CLEAN AIR FUND

CLEAN AIR ZONES: PRACTICAL GUIDANCE FOR CITIES ANNEX

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Health and Care

Clean Air Zones: Practical guidance for cities - Annex

Contents

A.1 Literature review

An expert review of Clean Air Zone development has been carried out, include a detailed literature review.

This section of the Annex provides a summary from the review and the list of resources from existing literature.

A.1.1   SUMMARY

Most existing research has focused on the assessment of CAZ in Global North cities and has been a review of outcomes rather than providing insights on implementing a new CAZ. This research has demonstrated that in cities where a CAZ has been implemented, it has the potential to deliver air quality benefits, reduce emissions and advance climate objectives.

Other technical assessments have reviewed the health effects of a CAZ and have highlighted the substantial health benefits, including reductions in childhood asthma and premature adult mortality, particularly when larger perimeters and stringent vehicle standards are implemented. Economic benefits from prevented deaths and reduced asthma cases are also highlighted in the literature. However, the equity aspect of a CAZ remains relatively underexplored.

With increased awareness around the benefits that a CAZ can deliver, there has been some guidance developed aimed at supporting cities' understanding of how to plan for a CAZ. C40 launched the Cities Clean Air Toolbox[1], aimed at supporting cities with understanding how to deliver a CAZ. The Clean Cities Campaign also provides guidance for European cities on developing low emission zones[2]. There are overlaps with this guidance and the C40 toolkit and this guidance builds on the information provided to complement their work and avoid duplication.

Despite the findings in literature and recent toolkit development, there are still significant information gaps:

- Most studies have focused on cities in the Global North, which have been early adopters of CAZ. This focus limits the applicability of findings to the Global South where the challenges may differ.

- The literature tends to emphasise the impacts and benefits of CAZ without covering the lessons learned, knowledge sharing and practical steps for planning, designing and implementing CAZ.

A.1.2   RESOURCES

The resources considered in the literature reviewed are outlined below:

Holman, C., Harrison, R., & Querol, X. (2015). Review of the efficacy of low emission zones to improve urban air quality in European cities. Atmospheric Environment, 111, 161-169.

Greater London Authority, (2020). Central London ultra-low emission zone–ten-month report. https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/central-london-ulez-ten-month-report

Gonzalez, J. N., Gomez, J., & Vassallo, J. M. (2022). Do urban parking restrictions and Low Emission Zones encourage a greener mobility? Transportation Research Part D: Transport and Environment, 107, 103319.

The London-wide Ultra Low Emission Zone First Month Report. https://www.london.gov.uk/programmes-strategies/environment-and-climatechange/environment-and-climate-change-publications/london-wide-ultra-lowemission-zone-first-month-report

Peters, J. F., Burguillo, M., & Arranz, J. M. (2021). Low emission zones: Effects on alternative-fuel vehicle uptake and fleet CO_2 emissions. Transportation Research Part D: Transport and Environment, 95, 102882.

Ellison, R. B., Greaves, S. P., & Hensher, D. A. (2013). Five years of London's low emission zone: Effects on vehicle fleet composition and air quality. Transportation Research Part D: Transport and Environment, 23, 25-33.

Wang, Y., Song, S., Qiu, S., Lu, L., Ma, Y., Li, X., & Hu, Y. Study on International Practices for Low Emission Zone and Congestion Charging. 2017.

Ku, D., Bencekri, M., Kim, J., Leec, S., & Leed, S. (2020). Review of European low emission zone policy. Chem. Eng, 78, 241-246.

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Moreno, E., Schwarz, L., Host, S., Chanel, O., & Benmarhnia, T. (2022). The environmental justice implications of the Paris low emission zone: a health and economic impact assessment. Air Quality, Atmosphere & Health, 15(12), 2171-2184.

Santos, F. M., Gómez-Losada, Á., & Pires, J. C. (2019). Impact of the implementation of Lisbon low emission zone on air quality. Journal of hazardous materials, 365, 632-641.

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Moral-Carcedo, J. (2024). Dissuasive effect of low emission zones on traffic: the case of Madrid Central. Transportation, 51(1), 25-49.

Tarriño-Ortiz, J., Soria-Lara, J. A., Silveira-Santos, T., & Vassallo, J. M. (2023). The impact of Low Emission Zones on retail activity: Madrid Central lessons. Transportation Research Part D: Transport and Environment, 122, 103883.

Mudway, I. S., Dundas, I., Wood, H. E., Marlin, N., Jamaludin, J. B., Bremner, S. A., ... & Griffiths, C. J. (2019). Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study. The Lancet Public Health, 4(1), e28-e40.

Pestel, N., & Wozny, F. (2021). Health effects of low emission zones: evidence from German hospitals. Journal of Environmental Economics and Management, 109, 102512.

Sarmiento, L., Wägner, N., & Zaklan, A. (2022). Low emission zones improve air quality and health but temporarily decrease life satisfaction. DIW Weekly Report, 12(13), 99-106.

Cyrys, J., Peters, A., Soentgen, J., & Wichmann, H. E. (2014). Low emission zones reduce PM10 mass concentrations and diesel soot in German cities. Journal of the Air & Waste Management Association, 64(4), 481-487.

