the most important piece of evidence to make the case for the proposed CAZ restrictions. The purpose of the CAZ is to improve the air quality problem in that area; therefore, modelling pollutant concentrations can clearly demonstrate the level of impact that the restrictions are likely to have.

Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere. Inputs such as meteorological data, source information and emissions rates are used to characterise primary pollutants (emitted directly into the atmosphere) and, in some cases, secondary pollutants (formed as a result of complex chemical reactions within the atmosphere). Commonly used models include Gaussian plume models such as ISCST3 and AERMOD; chemical transport models (CTM) like WRF-Chem CTM or WRF-CMAQ would also be appropriate.

As the minimum, and air quality modelling study requires three scenarios in order to estimate the impact of CAZ restrictions on pollutant concentrations:

- **Historic baseline scenario** – this baseline scenario should be from a recent year where extensive air quality monitoring information is available. The modelling outputs from the historic baseline are compared to the measured air quality data for that year to enable the air quality model to be adjusted for the local area.
- **Future baseline scenario** – the future baseline scenario should use available information / projections for the year the CAZ is expected to be implemented, however, it does not include any CAZ restrictions. It is also sometimes referred to a 'business as usual' scenario because no policy changes are being made.
- **Future CAZ scenario** – this scenario is modelled for the same year as the future baseline; however, the CAZ restrictions are included in whatever data has been put into the model (for example, changes to the road network and changes to the fleet travelling on the road network).

The impact of the CAZ restrictions can then be determined by examining the changes in concentration between the future CAZ scenario and the future baseline scenario:

$$[\textbf{Impact of CAZ restrictions}] = [\textbf{Future CAZ scenario conc.}] - [\textbf{Future baseline scenario conc.}]$$

If concentrations are modelled throughout the city, air quality modelling can be used to identify the impact at pollution hotspots, as well as if there have been increases in pollutant concentrations anywhere in the city as a result of the CAZ restrictions.

A huge benefit of air quality modelling is that multiple 'future CAZ' scenarios can be set up with different restrictions in each one. Allowing you to identify a preferred option, which achieves the required improvement in air quality, whilst causing the least disruption.

The results of air quality modelling assessments can feed into the economic assessment (e.g. to calculate the cost benefit of the improvement in air quality) as well as other impact assessments (e.g. distributional impact, health studies).

4.3 Economic impacts

An economic assessment comprises identifying, calculating and comparing the costs and benefits of a proposed CAZ scheme in order to evaluate the merit of the scheme, either absolutely or in comparison with alternative options. The following outlines some of the key considerations of an economic assessment completed in support of a CAZ.

4.3.1 Implementation costs

The cost of implementation comprises the total of all the costs to get the CAZ up and running, including all restrictive measures, and communications. Implementation costs are likely to include, but are not limited to:

- Designing the CAZ
- Data requirements (some data may need to be purchased for inputs into impact assessments)
- Expert impact assessments (e.g. traffic, air quality, economic assessments, etc.)
- Signage
- Setting up enforcement (e.g. production of permits / stickers, set-up of cameras, having framework for enforcement in place)
- Marketing
- Communications and education
- Internal resourcing

4.3.2 Operational costs

The cost of operation is the sum of all the costs required for the ongoing day-to-day running of the CAZ. Operational costs are likely to include, but are not limited to:

- Maintenance of signs
- Enforcement (e.g. continued permit / sticker production, maintenance of cameras, administration, follow-up of non-compliances)
- IT support / maintenance
- Marketing
- Communications, education, and helpdesk
- Internal resourcing

4.3.3 Cost-benefit analysis

A cost-benefit analysis (CBA) is the process used to measure the benefits of a scheme minus the total costs associated with the scheme. A CBA involves both measurable financial metrics, such as revenue earned, or costs saved as a result of the CAZ, as well as intangible benefits and costs / effects such as citizens' health and happiness.

Some of the costs that may not have been considered under implementation and operation include:

- "Welfare loss" – the loss incurred by non-compliant vehicle owners who move from their current vehicle to a compliant alternative.
- Lost value of asset – accelerated fleet turnover will reduce value of older vehicles.
- Cost of avoided trips – some drivers will incur costs from changing route, not making a journey or shifting mode.

