

CLEAN
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CLEAN AIR ZONES IN ASIAN CITIES

Lessons and Reflections



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EXECUTIVE SUMMARY

SETTING THE CONTEXT

Air pollution is one of the most urgent matters of our time. Around 7.9 million deaths were attributed to air pollution in 2023, with 70% of pollution-related deaths occurring in Asia-Pacific alone.¹ In parts of Asia, PM_{2.5} levels – the inhalable particulate matter that poses serious health risks – frequently exceed WHO air quality guidelines.²

Polluted air is also a threat to food and water security, already-fragile climate systems, and to economies. Countries in Asia lost 4–11% of gross domestic product (GDP) in 2019 due to citizens' exposure to PM_{2.5}.³

Continued fossil fuel dependence and transboundary pollution makes improving air quality in Asia a multi-faceted challenge. Without proper planning and strategic integration, clean air initiatives can meet implementation challenges and involve time and costs for authorities, with many cities facing technical and resource constraints.

However, because of the impacts of air pollution, cities often act as first responders and drivers of innovation and action, with Clean Air Zones (CAZs) and related measures representing one approach city leaders and planners can take to address the challenge.

WHAT ARE CLEAN AIR ZONES (CAZS)?

CAZs, and similar schemes such as Low Emissions Zones (LEZs) and Zero Emission Zones (ZEMs), are one of the tools available to cities seeking to address air pollution. Typically, they are designated urban areas where targeted actions are implemented to improve air quality and reduce public exposure to pollutants. The exact nature of CAZs depend on a city's priorities and resources, and can take different forms and serve different purposes, such as expanding active mobility and public transport, restricting vehicle emissions, or increasing greening.

In this report we focus on vehicle emissions and view CAZs as a specified area, designed by an authority, in which vehicles are required to meet minimum emission standards. Not all cities are ready to implement a CAZ in its most complete form, and examples of interim measures are also highlighted in this study to show what options cities might want to explore.

Tackling air pollution by addressing vehicle emissions represents significant opportunities, with clean air measures stimulating local economies, improving health outcomes, and supporting climate and net zero ambitions. By taking action on air pollution, cities can improve their reputations and rankings, and demonstrate leadership and innovation. There are possibilities for revenue creation, placemaking and urban regeneration, as well as for impactful policy reform, regional cooperation and setting new benchmarks for human and planetary wellbeing.

As this report demonstrates, these outcomes are possible and are already being realized in several cities throughout Asia.

For example, Seoul's CAZ measures have led to a 42.4% decrease in CO, 38.7% decrease in CO₂, 36.6% decrease in NO_x, and a 36.7% decrease in PM_{2.5}.⁴ In Chengdu, between 2022 and 2024, the citywide average roadside NO₂ concentration dropped by 16% as a result of the city accelerating the clean and low-carbon transition of heavy-duty vehicles.⁵

OBJECTIVES OF THIS REPORT

This report provides a comprehensive overview of CAZ measures and related approaches across Asian cities and highlights key findings for planners and leaders who are considering ways to improve air quality in their own jurisdictions. It is intended for city and national government officials, enforcement agencies, public health authorities, and finance and budgeting teams. However, it will also prove valuable to any entity interested in addressing air pollution, including civil society organizations, research institutions, development partners, and private-sector operators.

Every city has its own specific set of circumstances and, for some, CAZs are not the right approach. The measures put in place need to be tailored to the particular characteristics of each city. As such, we have provided a variety of good practice case studies to inform planners and leaders to identify relevant approaches and learn from those that face similar challenges. We hope that the findings presented here serve as a catalyst for clean air action, so that all cities in Asia can enjoy the benefits.

REPORT METHODOLOGY

This report explores the implementation, challenges, and successes of policy measures that underpin CAZs across 10 Asian cities: Agra, Bangkok, Chengdu, Delhi, Jakarta, Kathmandu, Pasig, Seoul, Shanghai, and Ulaanbaatar. A comparative analysis was conducted using mixed-method research, with a baseline study of each city validated through stakeholder interviews.

A total of 25 stakeholder interviews were conducted across the 10 Asian cities. The stakeholders were representatives from universities, research institutes, government bodies, implementing units, private sectors, non-government organizations, affected transport drivers, and financing institutions. These stakeholders had both direct and indirect involvement in the inception and implementation of CAZs, while others have been directly impacted by CAZ measures.

This selection of cities represents a wide variety of motivators, levels of ambition, mandates, market conditions, and social realities. However, these cities often share the same friction points.

While CAZ measures can be compelling, many cities find implementation stalls when legal or regulatory mandates are ambiguous, institutional roles are fragmented, enforcement capacity is uneven, evidence chains are incomplete, and distributional impacts (on low-income groups, for example) are not proactively managed.

This report identifies that these patterns typically span four key structural areas, which need to be addressed simultaneously if CAZ measures are to be successful in achieving scale.



1. GOVERNANCE, REGULATION, AND INSTITUTIONAL CAPACITY

Many cities face foundational governance challenges that weaken their ability to design and implement clean air and vehicle restriction measures. Common issues include the absence of a clear legal basis or explicit regulatory mandate, fragmented or overlapping authority among agencies, unclear leadership, and disconnected data and enforcement systems. These gaps can lead to slow decision-making, inconsistent rules, and difficulty sustaining measures beyond pilots or short-term political cycles.

The starting point of a city's governance reflects how far and how quickly it can advance CAZ measures. Cities with clear governance, regulation and institutional capacity can more easily enable targeted restrictions and integrated planning across transport or environment sectors. Below this level, cities often rely on temporary task forces, project-based coordination, or partial mandates, and those with less robust forms of governance typically begin with small-scale or manual enforcement actions due to limited institutional capacity.



2. QUICK-WIN TRANSITIONAL STRATEGIES AND EMERGING PRACTICES

Despite their differences in context and priorities, cities often face a similar set of pressures that motivate the adoption of CAZ measures. While these pressures are typically reactive in nature – such as sudden spikes in pollution, worsening congestion, rising transport-related emissions, or evidence pointing to specific high-emitting vehicle groups – they create social, environmental, and political urgency for cities to act. As a result, cities typically start with ‘quick win’ measures that can deliver immediate and tangible impacts while long-term strategies are still being developed.

Cities with high institutional capacity and integrated data systems are better positioned to expand and sustain existing CAZ pilot schemes, using outcomes to strengthen baseline data, leverage integrated monitoring systems, and refine targeted interventions. Cities with less capacity primarily rely on pilot-level interventions and existing infrastructure to establish basic baseline data, although these efforts remain constrained by funding, technical capacity, and fragmented mandates.

Typical quick-win measures in these cities include practical, low-cost support to ease compliance burdens, such as vehicle air filters and maintenance checks, and building on existing infrastructure and capacity.

Also, under the theme of Quick-win Transitional Strategies and Emerging Practices, we have identified a cross-city challenge: pressure to demonstrate early results. Short-term or episodic measures, such as alert-based restrictions, may be indicative of responsiveness, but they can make compliance unpredictable and difficult to enforce.