Wood, H. E., Marlin, N., Mudway, I. S., Bremner, S. A., Cross, L., Dundas, I., ... & Griffiths, C. J. (2015). Effects of air pollution and the introduction of the London Low Emission Zone on the prevalence of respiratory and allergic symptoms in schoolchildren in East London: a sequential cross-sectional study. PLoS One, 10(8), e0109121.

Chamberlain, R. C., Fecht, D., Davies, B., & Laverty, A. A. (2023). Health effects of low emission and congestion charging zones: a systematic review. The Lancet Public Health, 8(7), e559-e574

Charleux, L. (2014). Contingencies of environmental justice: The case of individual mobility and Grenoble's low-emission zone. Urban geography, 35(2), 197-218

Brussels Low Emission Zone website: https://lez.brussels/mytax/fr/alternatives?tab=Primes

Müller, J., & Le Petit, Y. (2019). Low-Emission Zones are a success-but they must now move to zero-emission mobility. Transport & Environment: Brussels, Belgium.

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Leonhart, M., & Urban, P. (2017). Environmental and social effects of the Rotterdam low emission zone: an empirical approach.

Szarata, A., Nosal, K., Duda-Wiertel, U., & Franek, L. (2017). The impact of the car restrictions implemented in the city centre on the public space quality. Transportation Research Procedia, 27, 752-759.

Transport Scotland, 2021, Low Emission Zone Guidance, https://www.transport.gov.scot/media/50416/low-emission-zone-guidance-october-2021.pdf

Transport Scotland, 2021. Low Emission Zone Guidance checklist, https://www.transport.gov.scot/publication/low-emission-zone-guidance/

C40 Air Quality Technical Assistance Report, 2023, Rio de Janeiro: Assessment of a low emission zone and truck restrictions in the central business district

C40 Air Quality Technical Assistance Report, 2022, Lima: Assessment of low emission zone in Damero de Pizarro

Bernard, Y., Tietge, U., German, J. and Muncrief, R. (2018) 'Determination of real-world emissions from passenger vehicles using remote sensing data'. The Real Urban Emissions Initiative. Available at: https://theicct.org/publication/determination-of-real-world-emissions-from-passenger-vehicles-using-remote-sensing-data/.

A.2 Data collection in the CAZ planning phase

Chapter 4 of the Clean Air Zones: Practical Guidance for Cities set out the considerations for planning and gathering the right data is an important part of the process.

In this appendix we provide further information on the types of data to be gathered.

As set out in Chapter 4 of the Clean Air Zones: Practical Guidance for Cities the main types of data that cities draw on when developing CAZ proposals include:

People and demographics

Vehicle fleets

Transport network

Air quality and the environment

Business and economy

Perceptions

This section covers each of these areas.

Table 1 sets out the data by priority by the following each theme to identify the broad areas where data is needed and considerations for building up the understanding to inform the CAZ. This recognises that cities will have different types and level of data available, and for some, the development of a CAZ may be the start of a data collection journey on some topics.

The tables in the following sections then provide detail about what the data should include under each theme. These demonstrate where there are options to balance the level of detail, taking into account that access to key data can be a challenge. Not all data is required to create a CAZ but will generally help in creating a more effective and equitable CAZ.

Table 1: Data inputs by priority and theme

	People and demographics	Air quality and the environment	Transport network	Vehicle fleets	Business and economy	Perceptions
Must have	Spatial population distribution (current, at high resolution).	An understanding of where air quality is poor. This could be inferred based on areas of high transport emissions if no air quality data is available.	Clear and recognisable boundaries to help determine a CAZ boundary.	Age and fuel used by the fleet. Are there electric car policies or emission standards which already exist.	Business size distribution and dependency on vehicle usage.	Political support and opposition.
	Vulnerable populations (e.g. schools, hospitals, aged care facilities).	Ideally some air quality information would be available at key receptor locations – low cost sensors could be used to monitor the baseline situation.	Proximity to receptors (e.g. schools, hospitals, residential areas).			
Should have	Household income.	Air quality modelling.	Public transport access and quality.	Vehicle populations.	Target business growth areas.	Perception of air quality.
	Workers, commuters.	Air quality forecasts.	Active transport access and quality.	Vehicle emissions breakdown / data.	Spatial employment density.	Perception of a CAZ.
	Minorities.	Air quality health impacts on the current population.	Traffic accident data.	Vehicle use (how much, where, when, by whom).	Types of businesses (e.g. freight, service, tourism, etc.).	Community specific issues.

	People and demographics	Air quality and the environment	Transport network	Vehicle fleets	Business and economy	Perceptions
	Elderly, youth, children.	Non-transport sources of pollution.	Transport costs, including public transport, vehicle registration, fuel, etc.	Cost to upgrade to a cleaner vehicle.		
	People with disabilities or underlying health conditions.		Modal split.			
	Motor vehicle dependence.		Existing road tolls or congestion charges (where relevant).			
Nice to have	Spatial population distribution (future).		Vehicle counts.	Vehicle population forecasts.	Business footfall.	
	Quality of life.		Traffic modelling and forecasts.	Vehicle emissions forecasts.	Spend at businesses.	
					Freight and logistics data, e.g. delivery times.	
Further details in:	Table 2	Table 3	Table 4	Table 5	Table 6	Table 7