Key benefits to be included in a CBA include:

- Air quality impacts – These benefits primarily relating to premature mortality from PM and NOx exposure. These can be assessed via a damage cost approach, using the links between air pollution and mortality (this is the approach in the UK).
- Greenhouse gas (GHG) reductions – Newer vehicles use less fuel and therefore will reduce GHG emissions. This impact is assessed alongside benefits from some journeys being cancelled.
- Traffic flow improvements – Fewer vehicles on certain roads will lead to traffic flow improvements, shortening journey times for those who still travel. This can be assessed by considering the value of time (i.e. time saved).

4.4 Other wider impacts

In order to develop a business case for a CAZ it may also be necessary to consider the broader impacts of the proposed scheme on society and human health. The following presents some of the areas that may require further consideration.

4.4.1 Social impacts

Poor air quality is a social issue, with a clear link between air pollution and mortality. The CAZ, if successful, will deliver a social benefit by preventing many deaths from air pollution; however, there may also be negative social impacts resulting from the introduction of the restrictions.

Ideally, modelling to estimate the potential scale of social impacts should be undertaken. If modelling is not feasible, it would be useful to list the potential social impacts of the proposed CAZ restrictions. This could be achieved by consulting with the relevant departments to identify possible impacts and determine their likelihood (e.g. low, medium or high) as well as the severity of the impacts (again low, medium or high).

An important way of considering social impacts of CAZ restrictions is distributional analysis. Distributional analysis is the process by which the effects (good and bad) that the proposed scheme may have on individual groups within society, is measured. The population can be split into these groups using a variety factors, including: geographic location, income, ethnicity, age, socioeconomic status, business size, industry or any other characteristic that might be considered relevant to policy making. Often, the information used to split the population into these groups can come from census data. Transport data, traffic modelling, air quality monitoring and the results of air quality modelling are also important inputs to the assessment.

Distributional analysis can be used to determine:

- How the impacts of the proposed CAZ restrictions are distributed amongst the different socio-economic groups.
- Whether any key amenities such as schools, hospitals etc. are adversely affected through changes in access or the surrounding air quality.
- Whether additional measures to mitigate the impact of the policy on those groups are required, or if amendment of the CAZ restrictions themselves are needed.

4.4.2 Health impacts

Health Impact Assessments (HIAs) are widely used throughout Europe and the rest of the world to quantify the impact of air pollution on citizens' health. HIAs may attempt to answer the following questions with respect to a CAZ:

- In the current situation, what are the public health risks of air pollution concentrations on the
- population?
- What are the health benefits of a certain policy implementation (e.g. the proposed CAZ restrictions)?
- Which combination of air quality measures will result in the largest improvement of public health?

There are HIA tools available to assist in completing the assessment to a high standard. These tools are generally models that calculate the burden of disease due to air pollution, based on inputs (such as pollution concentrations, population characteristics, the baseline situation and concentration-response functions). A number of existing HIA tools for air pollution have been reviewed in a report commissioned by Urban Agenda for the EU, Priority Urban Partnership for Air Quality, Action N°4 – Better Focus on the Protection and on the Improvement of Citizens' Health.[33] The following table provides an overview of some of the tools available:

[33] The use of Health Impact Assessment tools in European Cities, A guide to support policy towards cleaner air and improvement of citizens' health, Iris van den Brenk, 2018, https://ec.europa.eu/futurium/en/system/files/ged/the_use_of_health_impact_assessment_tools_in_european_cities.pdf

Table 1: Overview of a selection of commonly available HIA tools.