For example, we found that early alert-based traffic restriction pilot schemes frequently generate unintended traffic displacement and congestion, which weakens air-quality gains and complicates corridor management. Meanwhile, enforcement approaches that combine manual checkpoints with fledgling automation systems introduce discretion and variability, which can create uneven outcomes across locations. Without consistency, initiatives may struggle to transition from pilot to policy.



3. EQUITY, INCLUSION AND TRANSPORT IMPACTS

CAZ measures carry equity risks, with the burden, cost and disruption of vehicle restrictions typically falling on low-income workers, informal sector earners, small operators, commuters, and vulnerable households who may have access to fewer clean transport options compared to those on high(er) incomes.

Changes in access rules can threaten livelihoods, while residents and small businesses within or adjacent to restricted zones can be impacted by parking and foot traffic. For vulnerable commuters, restrictions that advance faster than improvements in public transport can increase inconvenience and perceptions of unfairness, while freight operators and small logistics providers often face disruptive compliance burdens, particularly where vehicle transitions affect daily operating ranges, duty cycles, or refueling and charging logistics.

Without targeted support measures, these impacts become more severe and disproportionately affect groups that already have limited resilience, translating into political pressure to dilute or delay measures.

However, across all the cities assessed in this report, early and proactive communication proved to be a critical factor for equity and public acceptance. Clear messaging and positive framing improved cooperation, while weak or late communication led to confusion, resistance and distrust, especially among informal operators, low-income groups, and local residents.



4. INFORMAL TRANSPORT DYNAMICS AND INTEGRATION

Informal transport refers to privately operated, often unregulated, and unscheduled transit services such as minibuses, rickshaws, and tuk-tuks. In cities where these services are active, informal transport operators are among the most affected by CAZ restrictions. Informal transport groups are subject to restrictions, permits, and administrative requirements, but they are not effectively integrated into transport planning or transport systems, and operators are often excluded from planning and decision-making. This exclusion results in limited or inadequately targeted support measures to address equity concerns and operational vulnerabilities.

Additionally, the limited engagement of informal operators during planning means that rules are often poorly understood, and a threat to livelihoods creates a strong incentive to evade or contest regulations. Support measures such as transition assistance, route adjustments, or operational pathways can mitigate these risks, but when coordination takes place after the rules are set, implementation becomes a process of post-hoc negotiation and piecemeal adjustment, which delays progress.

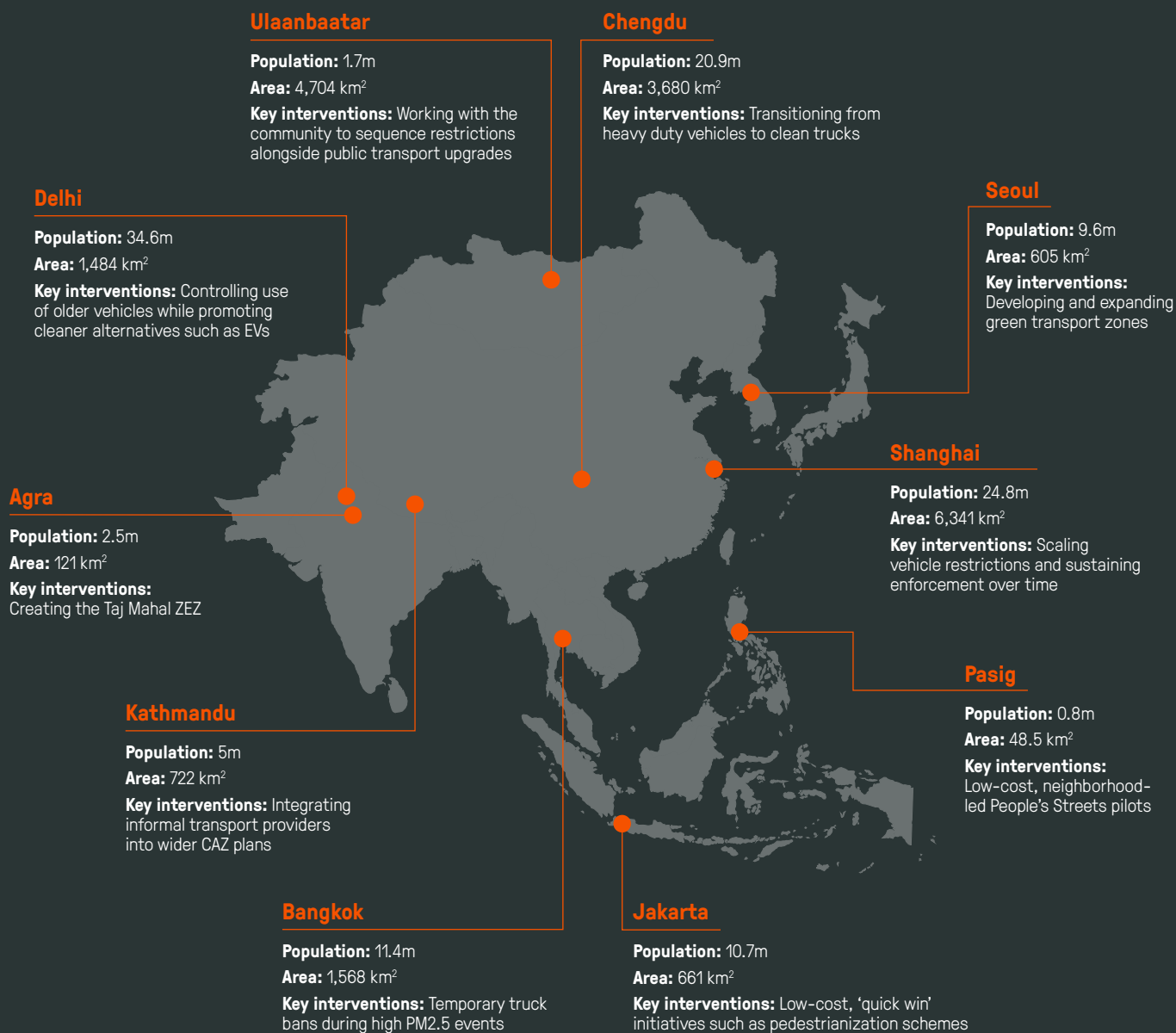


OPPORTUNITIES FOR LEADERS AND PLANNERS

Viewed together, these four factors explain why CAZ initiatives in some Asian cities struggle to progress beyond the pilot stage. However, these challenges have been successfully tackled in a variety of ways.

We have used these themes to structure our recommendations and examples of best practice, demonstrating how addressing these themes in an integrated manner means the economic, health and environmental benefits of CAZ measures can be realized fully.

MAP OF THE CITIES WE RESEARCHED



RECOMMENDATIONS

Our research considered the lessons of CAZ measures implemented across the 10 cities within the context of these four themes. From this analysis, we have developed the following recommendations, designed to inform city planners and leaders considering their own CAZ initiatives.