A.2.1 PEOPLE AND DEMOGRAPHICS - METHODOLOGY

Table 2: People and demographics data

Question	Data and collection methods
Overall population • *How is the population distributed now?* • *How will this change in future?*	Ideally, this should consider places of residence, as well as locations visited throughout the day – such as schools, workplaces, and other destinations. Where available, this may be determined from Census data – for example population and employment density. Data can also be derived from: • Population registers (from administrative sources including business, tax, education and employment) • Sample surveys (such as household travel surveys) • Modelling and estimation-based techniques, or human mobility datasets. • Public health teams and organisations Outputs: • Mapped spatially and overlaid with air quality data, this can help to assess which areas have the highest overall exposure to air quality – informing CAZ boundary selection and quantification of overall impacts.
Vulnerable populations • *Which groups are most susceptible to the effects of poor air quality?* • *Where do the vulnerable populations aggregate?*	Vulnerable groups particularly susceptible to poor air quality can include: • People living with disabilities • People with long-term health conditions • People who are young, pregnant, or elderly. Data could include: • Population demographics datasets: Including Census or representative survey data • Locations of key receptors: This can include schools, hospitals, aged care facilities, or outdoor sport/recreation facilities where community may congregate. Sources may include Government data sources, manual data collection, or third-party open data such as open source mapping. Outputs: • Mapped spatially, this can be used to refine the CAZ boundary to maximise the benefits it offers.
Demographics • *Which groups may be most adversely impacted by implementation of a CAZ?*	This step helps ensure common understanding within city departments of key impacted groups before designing or implementing a CAZ. Typically, most impacted groups include: • Low-income communities • Outdoor workers, temporary workers, gig workers

Question	Data and collection methods
	• Informal workers and traders
	• Racial and ethnic minorities
	• Women
	• Pregnant people
	• People with limited mobility
	• People who have migrated or been displaced
	• Religious minorities
	• People with disabilities
	• People with underlying health conditions
	• Elderly, youth people, children
	• Commuters (e.g. from metro area) delivery drivers and commercial passenger vehicles
	Disaggregated data allows for a more precise appreciation of local contexts to inform and adapt the policy responses. It also allows you to identify the needs of diverse groups, for e.g. the needs expressed by women of different ages, ethnic groups, sexual and gender minorities, and people living with disabilities.
	An intersectional lens can help identify how overlapping identities strengthen or weaken existing injustice. For example, those living in poverty tend to experience more barriers when accessing jobs and training. Often this disadvantage and discrimination is compounded by being a woman of colour, with different experiences for Asian and Black women.
	Data sources can include:
	• Census, tax, health, and other population-scale government data sources
	• Representative surveys
	• Locations of key receptors
	• Engagement with communities
	• Academia, civil society, and community groups can also provide valuable insight into residents' lives, particularly those who may be harder to reach, or who have historically been left out of decision making. Consider consulting these groups at an early stage or inviting them to specific meetings of the working group. This will help redress any imbalance, engage different groups from the outset, and identify additional equity challenges
	Outputs:

Question	Data and collection methods
	• Mapped spatially, this can be used to minimise adverse impacts through boundary choice, scheme design, and in ensuring alternatives are provided
Health, wellbeing and quality of life of population	• Health data on hospitalisations and emergency visit rates • Disease prevalence (e.g. cardiovascular and pulmonary diseases) and mortality • Life expectancy • Quality of Life Index

A.2.2 AIR QUALITY AND ENVIRONMENT - METHODOLOGY

Table 3: Air quality and environment

Question	Data and collection methods
Air quality • *Where is air quality worst, or above limits?* • *How is air quality distributed spatially?* • *How does air quality change throughout the day?* • *How is this forecast to change?*	Air quality monitoring and modelling data can support the understanding of pollutant concentrations in a CAZ, trends and to carry out local air pollution management. Includes: PM_{10}, $PM_{2.5}$, NO, NO_2, NO_x. Air quality can be measured using a range of monitor types: • automatic monitoring sites to provide detailed short- and long-term data for all pollutants; • low-cost automatic sensors can collect real-time pollutant concentrations at a range of temporal resolutions for comparison against air quality objectives, which allow measurements to be made across a city on a dense network across different urban environments, although care must be taken to address limitations in data quality and comparisons; • passive monitoring, such as NO_2 diffusion tubes, can also provide a cost-effective indication of long-term trends. Air Quality Indices are often used to benchmark and communicate air quality, incorporating a range of different pollutants into one score. Air quality monitoring can be used to inform dispersion modelling studies. A CAZ could be assessed using a dispersion modelling study to estimate the concentration of pollutants emitted in the city and change due to a CAZ. Dispersion modelling can be carried out for past, current or future scenarios. It is important to note that air quality challenges vary over spatial and temporal scales, for example reflecting patterns in vehicle traffic. Outputs:

Question	Data and collection methods
	• Mapped spatially and overlaid with the *People* data, this can help to assess which areas have the highest exposure to air quality – informing CAZ boundary selection and quantification of overall impacts. • Informing CAZ policy design based on the spatial, temporal distribution of pollution concentrations and its likely sources. • Monitoring the spatial and temporal air quality concentrations for comparison against air quality objectives (where applicable).
Health impacts • *What are the impacts of air quality on the current population?*	Where available, data collection should include levels of relevant public health impacts such as paediatric asthma diagnoses and admissions, cardiovascular disease, or pneumonia. This data is usually derived from local health departments, national health agencies, centres and institutes, public health databases, chronic disease databases and systems, and research institutions. Outputs: • Overall quantification of the problem and ongoing monitoring
Non-transport sources of pollution	Background concentrations refer to the existing levels of pollution in the atmosphere, produced by a variety of stationary and non-stationary sources, such as roads and industrial processes. Background data include domestic sources such as heating from domestic, institutional and commercial. Background concentrations also comprise secondary and natural residual sources such as sea salt. Background pollutant concentrations vary globally and are impacted by activities in neighbouring geographic areas such as seasonal crop burning and industrial emissions. Background concentrations are also impacted by environmental factors such as meteorological conditions. Outputs: • Informing CAZ policy design – e.g. whether a transport based CAZ will be beneficial, or if other sectors need to be targeted.