HIA Tool	Link(s)	Overview
GGD (Netherlands Public Health Services)	https://www.ggdghorkennisnet.nl/thema/gezondheid-en-milieu/publicaties/publicatie/17943-kwantificeren-van-de-gezondheidsschade-door-luchtverontreiniging-voor-ggd-en	This tool was developed to allow all health services in the Netherlands the resources to carry out HIA, even if they lacked expertise in HIA. The tool was built so that only the pollutant concentrations and number of exposed people have to be inserted; however, the fixed numbers in the model are applicable to the Dutch population and cannot be changed. The tool comes as an Excel spreadsheet in which only a few numbers have to be inserted. The entire analysis automatically appears on the sheet once it is complete.
AirQ+ (WHO)	http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2020/health-impact-assessment-of-air-pollution-airq-life-table-manual-2020	A tool meant for any stakeholder that wants to carry out HIA and is developed in the form of software. To carry out an impact evaluation, concentration and population data must be inserted; an incidence rate should also be inserted for the chosen health indicator. Many morbidity and mortality health indicators are included in the software, but for every health indicator a separate analysis must be carried out. A handbook is also available online.
Health Economic Assessment Tool (HEAT) (WHO)	https://www.euro.who.int/__data/assets/pdf_file/0010/352963/Heat.pdf	The Health Economic Assessment Tool (HEAT) is designed to enable users without expertise in impact assessments to assess the economics of the health effects of walking or cycling. The tool works using the best available evidence and transparent assumptions. It is intended to be simple to use by a wide variety of professionals; these may include transport and urban planners, traffic engineers or interest groups working on transport, walking, cycling or the environment.
GAINS (International Institute for Applied Systems Analysis, IIASA)	https://iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html https://iiasa.ac.at/web/home/research/researchPrograms/air/Asia.html	The GAINS model estimates historic emissions of 10 air pollutants and 6 GHGs for each country based on data from international energy and industrial statistics, emission inventories and on data supplied by countries themselves. It then calculates, for the user's specific scenario, the resulting effects on ambient air quality (fine particles, ground-level ozone, deposition of sulphur and nitrogen), and the subsequent impacts on human health and ecosystems. There is a specific version of the model called GAINS-Asia for China and India.
IOMLIFET (Institute of Occupational Medicine, IOM)	https://www.iom-world.org/research/our-expertise/iomlifet/	This is a spreadsheet system for life-table calculations that can be used to predict the patterns of mortality and life expectancy ensuing from a change in mortality rates, from different sources or policy interventions. Four ZIP files can be downloaded for use, free of charge.
EcoSense (REEEM)	https://www.reeem.org/ecosense/	This is an integrated assessment model for estimating and assessing health and environmental impacts arising from the release

HIA Tool	Link(s)	Overview
		of toxic substances (and their precursors) into the environment. The tool includes atmospheric dispersion modelling based on the EMEP Unified Model, before estimating health impacts using WHO-recommended concentration-response functions. All impacts are translated into monetary values reflecting damage costs, which can be used for CBA.
TM5-Fast Scenario Screening Tool (TM5-FASST) (Joint Research Council, JRC)	https://publications.jrc.ec.europa.eu/repository/handle/JRC110890	This model is a global reduced-form air quality source-receptor model that computes ambient pollutant concentrations as well as a range of related impacts related to human health, agricultural crop production, and short-lived pollutant climate metrics. Annual pollutant emission data aggregated at the national or regional level is the main input, and the full chemistry-transport model TM5 for computation of pollutant concentrations.

HIA tools are also very useful as communicative instruments; as mentioned previously it is sensible to frame air quality actions with a central theme of citizens' health. Therefore, HIAs are another important piece of evidence for the CAZ case, as well as being a good tool for communication and engagement with the general public.

5 Consultation

The introduction of a CAZ requires extensive engagement and consultation with the relevant authorities, local communities, and businesses to: explain the aims of the project, including the potential health and economic benefits; understand any concerns that stakeholders may have; and contribute to assessing the need for any mitigating actions.

Early engagement in the planning of a CAZ will help raise awareness about the scheme and allow people to get used to, and accept, the idea that these changes are likely to occur. The further in advance that engagement begins, the more time individuals and businesses have to prepare for the CAZ's introduction and to understand how their personal circumstances are going to be affected.

In the sections below, more information on the four main groups to consider for consultation is presented.

5.1 Politicians

Vocal and powerful supporters are helpful in overcoming opposition and implementing CAZ policies. Political support is therefore vital for the implementation of a CAZ. Cities should consider setting up a body to facilitate collaboration with business groups, government authorities and representatives of public interest groups, in the design of the CAZ. Indeed, the current political leaders should be educated via presentations and workshops about the aims of the CAZ at the planning stage; the evidence base of the proposed CAZ restrictions can then be presented at a later date.

To ensure the longevity of the CAZ beyond political cycles, support from residents and local businesses should also be sought.

5.2 Residents

Support and understanding from residents living in and around the proposed CAZ area is vital for the CAZ restrictions to be accepted. These groups are the most likely to be directly affected by the proposed restrictions due to their proximity to the zone. In particular, consultation with residents is important to help set out any exemptions to CAZ restrictions – for example temporary waiving or discount to charges, or supporting measures like grants to assist residents in upgrading to a low emission vehicle.