KEY



**Governance,
Regulation, &
Institutional
Capacity**



**Quick-win
Transitional
Strategies
& Emerging
Practices**



**Equity,
Inclusion &
Transport
Impacts**



**Informal
Transport
Dynamics &
Integration**



Heavy traffic in India



1. ENSURE CLEAR LEGAL BACKING

Cities with clear legal authority enforce and expand measures more confidently, while those with unclear mandates face confusion, delays, and resistance. Where rules are formalized, enforcement is smoother and more credible. Where the basis is weak or temporary, agencies hesitate and stakeholders contest decisions.

Across all 10 cities, measures progressed wherever a minimum legal or administrative mandate existed – even in the absence of more comprehensive CAZ legislation. Such mandates provide sufficient authority to introduce and enforce measures, while allowing flexibility in scope and timing. Positive outcomes are also more consistent when enforcement and oversight roles are clearly allocated across agencies, which reduces ambiguity around responsibility.

Best practice examples in this space include Agra, whose measures are supported by a Supreme Court mandate, and Shanghai, which uses a highly-codified regulatory framework. Legal clarity is therefore a decisive factor in whether cities act with confidence or remain constrained by uncertainty.

Chengdu has established a well-structured institutional and technical framework to support the city's clean transport transition, with strong coordination among multiple government departments led by the ecological and environmental authorities in Chengdu.

2. ESTABLISH STRONG DATA MANAGEMENT

Strong and well-integrated data systems are central to CAZ measures as they allow cities to confirm whether vehicles are compliant. Cities with better-integrated data systems can match detections with vehicle registrations, permits, and exemption records quickly and accurately. This makes enforcement more consistent and reduces the need for manual checking or discretionary decisions, which can cause inconsistencies.

Reliable enforcement hinges on data platforms that can link traffic, ANPR (Automatic Number Plate Recognition), CCTV and air quality data with open APIs (Application Programming Interfaces) and dashboards for real-time agency action. At the mature end, Seoul's TOPIS (Transport Operation and Information Service) city management hub integrates big-data with open APIs to enable real-time, multi-agency responses. Elsewhere, Bangkok is linking CCTV with environment data to enforce its LEZ, while Kathmandu is combining AI-enabled CCTV/ANPR with a citywide air quality management dashboard.

3. COMBINE RESTRICTIONS WITH PHASED IMPLEMENTATION

Instead of enforcing penalties immediately, many cities roll out enforcement gradually through pilots, grace periods, or warning-only phases to help people adjust. These staged approaches help operators and residents understand the rules, give agencies time to test their systems, and reduce resistance or confusion. Gradual rollout makes the transition smoother, especially in places where institutions or technology are still developing.

In Chengdu, the city has adopted a stepwise approach to increasing the share of electric vehicles among dump and concrete mixer trucks, while progressively restricting diesel vehicles in core urban zones within its Ring Expressway. In Pasig, the city holds trial restrictions, such as Saturday closures and weekend models, before implementing regular car-free days, which helps to build compliance and familiarity.

However, cities adopting these measures should design a clear pilot-to-policy pipeline, otherwise phased initiatives can continue indefinitely, cost more, and damage credibility.



4. WORK WITH EXISTING INFRASTRUCTURE

Instead of building expensive new CAZ enforcement systems that require large investments, cities can maximize the use of existing infrastructure. This is most feasible in cities that already have a monitoring infrastructure in place, as operating units can perform routine procedures, and legal processes are already authorized to automate evidence and sanctions, allowing rapid scale-up without major new capital.

In Bangkok, for example, ANPR is layered onto the CCTV grid to ticket violators and manage curb access through routine police workflows. This repurposes current assets and keeps operations cost-efficient, transferable, and manageable through existing institutional processes.

5. EMPLOY TACTICAL MEASURES AND PILOT SCHEMES

Short-term measures such as pilot schemes are effective transitional strategies that allow cities to test feasibility, refine designs, and build public and institutional support, often at low cost, before committing to full-scale adoption – often with low data requirements.

In Delhi, for example, multi-agency operations plus routine monitoring support quick anti-idling measures, access restrictions, and trial pedestrian zones, with basic and consistent enforcement capacity and visibility ensuring these measures produce tangible short-term impacts instead of remaining symbolic.

Implementation of quick-win measures tends to be more effective in cities that have operational flexibility, enabling them to pilot, modify, or discontinue actions without the need for lengthy legal or political approval processes.

6. PROVIDE LOW-COST SUPPORT TO EASE TRANSITION

Citizens and stakeholders are more accepting of CAZ measures when they involve minimal financial costs. Therefore, compliance can be increased by adopting relatively low-cost supporting measures that reduce burdens on operators and vehicle owners as CAZ measures are implemented. These measures can include air filter additions and replacements, vehicle retrofitting programs to reduce emissions, subsidized tune-ups, and basic maintenance, all designed to improve air quality in congested areas.

In Bangkok, CAZ enforcement is paired with truck-focused maintenance clinics and filter campaigns, as evidence shows that properly installed vehicle after-treatments and maintenance deliver substantial particulate matter reductions without requiring immediate vehicle replacement.⁶

In Agra, electric rickshaws and battery-operated vehicles are incentivized through subsidies and preferential access within the Taj Mahal ZEZ, providing alternatives for informal operators.



7. COMMUNICATE AMBITION TIMELY AND COMPREHENSIVELY

Across all the cities in our study, the early and sustained communication of plans about CAZ measures and restrictions mattered most for public acceptance. When cities explained proposed measures early and clearly, framed them positively, and created two-way forums to give affected stakeholders an opportunity to have their concerns acknowledged, communities were more willing to cooperate. By contrast, delayed or weak messaging typically produced confusion or uneven buy-in.

In Pasig, for example, a “People’s Streets” initiative – launched under the Pasig Green City Programme – aims to create a greener, more livable city by prioritizing pedestrians. Its sustained communications program, which frames vehicle restriction in a beneficial way, has been instrumental in shifting public behaviors towards active and shared mobility. Surveys conducted by the Pasig Transport Office found foot and cycling traffic was up by 40% in pilot areas, alongside a decline in short-distance motorized trips.

8. PROVIDE TRANSPORT ALTERNATIVES

If CAZ measures involve closures or restrictions that will disrupt journeys, there must be affordable and viable mobility alternatives in place. This is especially pertinent for low-income users, informal operators, and other disproportionately-affected groups, who frequently bear the consequences of displaced journeys and are therefore more likely to demonstrate resistance to CAZs.

Restrictions become more acceptable if public transport is expanded and last-mile connections are protected, with clear service information and inter-agency coordination. In Seoul, for example, CAZ restrictions have been introduced alongside major public transport upgrades, while Delhi has expanded its e-bus and metro services. Chengdu has invested heavily in expanding its public transport network, including one of the world’s fastest-growing metro systems.