A.2.3 TRANSPORT NETWORK - METHODOLOGY

Table 4: Transport network

Question	Data and collection methods

Alternative transport options
 	
• *What alternative transport modes are available?*
  ○ *Public transport*
  ○ *Active travel*
  ○ *Shared mobility*
• *How reliable, affordable, and safe are the alternative modes?*
• *Is purchasing a cleaner vehicle an affordable option?*
	Transport patterns and choices:
	
	• Understanding current travel patterns: Community engagement, household travel surveys, Census
	• Understanding the affordability, reliability and safety of transport options: community engagement (surveys, questionnaires, interviews)
	• Ticketing or transit usage data to understand the sources of alternative transport options being used
	
	Public transport availability:
	
	• Government and operator sources (e.g. schedules)
	• Manual identification
	
	Active transport availability:
	
	• Understanding walking and cycling routes through government data sources, or third-party open mapping data (e.g. Open Street Map or Overture Maps)
	• Identifying walking and cycling routes through human mobility datasets
	
	Outputs:
	
	• Mapping spatially walkability, and access to public transport options that suit residents' transport needs.
	• This can inform boundary choice (e.g. preferring a CAZ in locations with high accessibility to other modes), and the design of the CAZ policy (e.g. enforcement options and the behaviour changes being targeted).

Existing tolling schemes • *Where are they?* • *How much do they cost?* • *Have they impacted the surrounding transport network?*	Tolling schemes (including congestion charges) may be integrated with CAZ policies, or may compound negative impacts such as transport affordability. When implementing a CAZ scheme in an area that already has congestion charging or road tolls, the following data points may be considered: - Locations and coverage of tolling stations - Revenue generated from tolling stations - Impacts on broader transport network (where available). Outputs: • Dependent on the data available, and the alignment with the CAZ's objectives.

Question	Data and collection methods
Congestion and traffic • *How severe is traffic, and is it expected to get worse?* • *What is the immediate impact of vehicles on public safety?*	This may include: • Traffic counts (automated, or manual counts at specific locations) • Modelling, where available • Crash and traffic accident data (e.g. from police or insurance records) • Human mobility or floating car datasets (for relative traffic volumes) • Congestion and monitoring data (e.g. Inrix global scorecard, google maps data)

A.2.4 VEHICLE FLEETS - METHODOLOGY

Table 5: Vehicle fleets

Question	Data and collection methods

Fleet make-up
 	
• *What's the current and projected future vehicle make-up?*
 	
    ○ *How many vehicles are there?*
 	
    ○ *How much pollution do they cause?*
 	
    ○ *How much are they used, and where?*
 	
    ○ *What are they used for (e.g. personal or commercial use)?*
	Understanding which vehicles are contributing to poor air quality is important for understanding how the policy options should be targeted.
	
	Potential data sources include:
	
	• Registration data: This provides a total number of vehicles, but does not incorporate their real-world use. It may include some data about emissions (e.g. emissions standard level, size, fuel type, age, or weight).
	
	• Household travel surveys: This can help to understand the real-world use (e.g. passenger kilometres) for different vehicle types.
	
	• Camera-based surveys or local manual counts: Counting vehicles in particular locations can provide more detailed data about which types of vehicles are actually driving within the areas of interest. Ideally this is cross-referenced with registration data to help estimate emissions.
	
	• Remote vehicle emissions sensing: To assess real-world emissions of real-world fleet.
	
	• Human mobility data: "Big data" can provide overall movement patterns from mobile phone or navigation devices. This cannot disaggregate by vehicle type or emissions level, or provide total quantities, but it can help to identify areas of high overall traffic volumes.
	
	Some considerations for data gathering include:
	
	• Consideration of different vehicle types: e.g. some cities may have higher proportions of 2-3 wheeled vehicles.

Question	Data and collection methods
	• Availability and accuracy of vehicle emissions databases. For example, real-world monitoring in Europe has found vehicle emissions to be higher than those allowed by their corresponding Euro standard[3] for pre-Euro 6d vehicles. • Including multiple data sources: In the absence of real-world monitoring or detailed vehicle datasets, it may be necessary to estimate emissions based on factors such as fuel type, age, weight, and vehicle class. • The role of licencing systems and data e.g. some global south cities have unlicenced public transport systems. Outputs: • Breakdowns of emissions by vehicle type to inform CAZ policy design based on the key contributors of air pollution; e.g. commercial vs private vehicles, diesel vs petrol, etc.
Carbon emissions	Modelling and calculations informed by: • Vehicle counts (pre- and post- CAZ) • Age and type of vehicles

A.2.5   BUSINESS AND ECONOMY

Table 6: Business and economy

Question	Data and collection methods
Vehicle dependent sectors	This can include: • Data on who is operating the fleet; • Data to confirm which types of vehicles are being used; • Survey to understand what the key business uses and markets are.
Cost of living	• Cost of Living Index • Consumer Price Index
Economic activity Spend Footfall	• Surveys with businesses and residents (as conducted in Madrid: The impact of Low Emission Zones on retail activity: Madrid Central lessons.) • Manual counts for: business footfall • Surveys for spend in shops
Businesses Target growth areas Employment density % small businesses,	• Industry reports or market research on industry growth projections • Chamber of Commerce data on business trends, proportion of small businesses

Question	Data and collection methods
Types of businesses – e.g. freight, service sector, tourism	• Number of employees or businesses per unit area • Business directories • Surveys on businesses by sector
Freight	• Average freight delivery time (pre- and post- CAZ).