It is also important to engage with the wider population of the city. Many of these people may work in the CAZ, or travel there to access shops, visit friends / family, or for leisure or tourist activities. If the CAZ is located around a tourism or heritage site, or is to be a social hub, then more people are likely to travel to the zone and further consultation needs to be considered (see section 5.4).

Even if there is initial public support for the implementation of the CAZ, this can quickly be lost if the proposed scheme is considered unworkable or is not well understood. Public consultations and awareness campaigns should be used to promote understanding of how the CAZ will work and the benefits it will deliver, as well as to understand and address public concerns. As detailed in section 3.2, citizens must be kept informed about the timing of upcoming restrictions or charges, when they will be affected, and how they can prepare.

5.3 Businesses

Implementation of CAZ restrictions can be particularly concerning for businesses operating within the proposed zone for a number of reasons:

- Worries about reduced customer numbers as people choose to avoid entering the zone.
- Concerns about the delivery access, as heavier vehicles may be targeted by the CAZ.
- The cost of upgrading a business' fleet to cleaner vehicles.
- Feeling as if CAZ restrictions are being imposed on them, and the effects are disproportionate.

Securing the support of businesses based within the CAZ is vital, especially in cases where the CAZ is planned to be a social area. Both major business groups and small businesses should be consulted to make the case based on evidence of the likely benefits for businesses, which might include:

- Reduction in time lost to congestion (e.g. for deliveries, commuters, visitors).
- Increased footfall for shoppers not in cars.
- Providing promotional opportunities / giving them a green reputation from being based in the CAZ (e.g. attracting customers on foot / by bicycle, switching to green 'last mile' deliveries, advertising the businesses whilst promoting the CAZ).
- Highlighting any exemptions the businesses can receive.
- Providing advice and support to enable the businesses to make greener choices (e.g. grants to upgrade vehicles, help in installing workplace EV chargers).

As with consultation for residents, businesses should be consulted in particular when considering any exemptions that could benefit them and help them to make the changes required by the CAZ. There is also the possibility that cities may need to alter the CAZ plans to secure the support of local businesses, for instance by altering planned timing of restrictions or taking a more incremental approach.

5.4 Heritage / tourism

Finally, if the CAZ will encompass a heritage area or tourist site then the operators of those sites will need to be consulted. There may also be charities or local interest groups for the sites that are relevant. For heritage sites, there may be fewer concerns or negative impacts for the sites and more benefits; the likelihood is that the CAZ restrictions will provide protection from air pollution for the sites. Therefore, the sites will be in better condition and maintenance costs may be reduced.

On the other hand, there may be concerns that imposing CAZ restrictions will hinder tourism in terms of number of visitors to the zone. Charges or blanket bans that make it more inconvenient to visit the area can potentially reduce visitor numbers. When dealing with these concerns, it's important to promote the benefits of the restrictions for tourism – e.g. cleaner air, cleaner streets, less traffic, reduced congestion, and a more pleasant environment – and highlight any changes to the zone that transform it into a more tourist-focused / tourist-friendly zone than before the CAZ restrictions.

6 Implementation

The implementation phase of the CAZ project involves taking everything from the prior stages of the project – choosing the type of CAZ, defining the scope, considering supporting measures, assessing the potential impacts, and undertaking consultation – and turning these plans into actions. All the way through the implementation stage, the focus should be on the project's goals: to improve air quality in the zone, whilst supporting local growth and ambition, and accelerating the transition to a low emission economy.