9. ENGAGE WITH INFORMAL OPERATORS

Cities adopting restriction-first measures need to ensure that operators have accessible support, because restrictions without safeguards can create income loss, exclusion, and weak compliance.

In cities with informal transport, the implementation of CAZ measures is more workable when informal transport is explicitly recognized as part of the urban transport system, rather than treated as an external issue or afterthought.

Recognition of informal operators as legitimate stakeholders creates a platform for engagement and typically reduces immediate resistance

during implementation. Dialogue, feedback, support, and adjustment of measures all allow policymakers to better understand operational realities and livelihood concerns. As a result, CAZ initiatives become more inclusive and context sensitive.

Kathmandu provides a strong example of transformative integration in this space. Through proactive engagement with informal operators, the city has pursued thoughtful and considered measures such as consolidating operator associations, reallocating routes for displaced operators, forming cooperatives to operate high-capacity buses, and providing operators with training and other support.

KEY TAKEAWAYS

Every city is different, so planners and leaders need to design and test CAZ measures that respond to specific circumstances, needs and capacities of individual cities and urban areas. A wide variety of initiatives, from on-the-ground quick wins to systemic governance shifts, means that cities of different sizes, demographics and economies can feasibly consider CAZs and related measures of their own.

We hope that city planners and leaders reading this report will consider these recommendations in the context of their own opportunities and challenges, and use them as a catalyst for conversation with peers and other decision makers, so that clean air action can be accelerated across Asia.



MAIN REPORT

INTRODUCTION

As cities around the world strive to meet ambitious environmental targets, improve health outcomes for citizens, and ensure continued sustainable development, CAZs and related measures represent one of the opportunities for multi-outcome action, with significant potential in Asia.

According to the United Nations Environment Programme (UNEP), CAZs in Asian cities have the potential to reduce PM2.5 by as much as 70% by 2030,⁷ yielding a wide range of benefits such as reduced pollution, enhanced public health and wellbeing, and strengthened economic activity.

Cities across Asia – and indeed those referenced in this report – have varying levels of approach, ambition, and scope for implementing CAZ measures. Alongside air quality management and reducing emissions, tackling air pollution is one of the main motivators for action. For some cities, CAZs exist to drive improvements to vehicle technology and upgrades to public transport systems to mitigate traffic congestion. Elsewhere, cities opt for CAZ measures designed around cultural and heritage preservation. In this report we refer to CAZs meaning the complete policy of reducing vehicle emissions across a geographic zone which is actively implemented and enforced and which may include supporting policies such as scrappage schemes.

We also use ‘CAZ related measures’ which apply to cities that might not have a full CAZ in place but are taking measures that can be seen as interim steps towards a CAZ.

This report does not state or take the position that a CAZ is right for every city. The report focuses on those cities that have stated their interest in pursuing CAZ policy actions, enabling comparisons of different approaches and their impacts.

CAZs can be implemented via a variety of interventions, from dedicated low emission zones and corridor-based restrictions, to vehicle electrification, pedestrianization and integrated transport planning. Success depends on a number of factors, such as evidence-based design, strong political leadership, effective enforcement, targeted public awareness campaigns, and the creation of clear, long-term goals. In contrast, CAZ measures tend to stall when legal mandates or regulatory frameworks are ambiguous, institutional roles are fragmented, enforcement capacity is uneven, evidence chains are incomplete, and distributional impacts (particularly on vulnerable groups) are not proactively managed. This study focuses on five components that are critical to successful implementation of CAZs and related measures.



SUCCESSFUL CAZ MEASURES ARE BUILT ON FIVE READINESS ASPECTS:

1. Legal and Governance Readiness

Do cities have a clear and explicit legal mandate to implement CAZ measures? A well-established governance framework not only legitimizes CAZ-related actions but also provides the necessary regulatory backbone for effective enforcement and coordination among relevant agencies.

2. The Institutional Capacity to Enforce CAZ Measures

Do cities have dedicated bodies or teams tasked with implementing and enforcing emission reduction measures? Cities with prior experience in implementing similar initiatives often demonstrate higher operational capacity, enabling more effective monitoring, enforcement, and adaptive management throughout the policy cycle.

3. The Availability of Data and Monitoring Systems

Do cities have reliable data and robust monitoring systems needed to form the technical foundation for evidence-based policymaking? Datasets related to air quality, vehicle emissions, and transport activity not only support policy design and evaluation but also build transparency and public trust. These can range from low-cost sensors to more sophisticated data monitoring systems.

4. The Readiness of the Public Transport System

Are clean and affordable transport options available as alternatives to private or high-emitting vehicles? For example, cities with comprehensive and accessible transport options are better positioned to mitigate disruptions and ensure mobility equity when implementing CAZ measures. Where cities do not have affordable alternatives, additional measures will be required to ensure public uptake.

5. Equity-Oriented Strategies and Social Acceptance

Do cities have strong safeguards that protect low-income users, informal operators, and other vulnerable groups who may be disproportionately affected by emission control measures? Cities that integrate social inclusion, consultation, and transparent dialogue into their approach, from design to implementation, tend to foster greater acceptance and long-term sustainability of clean air initiatives.

A city's readiness levels based on these five aspects will often dictate the initial parameters of CAZ measures, including:

- **Location and scale:** Ranging from selected streets and specific districts to citywide and even regional implementation.
- **Operational hours:** From episodic measures (typically in response to triggering polluting conditions), to a defined schedule (such as restrictions on certain days or times), or permanent measures.
- **Vehicle scope:** Whether restrictions apply to specific vehicles, or if special exemptions are made for particular vehicles – such as electric vehicles – or residents of certain areas.
- **Penalties:** Whether motorists are charged for entering CAZs or if fines are issued for violations and non-compliant vehicles.

In practice, cities frequently layer or sequence multiple interventions and treat them as components of broader city-wide programs rather than standalone measures.

KEY CONSIDERATIONS

Cities throughout Asia demonstrate a mix of readiness factors. While some boast strong governance, institutional capacity and robust data systems, their transport systems and equity safeguards could benefit from improvements. Equally, cities that show gaps in regulatory mandate and data availability may demonstrate good progress in institutional capacity and equitable management.

Many cities have implemented CAZ measures successfully, but this does not mean they have not faced challenges, or encompassed areas that require further attention. As such, the findings of this report identify four key themes that must be addressed in the creation of CAZ initiatives. Below, we highlight our key findings and considerations for each theme, outlining why city stakeholders must consider each when approaching CAZ measures within the context of their own city's strengths and weaknesses.



1. GOVERNANCE, REGULATION, AND INSTITUTIONAL CAPACITY

Many cities struggle with core governance issues that limit their capacity to plan and carry out clean air and vehicle restriction policies. Typical problems include a lack of clear legal authority or mandate, overlapping or fragmented responsibilities across agencies, ambiguous leadership, and poorly integrated data and enforcement systems. As a result, decisions are often delayed, regulations can be inconsistent, and policies are hard to maintain beyond pilot phases or short political timelines.