A.2.6   PERCEPTIONS

Table 7: Perceptions

Question	Data and collection methods
Perceptions • *What are the communities' perceptions of a CAZ?* • *What community specific issues exist?* • *Business community perceptions?*	It is useful to gather and understand what the public perception of air pollution is in their area, are they concerned, is education needed and does the perception align with the health impacts received. Public participatory processes can take many forms, including surveying or polling residents, organising focus groups, facilitating discussion forums, e-voting systems, local workshops, interactive events, or public debates. Strategies to actively and effectively listen to public provided are expanded upon in the C40 CAZ toolkit. Question types and examples include: - Socio-economic (age, gender, ethnicity, educational background, job status, income, car ownership, household size) - Transport modes used - CAZ features (perceptions of fairness, effectiveness, and complexity of scheme, support for scheme, understanding on the need for a CAZ, biggest opportunities and concerns) - Built-environment and travel-related attributes (perceived time to walk to nearest PT, travel time on various modes, commute frequency to the city, shops, school, work, social events, medical trips, entertainment) - Political (perceptions of government trust) - Stakeholder views - Environmental awareness (awareness and concern with air pollution, importance of air quality, comparison to other locations, responsibility to improve air quality) - Complementary measures that work alongside with CAZ (opinions on HEV adoption) Specific questions may be targeted to socio-demographic groups to identify and understand community specific issues.

A.3 Communication channels

Chapter 5 of the Clean Air Zones: Practical Guidance for Cities discussed why transparency, building trust and communication is so important for your CAZ.

In this annex section we provide further information on the communication channels which can be used along with a summary of opportunities and risks.

Table 8: Communication channels

Communication Channel	Description	Opportunities/Risks
Websites or mobile applications	Dedicated websites or apps that contain relevant information, FAQs, registration forms, maps, compliance of vehicle with standards[4] and for account holders to manage their payments, fines, and appeals.	Provides a platform that holds information all in one place, which can provide real-time updates. People will need to actively seek the information. Those who are unaware may not visit these platforms.
Customer service centres	Call centres and customer service centres, this may include an automated webchat or call service.	Provides direct assistance and support related to CAZ regulations and compliance. Requires people to visit the customer service centres. Limited reach to those unwilling or unable to visit.
SMS	Sending text messages	Sending to registered users can provide quick updates, reminders, and notifications about CAZ regulations and compliance deadlines. May be ignored if too many messages are sent frequently.
Email	Sending Emails	Can be used to distribute newsletters, bulletins, and automated notifications to communicate with registered users. Emails may be overlooked due to too much information in inboxes or may be moved to spam.
Retail	Partnering with retail outlets or service centres to distribute informational materials. For example leaflets were produced and	In-person assistance can enhance accessibility and reach diverse demographics within communities.

Communication Channel	Description	Opportunities/Risks
	disseminated around trading estates across the Manchester to increase awareness[5].	Implementation across different outlets may be inconsistent and uneven.
Social media	Utilising platforms such as Facebook, X and Instagram	Can be utilised to reach a wider audience, share news, events, address inquiries, and foster community engagement. Information overload on social media can lead to important messages being overlooked.
Postal	Direct physical communication including informative leaflets, brochures, registration forms, and non-compliance notices	Some stakeholders may prefer physical communication. Potential delays in delivery of information.
Advocates and community leaders	Disseminating key messages through trusted figures within communities who have the influence, credibility and established relationships. Speaking to the media to further increase reach.	Can be used to reach specific communities, ensuring information is communicated in a way that resonates culturally. They can also gather feedback from the public to create a dialogue with city officials. However, there may be risks of inconsistent messaging and ability to represent communities wholly.
Traditional media	Using television, billboards newspapers and radio to broadcast key information.	Able to reach a wide and diverse audience, including those who may not use digital platforms. It can be used to amplify the messages shared by others. High costs for advertisements and does not allow two-way interaction with audience.
Public meetings and town halls	Open forums where policymakers can present plans and public can ask questions, express concerns and provide feedback	Allows for two-way communication, provides a platform for asking questions, expressing concerns. This can help to build trust, increase transparency and accountability. Time-consuming and may have limited reach.
Public announcements	Broadcasting information using public address systems or vehicles that drive through neighbourhoods.	Useful for widely engaging audience, particularly those not reached digitally. Does not provide opportunity for feedback and may be ignored by the public.

A.4 Scheme management

Chapter 7 of the Clean Air Zones: Practical Guidance for Cities set out the questions to answer when considering how a CAZ scheme is implemented and managed.

As this process could be different for each scheme some further considerations are detailed in this appendix to help provide a steer.