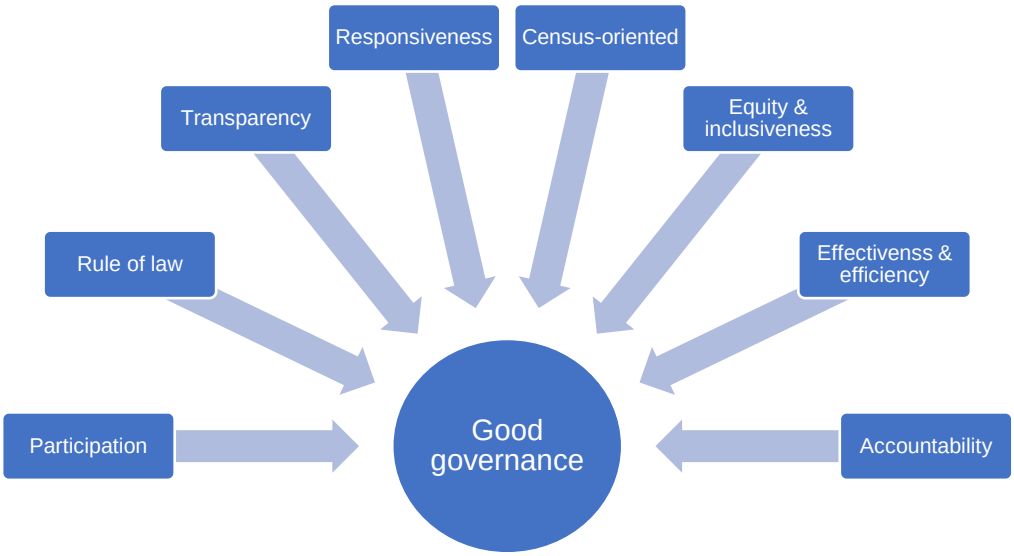
6.1 Governance

Project governance comprises the process of decision making, and the process by which those decisions are implemented (or not) during the project. According to the United Nations (UN), there are eight characteristics of good governance,[34] shown in Figure 2:

- Participation – by all types of people, in an informed and organised manner.
- Rule of law – fair legal frameworks that are enforced impartially.
- Transparency – information is freely available and accessible, decisions taken, and their enforcement are done in a way that follows rules and regulations.
- Responsiveness – stakeholders should be acknowledged / served within a reasonable timeframe.
- Census-oriented – agreeing (broadly) what is in the best interest of the whole community, and how this can be achieved.
- Equity and inclusiveness – all members of society feel included in the society, especially the most vulnerable.
- Effectiveness and efficiency – processes and institutions produce results that meet the needs of society, whilst making the best use of available resources.
- Accountability – anyone involved in any aspect of the project must be held accountable for the decisions they make and the actions they take.

Poor governance can put the project at risk, result in regulatory problems or allow the organisation to lose sight of its objectives and responsibilities to its stakeholders. Good governance can be highly beneficial for communicating with stakeholders and the general public. Therefore, ensuring good governance practices is vital to the success of CAZ implementation.

Figure 2: The eight characteristics of good governance (UN)



[34] What is Good Governance?, United Nations Economic and Social Commission for Asia and the Pacific, https://www.unescap.org/sites/default/files/good-governance.pdf

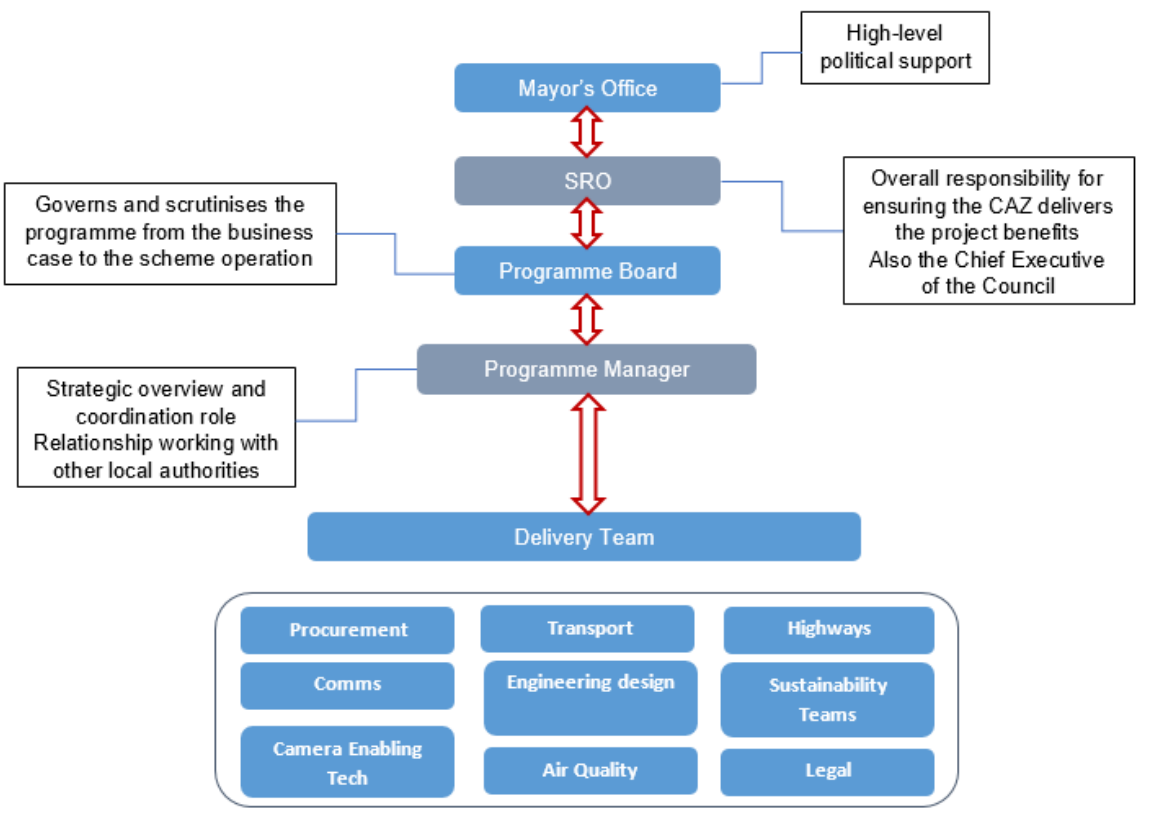
When considering governance of an air quality project, and specifically a CAZ, perhaps the most important aspect is that it's likely to be a multi-disciplinary team implementing the project. Air quality projects have cross-cutting implications for many service areas; working with and coordinating so many different departments can be a challenge for governance. There may be the need to reprioritise staff resource depending on the support the programme requires at that time, and external expertise may be required.