This is a critical consideration because:

- Cities with clear legal authority enforce and expand measures more confidently. Where rules are formalized, enforcement is smoother and more credible. Where the basis is weak or temporary, agencies hesitate and stakeholders contest decisions.
- Cities with stronger, well-organized coordination systems implement measures more smoothly, while cities with ad hoc or unclear structures struggle to enforce rules and keep programs running.
- Being able to reliably verify compliance is an essential component of an effective enforcement practice. Strong and well-integrated data systems are central to this verification process since they allow cities to confirm whether vehicles are compliant.
- Instead of enforcing penalties immediately, many cities roll out enforcement gradually through pilots, grace periods, or warning-only phases to help people adjust. These staged approaches help operators and residents understand the rules, give agencies time to test their systems, and reduce resistance or confusion.
- Some cities rely on administrative fines, escalating penalties for repeat offenders, or permit cancellation. Others make drivers turn back at checkpoints or, in rare cases, file criminal cases in instances of non-compliance. Cities also differ in how they resolve disputes, ranging from automated processing to case-by-case discussions handled by frontline staff. These differences shape predictability, fairness, and overall compliance.





2. QUICK-WIN TRANSITIONAL STRATEGIES AND EMERGING PRACTICES

Although cities differ in their contexts and priorities, they are often driven to adopt CAZ measures by a common set of pressures. These pressures are usually reactive, including sudden increases in pollution, growing congestion, rising emissions from transport, or data identifying particular high-emitting vehicle groups. Together, they generate social, environmental, and political urgency to respond. Consequently, cities tend to begin with “quick win” actions that produce visible, near-term benefits while longer-term strategies are still taking shape.

This is a critical consideration because:

- Investing early in baseline data and simple scenario modeling strengthens decision-making by allowing cities to design enforcement measures that are evidence-based, realistic, targeted, and informed by expected impacts.
- Low-cost and short-term measures such as tactical actions and pilots are effective transitional strategies that allow cities to test feasibility, refine designs, and build public and institutional support before committing to full-scale adoption.
- Cities that leverage existing enforcement infrastructure rather than building costly new systems can scale and replicate measures more quickly and in a cost-efficient manner, making this approach highly transferable and easier for institutions to manage.



Kathmandu, Nepal



3. EQUITY, INCLUSION AND TRANSPORT IMPACTS

Clean air and vehicle restriction measures can pose significant equity risks, as their costs and disruptions often fall disproportionately on low-income workers, informal earners, small businesses, vulnerable households, and commuters. Changes in access rules may threaten livelihoods, reduce foot traffic for residents and businesses in or near restricted areas, and create compliance challenges for freight and small logistics operators. When restrictions are introduced faster than improvements in public transport or without targeted support, they can increase inconvenience, perceptions of unfairness, and political pressure to weaken or delay implementation, particularly among groups with limited capacity to absorb these impacts.

This is a critical consideration because:

- Restrictions become acceptable if public transport is expanded and the last-mile connection is protected, because it provides alternative viable options that avoid mobility disruption.
- Early communication matters most for equity and public acceptance, especially where communities are included in the engagement and design process from the start. This will also enable introduction of support measures for most affected groups where needed.





4. INFORMAL TRANSPORT DYNAMICS AND INTEGRATION

Informal transport – privately operated, often unregulated services such as minibuses, rickshaws, and tuk-tuks – is particularly affected by CAZ restrictions, as operators face new rules and administrative requirements without being fully integrated into transport planning or decision-making. Because these services are often not fully integrated, documented, or monitored, they are frequently excluded from implementation frameworks. This exclusion limits the effectiveness of support measures, leaves rules poorly understood, and heightens threats to livelihoods, increasing incentives to resist or evade regulations. While targeted support such as transition assistance or route adjustments can reduce these risks, engaging informal operators only after policies are set leads to fragmented, negotiated implementation and delays overall progress.

This is a critical consideration because:

- Compliance-based approaches work when cities already have established regulatory framework and enforcement mechanisms; however, they limit integration when governance systems lack flexibility or when informal transport operators do not have access to structured channels for co-design participation.
- Adjustment to new restrictions works when rules are paired with concrete operator safeguards, such as targeted exemptions or phased requirements, maintenance/retrofit clinics, route/permit pathways, and last-mile alternatives.
- Cities planning to introduce CAZ restrictions should engage operators early and establish clear channels for dialogue, as structured pre-implementation coordination reduces conflict and avoids the disruptive, post-hoc negotiations that undermine enforcement.



SPOTLIGHT

CHENGDU: TRANSITIONING HEAVY-DUTY VEHICLES

Chengdu, the capital of Sichuan Province, is a rapidly growing megacity in western China known for its progressive urban and environmental policies. With a population exceeding 20 million, Chengdu has positioned itself as a national model for sustainable and livable urban development under air quality improvement needs. Over the past decade, the city has invested heavily in expanding its public transport network, including one of the world's fastest-growing metro systems, while promoting electric mobility and intelligent traffic management. These efforts reflect a strategic alignment between economic growth, technological innovation, and environmental sustainability.

Chengdu does not officially operate a single, branded CAZ. Instead, air quality control in Chengdu is delivered through a package of traffic restriction and emission control measures that together function like a CAZ.

Chengdu's central strategy to improve urban air quality focuses on accelerating the clean and low-carbon transition of heavy-duty vehicles. Recognizing that diesel freight trucks and other heavy-duty vehicles are major sources of particulate matter and nitrogen oxides, the city has implemented a phased program (introduced in 2014, tightened every one to two years) to modernize its freight sector through vehicle renewal, stricter emissions standards, and the promotion of electric trucks. By prioritizing data-driven monitoring, incentives for cleaner freight operations, and coordination among environmental and transport agencies, Chengdu demonstrates how targeted interventions in a high-emitting vehicle segment can drive substantial improvements in urban air quality.



Legal and Governance Readiness

Chengdu's implementation of CAZ and related traffic restriction measures is grounded in a comprehensive legal and governance framework that spotlights legitimacy, coordination, and enforceability. At the national level, the initiative draws its authority from foundational environmental and emergency management laws, including the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, and the Law on Emergency Response. These are supported by several guiding documents, which together provide the statutory and technical foundation for cities to establish and enforce local traffic management and emission control measures in response to air pollution challenges.

At the provincial level, Sichuan has localized laws and plans that grant the province and its municipalities clear legal authority to enact and adjust pollution control and emergency traffic restriction measures in line with local conditions.

Chengdu's administrative system for implementing CAZ measures is well-defined and multidimensional. It encompasses four major components: temporary restrictions during heavy pollution episodes, routine traffic management for freight vehicles, special restrictions for construction waste and concrete mixer trucks, and targeted promotion of new energy freight vehicles. Local legal authority is distributed across multiple agencies, supporting integrated governance and consistent enforcement.