We have provided suggestions/considerations to review when setting up the following elements of your CAZ:
- Back office
- Vehicle detection
- Signage
- Enforcement

A.4.1   BACK OFFICE

The CAZ back-office provides the administrative, operational, and strategic foundation for running the CAZ, and ensuring its effectiveness and sustainability. It also acts as the connector of ancillary systems such as:

- Roadside technology – See Section A.4.2: Vehicle detection;

- Communication channels– See Section A.4.3: Signage; and

- Enforcement processes – See Section A.4.4: Enforcement.

For charging schemes, that two main back-office functions are:

1. Operational back-office – gathering the roadside data records and assuring their quality; and

2. Commercial back-office (CBO) – reconciling payments, supporting customer channels and referring non-payers to the enforcement process.

The back-office addresses the following key business processes:

Reconciling non-compliant vehicle trip data with payments and customer accounts.	Gathering vehicle and owner data from the vehicle database.
Managing vehicles that have exemptions from the charge or discounts.	Working with other jurisdictions to gather details of non-compliant foreign vehicles and owners.
Managing customers and their accounts, including fleet accounts.	Issuing reminders to customers who have not paid.
Customer communications, managing queries and correspondence.	Finance, accounting, reporting and referral of non-payers to enforcement.

Managing customer and trip data quality so that billing/charging is accurate.	Processing account top-ups if a positive financial balance is required.
Verifying vehicle detection data – some anomalous transactions will occur.	Billing of post-pay accounts if the CAZ charge is payable after the trip.

The back-office functional requirements should be considered in relation to the business processes and the integration with communication channels, roadside and enforcement.

To determine the functional requirements, it should be determined whether the operational back-office system is integrated with:

- Camera/roadside systems; and/or

- Commercial back-office functions.

This choice can depend on supplier solutions, which can be determined through supplier engagement.

A.4.2   VEHICLE DETECTION

Roadside technology systems will usually form the backbone of any CAZ implementation and enablement.

The principal technology options to facilitate vehicle detection are:

- ANPR (Automatic Number Plate Recognition);

- Tags; and

- GPS (Global Positioning System).

Some key design elements around the selection and deployment of these technology options include the number of detection sites; aesthetics of the equipment and equipment robustness/reliability (minimise downtime). The options are discussed below.

Vehicle detection methods

ANPR camera technology is the preferred method for vehicle detection in a CAZ in Global North cities. These include (but not limited to) Toronto, Montreal, Rotterdam, Amsterdam, Milan, Rome and London. There are exceptions, for example Paris uses stickers for a lighter touch enforcement.

In the Global South, the approach to vehicle detection for managing CAZs is more varied and may involve different technologies depending on infrastructure development and resource availability. Whilst ANPR camera technology is used in Abu Dhabi and Doha, when the Shenzhen Green Logistics Zone was first implemented in 2018, ordinary cameras were used and manually enforced by the Traffic Police Department. It was identified that to further enhance enforcement efforts, the ANPR camera network would need expanding[6,7].

ANPR cameras

ANPR camera technology is a system to extract a text file with the Vehicle Registration Mark (VRM) from the number plate of vehicles in the field of view of a camera. The ANPR system should produce a Vehicle Passage Record (VPR) for every vehicle passing through the field of view of the camera. The VPR is then packaged and stored at the roadside, and then subsequently sent via the communications network to a back-office system.

When selecting locations for ANPR cameras, you should consult appropriate guidance and consider factors affecting the quality of images captured, and enforcement of a CAZ, as well as issues such as privacy, and practical considerations such as the availability of power.

Risks

Though licence plate format and materials are usually well controlled through legislation and approvals, there are risks that owners will deliberately obscure or tamper with the plates. Further analysis is needed of these risks. In general, we understand most drivers will cooperate with the rules of a scheme, however, this may not be the case with all drivers. Accurate detection of some classes can be challenging – e.g. motorcycles.

Tag detection

Beyond ANPR, schemes use "tag" technology to more reliably capture individual vehicle trips.

Tags use two technologies:

- Dedicated Short-Range Communication (DSRC); and

- Radio Frequency ID (RFID).

Combination of ANPR and Tags

The combination of ANPR cameras and in-vehicle RFID tags to detect and identify vehicles as they pass through tolling gates on major arterial highway routes is also possible. Tags can be associated with a licence plate registration so this can be

checked and if there is a discrepancy between the registered vehicle captured by the camera and recorded tag ID, it can be flagged, and the anomaly processed through special business rules. It is usual to deploy "Stickertags" in a form that cannot be removed from a vehicle and remain intact.

GPS and distance based charges

Many charging schemes use a distance-based toll so that the kilometres driven, and therefore damage caused to the highway, are related to the amount the customer pays, and therefore funds highway maintenance in proportion to customer usage. The majority of distance-based schemes use a GPS on-board unit to measure the distance driven and the applicable charge so that some areas can have no charge applied and others can be charged.

However, it should be noted that GPS distance based-charging schemes may not be as cost effective to serve a planned CAZ, compared to ANPR only or ANPR + tag, particularly from the perspective of the motorist e.g. due to purchase and installation of on-board vehicle equipment.

A.4.3   SIGNAGE

Signage is key to a driver understanding where the CAZ is. The proposed signage strategy for the scheme is to include:

- Advanced warning signs to notify drivers in advance of the CAZ.