CAZ programmes are often large and complex, so a tailored, comprehensive governance structure is needed in order to fulfil the characteristics of good governance outlined above.

Case study: Project governance for Bristol's CAZ

Bristol, a city in the south-west of England, plans to implement a CAZ that does not ban any vehicles from entering the zone, but charges the oldest and most polluting vehicles to enter. The CAZ will also include some supporting measures: loans and grants to help people switch to a cleaner vehicle or less polluting forms of transport, changes to traffic signal timings to improve traffic flows, and increased priority for buses, such as bus lanes and priority at traffic signals.[35]

The programme for the Bristol CAZ is being governed by the Bristol Clean Air Plan Programme Board, with the Mayor's Office playing a key role. The diagram below shows the relationship between all levels of the governance structure, including the Mayor's Office, Senior Responsible Owner (SRO), Programme Board, Programme Manager, and the various parts of the Delivery Team.



As well as highlighting the complexity of the hierarchy in project governance, the example for Bristol also demonstrates how many departments may be involved in the delivery team for a CAZ project. Collaboration across these teams is vital for successful implementation of the CAZ.

[35] https://www.bristol.gov.uk/streets-travel/bristol-caz/what-caz-is

6.2 Monitoring metrics

Monitoring is an extremely important aspect of CAZ implementation; the three main situations where monitoring data can be key are:

1. Baseline information / making decisions about the scope of the CAZ restrictions. In order to decide which restrictions are needed and which will suit a city's situation, baseline information is required. Baseline information is also vital to assess the impact of CAZ restrictions; it is necessary in order to determine the change in the monitoring metric from prior to the restrictions being implemented.
2. Monitoring the impact of the CAZ restrictions in the long term. Data collection as the CAZ restrictions are implemented, and in the years following their implementation, is the main method of assessing the success of the measures. Ideally continuous information should be gathered from the beginning of restrictions so the progress can also be continuously tracked, and changes made if the evidence points towards it. As in point 1, this information should be compared to the most recent data acquired before the restrictions were implemented.
3. Communicating with the public and stakeholders. Both baseline information and monitoring data as restrictions are being implemented can be used to show the public the scale of the problem, and then the progress the measures are making to resolve it. The types of metrics that are used to communicate must be carefully considered: visual, simple, and impactful data should be shown in order to grab people's interest, yet make things understandable for the entire audience.

As has been mentioned throughout this document, and especially when considering data requirements in section 4, plenty of metrics that are used to inform impact assessment and decision making with regards to the CAZ restrictions can be used in the long term to monitor the CAZ's implementation. Below are some of the metrics that can be used to monitor the success of the CAZ restrictions.