Electric buses

Institutional Capacity to Enforce

Chengdu has established a well-structured institutional and technical framework to support the city's clean transport transition, with strong coordination among multiple government departments led by the ecological and environmental authorities in Chengdu. Chengdu has built an inter-agency coordination mechanism based on the principles of "target assessment and information sharing."

Under this framework, the ecological and environmental authorities in Chengdu are responsible for identifying emission reduction needs in the mobile source sector based on air quality improvement targets. The transport authorities develop and implement policies to restrict the use of high-emission vehicles and provide incentives for their phase-out. Meanwhile, the housing and urban-rural development authorities incorporate requirements for the use of electric vehicles into practical policies related to areas such as construction. This approach strengthens cooperation and accountability among departments, creating a unified system where environmental goals are embedded across transport, construction, and fiscal management sectors.

Chengdu's operational capacity is supported by strong interdepartmental collaboration, dedicated manpower, and financial backing. The involvement of the finance authorities in Chengdu, for example, has established a sustainable fiscal support mechanism to fund electric vehicle subsidies, infrastructure expansion, and enforcement operations. Together, this cohesive institutional framework provides Chengdu with the governance and operational capacity necessary to drive its heavy-duty vehicle transition and broader clean air goals.

Data and Monitoring System

Chengdu has developed an advanced data-driven monitoring system that provides a robust foundation for assessing the outcomes of its CAZ efforts. The city's air quality and emissions data systems are anchored by a network of roadside air quality monitoring stations, which allow real-time tracking and analysis of air pollution along major roads and intersections. The city also integrates pollutant concentration trends with vehicle activity patterns to identify the relationship between air quality and vehicular movement, producing targeted recommendations that inform both short-term interventions and long-term emission control strategies.

To specifically tackle construction waste vehicles, Chengdu has established a "smart supervision platform" which consolidates data on each vehicle's identification, geographic location, and emission standards, using GPS and electronic geofencing technology to monitor their movements in real time. In parallel, Chengdu operates a citywide Transport Operation Coordination Center (TOCC), which aggregates vast streams of traffic monitoring data, linking it with the city's intelligent traffic command systems.

Transport System Readiness

Chengdu has a robust public transport system, comprising a rapidly expanding metro system, extensive bus services, and well-developed non-motorized transport infrastructure. However, the city's main CAZ initiative – which focuses primarily on restricting high-emission heavy-duty trucks and promoting their replacement with electric vehicles – operates largely independently of this network. Therefore, while the strength of Chengdu's public transport system contributes to the city's overall low-emission mobility profile, it does not directly influence the heavy-duty vehicle electrification measures that form the backbone of the current CAZ policy.

The availability and affordability of clean mobility options, particularly in the freight sector, are central to Chengdu's CAZ measures. The city's approach to heavy-duty vehicle electrification combines infrastructure investment and financial incentives, with the government providing purchase subsidies.

To ensure that electric vehicles are not only affordable but also practical for daily freight operations, Chengdu has prioritized the development of a comprehensive charging and battery-swapping network. Charging facilities are strategically located along major freight corridors, at city peripheries, in public parking areas and at highway service stations. The city also encourages construction sites and logistics hubs to install their own charging infrastructure.

Overall, Chengdu's clean mobility landscape – characterized by a strong formal transport network, minimal informal dependence, and a supportive ecosystem for new energy freight vehicles – creates a favorable environment for effective CAZ implementation and long-term air quality improvement.

Equity and Social Acceptance

While Chengdu's policies are designed to accelerate the transition toward cleaner freight operations, they also ensure that this process remains inclusive and socially sustainable. Through a combination of financial safeguards for low-income operators, participatory policymaking, and consistent institutional framework, Chengdu has built a supportive environment for both industry and society to embrace the shift toward electric vehicles.

The government provides substantial subsidies to encourage the scrapping of old diesel trucks and the purchase of new electric vehicles. Additionally, enterprises that operate clean energy concrete mixer trucks are granted preferential treatment in green production evaluations and enterprise credit ratings, which further incentivizes the adoption of clean vehicles across the value chain.

Public participation and transparent communication have played a key role in securing broad social acceptance of Chengdu's CAZ measures. During the policy formulation stage, government departments jointly conducted consultations to ensure measures are both practical and implementable, and all major policy documents and implementation guidelines are published online, allowing the public and affected industries to access and review them. Before introducing truck restriction policies, the government also solicited public opinions through open consultations, reflecting a proactive approach to consensus-building. As a result, policy support and acceptance levels among enterprises, drivers, and the general public has been notably high.

Finally, Chengdu's institutional framework has provided a stable and reliable foundation for long-term implementation. The municipal government has demonstrated consistent commitment to the electrification of heavy-duty vehicles, maintaining policy continuity across multiple planning cycles. This stability reduces implementation risks and provides confidence to investors, manufacturers, and operators.

IMPACTS AND OUTCOMES

The implementation of Chengdu's clean truck transition – particularly the large-scale adoption of electric vehicles in the construction freight sector – has produced significant environmental and economic benefits, with limited unintended consequences.

From an environmental standpoint, the introduction of electric dump trucks and concrete mixer trucks has contributed substantially to reductions in key air pollutants. In 2024, the city's dump truck fleet recorded a 52% year-on-year decrease in NO₂ emissions. Data from roadside air quality monitoring stations further confirm this progress: between 2022 and 2024, the citywide average roadside NO₂ concentration dropped by 16%, with a 21% decline within the Third Ring Road and an 8% reduction outside it. These improvements indicate that the electrification of heavy-duty vehicles has played a vital role in improving ambient air quality and curbing transport-related pollution in urban areas.

Economically, the transition has proven beneficial for both operators and the local economy. Chengdu's electric vehicle promotion policies – combining purchase and operational incentives with road access advantages – have enhanced the overall cost-effectiveness of electric freight vehicles. Total ownership cost analysis shows that electric dump and concrete mixer trucks achieved per-kilometer cost reductions of 17% and 13% respectively, while diesel vehicle costs rose by 11% and 8%. This suggests that the cleaner technology transition not only reduces emissions but also strengthens the financial sustainability of freight operations. Furthermore, allowing electric vehicles to operate during heavy pollution alerts provides operators with greater mileage opportunities, further improving returns on investment.

Socially, Chengdu's policies have yielded broad-based public health and welfare benefits. The resulting improvements in PM_{2.5} and NO₂ levels have enhanced residents' quality of life, while ensuring that economic and logistics benefits primarily accrue to companies in the freight and industrial sectors that actively adopt new technologies. Overall, Chengdu's heavy-duty vehicle electrification has achieved a balanced combination of environmental effectiveness, economic efficiency, and social equity, with minimal disruption to overall traffic patterns.