- Entry and Exit signs to notify drivers about entering and leaving the zone. These signs are likely to be located near the entry and exit detection sites for the zone.

- Repeater signs to reiterate the message about being within the zone. These signs are likely to be located near the internal detection sites within the zone.

A.4.4   ENFORCEMENT

If a vehicle is identified travelling through the zone, and it does not meet the necessary criteria and does not make a payment within a set period of time (if relevant), a 'Violation' or 'Penalty Notice', or equivalent, will be sent to the owner of the vehicle.

An enforcement notice will usually contain details on:

- The alleged offence;

- Registration number plate, time and date;

- Location to demonstrate vehicle was inside the relevant zone;

- Photographs of the vehicle;

- Amount of the violation, penalty or unpaid emissions charge;

- How to make payment and within what time frame; and

- How to dispute the charge/make a representation if the driver believes the violation notice has been incorrectly issued.

Figure 1 provides a high-level overview of the enforcement process.

Vehicle identification (ANPR and database) → Inspection and check of compliance → Issue of penalty notice, tax or equivalent (as defined by legal framework) → Recovery of funds and/or completion of appeal process
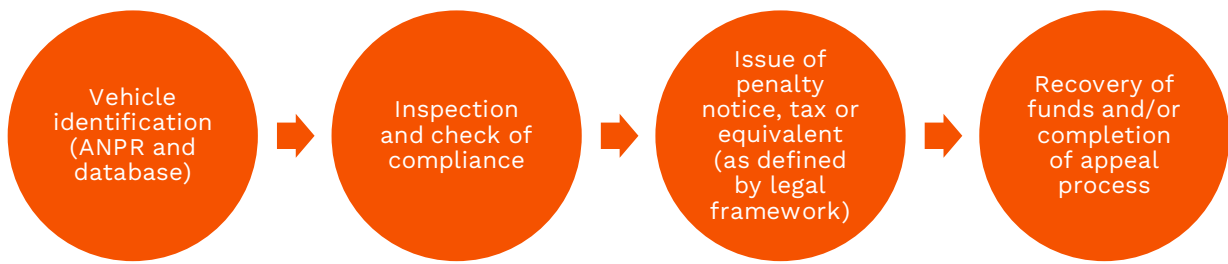
Figure 1: Summary of recommended high-level enforcement process

The approach to enforcement will usually be driven by:

- The legal framework imposed by the city;

- The type of offence that non-payment of the LEZ charge constitutes;

- The evidence needed to prove the offence gathered; and

- Whether fines are applied and what approach is used for debt recovery.

Interview Insights

Effective enforcement mechanisms and strategies for ensuring compliance have been cited as key to the success of a CAZ. Without proper enforcement, even the best-designed CAZ may fail to achieve its intended impacts. Cities have suggested that robust enforcement strategies are essential for ensuring that the rules of the CAZ are followed and that the desired air quality improvements are therefore realised.

"*...through the cameras and the plate recognition systems, we might enforce some sanctions and legal consequences on those that do not follow the rules...Then we can always say that the funding we gain from these sanctions will be used to promote and implement the system.*" - City representative,

Legal basis for enforcement

To develop a legitimate, effective enforcement process for a CAZ, specific legislation locally relevant to the scheme will dictate the mechanisms needed for enforcement. This is likely to consist of law(s) that assist in setting out:

- The emissions standards which vehicles must comply with.

- Where and when charges or penalties will apply for non-compliant vehicles.

- Which classes of vehicles are subject to a charge or constraint, including any discounts, exemptions and variations.

- Charge levels and how they may vary.

- The process for non-payment of the emissions charge or penalty to be followed if the charge remains unpaid including penalty/violation notices.

- The escalation process if there is no response to the violation, whether fines are applied.

"The legislative tools or frameworks that we need to put in place to manage a clean air zone would be an area of interest. We need that city level legislative framework at the city level so we can manage an air zone properly." - City representative, Global South

- The right to dispute the violation notice and challenge the evidence – most tolling and charging schemes allow for a dispute process.

- Operation of fines and debt recovery.

Usually, the enactment of laws and regulations will establish the CAZ, define its boundaries, set emissions standards and enforcement procedures. This will require setting the compliance requirements which detail the specific emission limits for the different vehicle categories. [8,9,10]

Legal Advice

Cities must ensure there is a legal basis to design, implement and enforce a CAZ. Legal advice will need to be sought when considering all the issues raised above as there can be much variation from location to location.

Enforcement Legal Cases

In Glasgow, motorists had their LEZ penalty charges cancelled after the Transport Appeal Tribunal for Scotland ruled Glasgow City Council LEZ fines could not be enforced as the council did not serve the fines using recorded or registered post[8]. This procedural error could impact more than 20,000 LEZ fines issued from June 2023 to the end of September 2023.

In Bristol, due to procedural, language or documentation errors of the CAZ fines (in the form of fixed penalty notices), fines have been overturned upon appeal[9].

Expansion Legal Case

London's ULEZ expansion in 2023 was contested by several outer London councils who launched legal action in February 2023[10]. It was argued that the Mayor of London had failed to adequately consult with businesses and residents, that the expansion was not wholly compliant with relevant legislation, and that insufficient data had been published to allow consultees to provide an informed response. Despite the high court dismissing this legal challenge, ruling that the legal basis for expansion was sound, lots of negative publicity for the scheme was generated. This can cause further public pushback.