6.2.1 Air pollutant concentrations

For many cities implementing CAZs, air pollutant concentration measurements may be the reason that for a CAZ being considered in the first place. Therefore, it follows that monitoring the success of the CAZ implementation should first and foremost be measured using the same metric. Section 4.2 provides more detailed information on the air quality monitoring, but the key points in terms of pollutant concentrations as a metric to monitor implementation are:

- Continuous / automatic, manual / non-automatic, low-cost sensors, or a combination of all three are a viable option for air quality monitoring. They each have their advantages and disadvantages, so a combination may be the most appropriate.
- Monitoring stations / sensor locations must be carefully planned in order to capture the impacts of the CAZ restrictions on air pollution levels. This is particularly important for the case of a targeted low-cost sensor study, where many sensors are placed in and around the CAZ to measure the impacts on a local scale.
- It's also important to make sure that air quality impacts away from the CAZ, especially on diversion routes and congested roads, are being measured.
- The way that air quality monitoring data is presented to the public must be considered; although it's important to be transparent about air pollutant concentrations, this data must be shown in a clear, simple manner, and do the utmost to avoid causing panic when concentrations are higher.

6.2.2 Emissions measurements

Emissions measurements are a great way to show how the fleet in a city is improving over time. Although the main aim of a CAZ is to improve pollutant concentrations, it also aims to facilitate a faster uptake of low emission vehicles than if no measures were put in.

One of the supporting measures outlined in section 3.5.2 is to increase emissions testing. This management measure can assist in making CAZ enforcement easier, as well as measuring the

progression of the vehicle fleet. Making regular emissions testing mandatory, as well as convenient and affordable, are the key aspects of using the data to monitor how the CAZ has impacted the vehicle fleet.

It is also worth considering a focused emissions testing campaign during the planning stage for the CAZ, in order to set the baseline for the fleet composition. This will help in determining which vehicles may need to be restricted, as well as to measure impacts at a later date.

6.2.3 Fleet composition surveys

Another way to measure the composition of the vehicle fleet is via surveys. A survey can be a much faster and cheaper option than the emissions testing described above, especially if the infrastructure for emissions testing isn't already set up in a city. However, the responses from a survey are likely to be considerably less reliable, and less detailed, than the data collected during emissions testing.

A survey focused on the vehicles people in the city own could also be a good chance to collect data on possible behavioural responses to the proposed CAZ restrictions. A survey might also be more appropriate for some local businesses, giving them an option to test a small proportion of their vehicle fleet in an official emissions testing centre, but complete a survey to provide information on the entirety of the fleet.

6.2.4 Traffic counts

Traffic count data has been discussed in section 4.1. The key considerations for this type of data are: manual or automatic counts, location(s) of counts, duration of the study or studies, and the level of detail in the data collected.

Traffic counts can be a good way to monitor, in particular: how the traffic modelling for a future scenario compares to what is happening in real life, how the behavioural responses that are expected compare to the real life situation, and if any hotspots are getting better or worse, or if new hotspots have been generated as a result of the CAZ restrictions. One of the key benefits of traffic counting is that the studies can be set up relatively quickly, on short notice, so they are a very flexible monitoring metric to use.

6.2.5 Active travel surveys

Collecting data on active travel may be more difficult than standard traffic counting, although those travelling by bicycle and on foot may also be included in traffic counts as discussed in section 4.1.

Surveys are another method that could be used to collect active travel data. It has been highlighted in the sections above that surveys are not the more reliable form of data collection, however, for a topic such as active travel people are likely to be more open and honest. This is because in the case of a CAZ, active travel is always something that is going to be encouraged, promoted, and funded. In contrast, motor vehicles are more likely to be restricted and penalised, so giving inaccurate information is more likely.

An active travel survey can also be used for engagement and consultation – if the survey includes space for participants to include their thoughts, ideas and feelings about what they would like to see in the city with regards to active travel, this is a great opportunity to highlight the benefits of the CAZ, generate some enthusiasm towards the project, and make people feel like they are being listened to.

6.3 Evaluation and reporting

A system for Monitoring, Evaluation and Reporting (MER) should be established in support of the CAZ. This will use the data described above, and any other relevant indicators, to track the performance of the CAZ over time. Regular reporting on the performance of the CAZ will allow decision makers to identify potential improvements, confirm additional funding requirements and demonstrate the benefits of the implemented measures.

7 Summary checklist

The following provides a summary checklist for each step to be completed in support of the development of a CAZ. This can be used as a guide and to identify areas that require further input / support.