AGRA: PROTECTING AN ICON

Agra is a historic city in Uttar Pradesh, the most populous state in India. It is a major tourist and cultural hub, internationally renowned for the Taj Mahal, Agra Fort, and Fatehpur Sikri, attracting millions of visitors annually. In 2024-25, as per ticketed sales data, about 6.9 million people visited Taj Mahal. The city's transport system includes formal modes such as city buses and registered taxis, alongside informal modes such as auto-rickshaws, e-rickshaws, cycle-rickshaws, and shared tempos, which play a critical role in last-mile connectivity. Road-based transport dominates the city's mobility, contributing significantly to congestion and air pollution, particularly near heritage sites.

In 1996, based on the order of the Supreme Court of India, a 10,400 km² trapezoid-shaped eco-sensitive area, called Taz Trapezium Zone (TTZ) was defined to protect the Taj Mahal from environmental pollution through stricter emissions control.⁸ The TTZ creation required all polluting industries falling within the zone to be relocated or shut down. In 2018, another smaller zone was created. The area within 500 meters of the Taj Mahal is extremely sensitive, with studies indicating that the acidic deposition from vehicular and industrial emissions is accelerating the yellowing and surface erosion of the Taj Mahal's marble.⁹ This situation prompted the creation of the Taj Mahal ZEZ within the TTZ.

The Taj Mahal ZEZ began as a pilot scheme in 2018, with a phased approach leading to full implementation in 2023. The Taj Trapezium Zone Pollution (Prevention and Control) Authority (TTZ Authority) oversees environmental compliance within the ZEZ around the Taj Mahal, ensuring restrictions on polluting vehicles and promoting clean mobility measures to protect the monument from air pollution.

The Taj Mahal ZEZ specifically targets high-polluting vehicles, including diesel trucks, older private cars, and buses that do not meet Bharat Stage VI emission standards¹⁰. Whereas residents living in the areas surrounding the Taj Mahal are granted permission by the Regional Transport Office (RTO) to operate their two wheelers/four wheelers. These permits are renewed annually. However, tourist vehicles are prohibited entry beyond 500M along approach roads towards both East and West Gates of Taj Mahal. It aims to improve air quality, ensure sustainable tourism, and safeguard public health in the immediate vicinity of the monument. WRI India's study of exposure to PM_{2.5} and PM₁₀ along the vehicle restricted zone showed 30 - 36% lesser levels of exposure along the approach roads compared to other areas in the city. Non-compliant vehicles are prohibited from entering the 500-meter radius area. Electric shuttle buses have replaced conventional tourist buses, and a combination of CCTV surveillance, vehicle registration checks, and fines ensures compliance.



Legal and Governance Readiness

The legal basis of the Taj Mahal ZEZ stems primarily from TTZ regulations set by the Ministry of Environment, Forest and Climate Change under the Environment Protection Act (1986) (Urban Emissions, 2019).

The initiative is governed through a well-defined administrative framework involving multiple agencies. The Uttar Pradesh Pollution Control Board (UPPCB) oversees air quality compliance and monitors emissions. The Agra Municipal Corporation (AMC) manages traffic enforcement and urban transport integration within the Taj Mahal ZEZ – particularly the operation of electric shuttle buses. The Archaeological Survey of India (ASI) ensures that heritage protection standards are observed, particularly concerning pollutant exposure limits around marble surfaces. Regulations specify vehicle emission standards, restricted entry for high-polluting vehicles, and the mandatory use of electric or battery-operated buses for tourism. Penalties are clearly defined, including fines and denial of entry for non-compliant vehicles, ensuring enforceability of the ZEZ rules.

Institutional Capacity to Enforce

The Taj Mahal ZEZ is predominantly enforced by the UPPCB, AMC and ASI, which hold regular coordination meetings to address operational issues such as vehicle entry management, traffic rerouting, and monitoring compliance within the 500-meter zone. Additionally, the Tourism Department of Uttar Pradesh collaborates to manage visitor flow, implement electric shuttle services, and raise public awareness about the ZEZ. This structured collaboration ensures that enforcement actions are consistent, technically sound, and sensitive to heritage preservation requirements.

Several previous and ongoing programs support institutional capacity. Agra has implemented electric shuttle services and battery-operated tourist buses to reduce vehicle emissions inside the ZEZ. AMC has introduced parking reforms, directing private vehicles to parking lots outside the ZEZ, while UPPCB enforces vehicle emission standards through regular inspections and fines for non-compliance. Traffic enforcement is supported by CCTV cameras and automated vehicle identification systems, allowing real-time monitoring of ZEZ compliance.



Free electric shuttle bus taking tourists to the Taj Mahal

Data and Monitoring System

The UPPCB operates continuous ambient air quality monitoring stations near the Taj Mahal measuring PM2.5, PM10, NOx, SO₂, CO, and O₃. CCTV cameras and ANPR systems monitor vehicle entry in the zone, while electric shuttle buses are GPS-tracked to ensure route compliance and operational efficiency.

Data is shared among UPPCB, AMC, and ASI for coordinated decision-making. Real-time public access to data is limited but increasing through online dashboards and apps.

Transport system readiness

The city's transport network includes public buses, cycle rickshaws, auto-rickshaws, private vehicles, and electric shuttle services, with coverage concentrated around the city center and major tourist areas. The informal transport sector plays a major role in last-mile connectivity, with an estimated 30-40% of urban trips relying on these modes. Clean mobility alternatives have been introduced in recent years to support ZEZ implementation, with Agra deploying electric shuttle buses for tourists that connect major sites and reduce private vehicle entry into the ZEZ. Battery-operated rickshaws are encouraged in zones surrounding the Taj Mahal, supported by municipal subsidies and charging infrastructure.

Equity and Social Acceptance

The AMC and UPPCB have implemented several measures designed to enhance equity and social acceptance. Electric rickshaws and battery-operated vehicles are incentivized through subsidies¹¹ and preferential access within the ZEZ, providing low-emission alternatives for informal operators. Municipal authorities have organized consultations with local transport unions, small business associations, and resident welfare groups to gather feedback and adapt enforcement strategies. Public communication includes signage at ZEZ entry points, social media updates, and coordination with tourist guides to educate visitors about alternative transport options. Administrative support and heritage conservation has allowed for the consistent enforcement of traffic regulations, adoption of electric mobility, and funding of monitoring infrastructure.

IMPACTS AND OUTCOMES

With proper attention given to equity measures – particularly around last-mile connectivity – the Taj Mahal ZEZ has been widely accepted by businesses, informal operators, and local residents. Support for low-income transport operators has proven essential for equitable outcomes, while continuous monitoring and community engagement have strengthened compliance and sustainability. Meanwhile, strong frameworks backed by robust data have ensured integrated governance and consistent enforcement.

As such, the initiative has driven an important shift in localized traffic patterns, with an increased use of electric shuttle buses, battery-operated rickshaws, and walking all contributing to reduced congestion, improved air quality, and enhanced pedestrian safety.



Bicycle rickshaws

KEY THEMES AND SUCCESS STORIES

As detailed above, our findings have identified four key themes central to the successful implementation of CAZ measures in Asian cities. Here, we examine those themes in the context of good practice case studies, enabling city leaders and planners to better recognize opportunities in their own jurisdictions, based on challenges shared with other locations.