Interview Insights

Cities representatives also note that they require assistance in developing appropriate legal and policy frameworks to support CAZ implementation, including guidelines and roadmaps. The absence of supportive legal frameworks or the lack of enforcement power can impede CAZ implementation.

"The gap where I think they still need assistance is in terms of policy development. I feel like the city is quite reliant on external expertise, they don't really have in-house expertise." - City representative, Global South

Exemptions

Exemptions will need to be established and maintained as part of the roadside capture business rules, that includes the registration details of the excluded vehicles. Depending on the design of the vehicle detection and capture system, this can be built into the camera or via the operational back-office.

A.5 Monitoring and evaluation

Chapter 8 of the Clean Air Zones: Practical Guidance for Cities provides a summary of what data will help you understand if the CAZ is achieving the goals.

This annex section adds to the information in the chapter with some further examples of metrics and the changes to observe.

A.5.1   METRICS

There are several metrics which should be monitored including air quality, climate emissions, economic and equity impacts, health impacts, transport and compliance statistics.

Table 9 provides examples of metrics which can be used. While these are outcomes which can be quantified, it is also important to consider qualitative input through engagement with the public to understand the full picture of impacts.

"Before the city gains momentum in terms of delivering clean air zones, I think we also need that kind of a partner who is going to work with us for some time, maybe to support the data monitoring infrastructure to support us in ensuring that maintenance of these infrastructures is still working." - City representative, Global South

Table 9: Monitoring and evaluation metrics

Impact	Example metric	Example outcome
1. CAZ Uptake		
1.1 Transport	Traffic volume	Reduction in traffic volumes
	Fleet composition	Vehicle contributions to different vehicle standards being applied Uptake of electric vehicles
	Vehicle kilometres travelled	Reduction in vehicle kilometres travelled by motor vehicles
	Public transport usage	Increase in public transport usage (passengers per day)
	Modal splits	Increase in uptake of active travel such as walking or cycling
	Congestion	Change in congestion patterns (spatial, temporal)
	Boundary roads	Measure change in trips on boundary routes where there may be risk of diverting traffic

Impact	Example metric	Example outcome
1.2 Compliance and enforcement	Vehicle compliance rates	Percentage of vehicle compliance within CAZ
	Number of fines issued	Number of fines issued for non-compliance
1.3 Public perception and engagement	Media coverage	Number of mentions of CAZ in media
	Social media tracking (engagement, reach, sentiment analysis)	Number of social media engagement and reach on CAZ-related posts
	Diversity of participants	Demographic diversity of participants in the CAZ consultation and decision-making processes, including representation of low-income communities, ethnic minority individuals and people with disabilities
	Feedback incorporation	Assess how much feedback from vulnerable of marginalised groups has been incorporated into the final CAZ design, tracking specific changes as a result of this input
1.4 Socio-economic Equity	Income-based participation rates	Track the engagement and participation rates in CAZ consultations across different income groups to ensure inclusive involvement
	Distribution of financial support	Measure the allocation of subsidies, grants, or discounts among low-income households, small businesses and other vulnerable groups
2. CAZ Outcome		
2.1 Air quality	Air quality monitoring concentrations for NO_2, PM_{10} and $PM_{2.5}$	Meeting relevant air quality standards or targets
	Vehicle air pollutant emissions for nitrogen oxides (NO_x) and PM	Reduction vehicle air pollutant emissions
2.2 Climate	Vehicle carbon emissions	Reduction in vehicle carbon emissions
2.3 Economic and equity	Impact on local businesses	Increase in costs due to vehicle fleet upgrades
		Increase in operational costs for small businesses
		Increased mileage as vehicles are re-routed to not pass through LEZs
	Job creation	Number of jobs created in relation to CAZ scheme
	Revenue generated from CAZ	Reduction in revenue generation from CAZ

Impact	Example metric	Example outcome
2.4 Health	Hospital admissions for cardiovascular and respiratory conditions	Reduction in number of hospital admissions for cardiovascular or respiratory conditions per 100,000 population
	Mortality rates attributable to air pollution	Reduction in number of deaths attributable to air pollution per 100,000 population
	Number of road incidents	Reduction in number of road incidents
2.5 Socio-economic Equity	Changes in transportation costs	Analyse the changes in transportation costs for different income groups before and after CAZ implementation to assess economic and social impacts
	Re-routed journeys	Analyse re-routed journeys across different income groups to assess the economic and social impact of re-routed trips
2.6 Health Equity	Reduction in pollution-related health disparities	Reduction on rates of respiratory and cardiovascular diseases across different demographic groups, particularly in marginalised or vulnerable groups
	Health outcomes by area	Compare improvements in air quality and associated health outcomes in different neighbourhoods, especially those with higher baseline levels of pollution
2.7 Accessibility and mobility	Public transport accessibility	Measure improvements in access to public transportation options, particularly in low-income communities, before and after the implementation of a CAZ
	Usage of Active Travel options	Track the increase in cycling and walking in various neighbourhoods, especially in areas where infrastructure improvements have been made
2.8 Behaviour Change Monitoring	Vehicle upgrades	Measure vehicle upgrades across different neighbourhoods and the level of upgrade obtained
	Mode shift – transport	Monitor individuals transport mode behaviour and shifts to new modes of transport
	Mode shift – route choice	Measure individuals route choices

A.6 References

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