Table 2: Summary checklist for implementation of a CAZ

Criteria	Status (incomplete / ongoing / complete)	Link to document / reference	Responsible department / individual	Estimated completion date
Type of zone				
What are the relevant emissions sources within the zone?				
What type of zone will be implemented (e.g. LEZ, CAZ, ZEZ, access management, or charging)?				
Defining the scope				
Which pollutants will the zone target?				
Scope of restrictions				
Which types of vehicles will the zone restrict?				
What will the boundary or boundaries of the zone be?				
Will the zone operate 24/7 or only at certain times of day?				
Will there be multiple levels of restriction and/or charging?				
What exemptions will be granted? To what extent will these be, and how long will the exemptions last for?				
What set of emissions standards will be used (e.g. Euro, Bharat, other)? How stringent will the standards be?				
When will the zone be introduced? Will there be a phased introduction?				
Legal basis				

Criteria	Status (incomplete / ongoing / complete)	Link to document / reference	Responsible department / individual	Estimated completion date
Are the powers to implement the CAZ already in place?				
Does the CAZ require approval from the National or State Government?				
Enforcement				
Will the enforcement be physical, manual, or automatic?				
What method of enforcement will be used, and who will be responsible?				
Supporting measures				
What signage is required for the zone, and where will it be located?				
What types of communication and educational strategies will support the zone prior to, and during its implementation? Which groups will these strategies target?				
Will any events be used to promote the zone, prior to or for the launch?				
Will increased emissions testing be implemented?				
Is there any need to amend the road network to support traffic that is avoiding the zone?				
Will there be any additional parking near the zone?				
What support will be provided for EVs, to accelerate their uptake?				
Does the public transport network need to be upgraded to accommodate journeys that would have otherwise been taken by private vehicle?				
What improvements will be made to footpaths / cycle paths / other travel options to support people switching to active travel?				
Assessing the potential impacts				
Implications for traffic				

Criteria	Status (incomplete / ongoing / complete)	Link to document / reference	Responsible department / individual	Estimated completion date
Will traffic count data be used to inform the project? If so, have the following been considered: manual or automatic counts, location(s) of counts, duration of the study or studies, and the level of detail in the data collected?				
How will information about the fleet be gathered, and how will it be used to inform the project?				
Will transport modelling be completed as part of the project?				
Air quality				
What air quality monitoring is already in place to inform the project (especially baseline air quality data)?				
Does further air quality monitoring need to be implemented (e.g. a local campaign of low-cost sensors) or is the current monitoring network sufficient?				
Will air quality modelling be used in the assessment? If so, which model will be used, and what scenarios will be tested?				
Economic assessment				
What implementation costs are expected, and what are their magnitudes?				
What operational costs are expected, and what are their magnitudes?				
Has a cost-benefit analysis exercise been completed?				
Other wider impacts				
What social impacts have been considered, and have their magnitudes been assessed?				
Has a distributional analysis exercise been completed?				

Criteria	Status (incomplete / ongoing / complete)	Link to document / reference	Responsible department / individual	Estimated completion date
What health impacts have been considered, and have their magnitudes been assessed?				
Which Health Impact Assessment tools could be used for the project?				
Consultation				
Have politicians been consulted, and is there political support for the scheme?				
Have residents been consulted, and what methods have been employed for them to share their views?				
Which local businesses been consulted, and what methods have been employed for them to share their views?				
Which tourism and heritage groups have been consulted, and what methods have been employed for them to share their views?				
Do any changes need to be made to the proposed scheme, based on the results of consultation with any of the above groups?				
Implementation				
Funding and finance				
What sources of funding are available for the scheme, and what is their magnitude?				
Has a financial plan for the lifetime of the scheme been mapped out?				
If the scheme generates any revenue (e.g. from charges or penalties), how will this be used?				
Governance				
Has the project governance framework been mapped out?				

Criteria	Status (incomplete / ongoing / complete)	Link to document / reference	Responsible department / individual	Estimated completion date
Have the requirements for cross-departmental coordination, especially in the delivery team, been mapped out?				
Monitoring metrics				
Which types of monitoring metrics will be used to measure the success of the project?				
For each monitoring metric, has a suitable baseline been determined from which to measure success?				
Has a monitoring framework for the lifetime of the project been mapped out?				
Evaluation & Reporting				
How will the results of the monitoring be taken into account in the scheme's evaluation?				
How will the results from consultation with the relevant stakeholders be taken into account in the scheme's evaluation?				
Has an evaluation framework for the lifetime of the project been mapped out?				
Has a system of regular reporting been defined and agreed?				

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