GOOD PRACTICE IN GOVERNANCE, REGULATION AND INSTITUTIONAL CAPACITY

Key findings of this study show that CAZ measures progress in cities where there's a minimum legal or administrative mandate – even in the absence of comprehensive or dedicated CAZ legislation. Even basic mandates provide sufficient authority to introduce and enforce measures, while also allowing flexibility in scope and timing. Outcomes are also more consistent

where enforcement and oversight roles are clearly allocated across agencies, reducing ambiguity in responsibility and supporting more predictable compliance. As such, it follows that cities demonstrating strong governance mechanisms are better positioned to implement successful CAZ initiatives.

SEOUL

Strong national legal backing and clear institutional roles have played a key role in the development of Seoul's CAZ measures, which have led to a 42.4% decrease in CO, 38.7% decrease in CO₂, 36.6% decrease in NO_x, and a 36.7% decrease in PM2.5.

As part of its commitments to the Post-2020 New Climate Regime, Seoul envisions itself as a role model in climate change response through its Promise of Seoul (2015). Among its 11 promises, the city aims to reduce its CO₂ emissions by 40% by 2030. In January 2021, the Seoul Metropolitan Government established the 2050 Greenhouse Gas Reduction Plan, which takes this vision a step further by targeting carbon neutrality by 2050, and a 70% reduction of CO₂ emissions by 2040.¹²

Through the Sustainable Transportation Logistics Development Act (STLDA), Seoul designated its first “Green Transport Zone” in 2019, within the old city walls. Inside these zones, Grade 5 vehicles, which have the highest emission class, are restricted from entering between 6am and 9pm. Non-compliance incurs financial penalties. In 2020, Seoul expanded its Green Transport Zones to include Gangnam and Yeouido districts.

Other measures included expanding bike lanes, road reorganization, increasing pedestrian and prioritizing public transport. The city also increased its public bike and car rental services and added new public bus routes within the Green Transport Zones, which operate at half the price of normal public buses. Traffic volumes and emissions of Grade 5 vehicles within the zone dropped significantly.

The STLDA has been critical to the development of Green Transport Zones, providing a clear legal basis that allows the Seoul Metropolitan Government to restrict Grade 5 emission vehicles. Furthermore, the city's transport policies are well-aligned and led by the Seoul Metropolitan Government Transportation Bureau, enabling a unified approach to fare collection, data collection, information processing, and policymaking.



Driverless autonomous electric shuttle bus

SHANGHAI

In Shanghai, highly codified regulations and long-term policy continuity have allowed the city to scale vehicle restrictions beyond pilots and sustain enforcement over time, resulting in substantial reductions in key pollutants. Against the backdrop of stable overall activity levels from mobile sources, the city's air quality saw notable improvement in 2025, with a 7.3% year-on-year decrease in NO₂ concentration.

Transport-related air pollution remains a pressing challenge for Shanghai. Heavy-duty diesel trucks, despite accounting for only about 5% of the city's vehicle fleet, contribute roughly 83% of NO_x and 81% of PM_{2.5} of the city's total motor vehicle emissions.¹³ These vehicles are characterized by high emission intensity and long operating hours. Problems such as low-quality fuels further aggravate their pollution levels, making them a dominant source of urban air pollution.

In response, Shanghai has set ambitious environmental goals. The 14th Five-Year Plan for Ecological and Environmental Protection (2021–2025) aims to stabilize PM_{2.5} concentrations below 35 µg/m³ and maintain an Air Quality Index 'good' rating of around 85%, eliminating heavy pollution days. The Clean Air Action Plan (2023–2025) further strengthens these targets, seeking to reduce major pollutants in line with national requirements, achieve over 90% 'good' air quality days, and keep PM_{2.5} below 30 µg/m³ while curbing ozone growth.

The city's approach centers on accelerating the phase-out of older, high-polluting diesel trucks and promoting energy transition through the adoption of cleaner technologies. Enforcement mechanisms combine regulatory controls, financial incentives, and enhanced monitoring. This includes strict emission standards for new registrations, dynamic supervision of in-use vehicles, regional traffic restrictions for non-compliant trucks, and on-road inspections to detect excessive emissions or tampering with after-treatment systems.

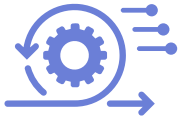
Supporting frameworks for CAZ measures in Shanghai are firmly grounded in a comprehensive legal and governance system that integrates national mandates with locally tailored regulations. At the national level, the legal foundation is provided by several key laws and policy documents, including the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, and the Law on Emergency Response to Incidents, which together authorize both proactive pollution prevention and emergency response measures.

At the municipal level, the Shanghai Municipal Regulations on Air Pollution Prevention and Control provide the primary legal authority for the city's LEZ and associated measures. These regulations empower local departments to set and enforce emission standards, impose traffic restrictions, and implement penalties for non-compliance. Under this legal structure, Shanghai has developed an integrated governance model that combines guidance, incentives, and constraints to achieve systematic diesel vehicle pollution control. The legal authority for implementation and enforcement is shared among multiple municipal agencies under a coordinated governance structure which ensures that the policy framework is not only legally enforceable but also administratively cohesive.

Simultaneously, a tiered subsidy mechanism with bonus components reduces financial burdens on vehicle owners and encourages the transition to electric vehicles. Enforcement is ensured through continuous roadside inspections, remote online monitoring for high-priority vehicles, and a robust penalty system targeting excessive emissions and regulatory violations.



Electric police vehicles



GOOD PRACTICE IN QUICK-WIN TRANSITIONAL STRATEGIES AND EMERGING PRACTICES

The implementation of quick-win measures tends to be more effective in cities demonstrating operational flexibility, enabling decision-makers to pilot, modify, or discontinue actions without requiring lengthy legal or political approval processes. Low data

requirements and clearly defined objectives allow cities to deploy transitional measures rapidly, while basic enforcement capacity and visibility ensure that these measures produced tangible short-term impacts instead of remaining piecemeal and resource-intensive.

BANGKOK

Despite partial legal frameworks, Bangkok uses episodic six-wheel and larger diesel truck bans during high PM2.5 events, leveraging existing CCTV and police systems to deliver rapid impact within the constraints of the city's logistics infrastructure.

Excluding agricultural burning, the transport sector of Bangkok is responsible for 60% of the city's emissions. Of those emissions, 40% come from trucks.

Since 2025, the Bangkok Metropolitan Authority (BMA) has activated temporary, episodic six-wheel and larger diesel truck bans during high PM2.5 events, in line with national air quality thresholds and in conjunction with the Green List Program. The Green List program represents a structured approach to vehicle eligibility, particularly for heavy-duty trucks. Under this program, trucks meeting specified emission criteria are permitted to operate during periods when restrictions are in place, while non-compliant vehicles face access limitations.

Only trucks registered online with the BMA confirming they have undergone proper maintenance to reduce emissions will be permitted within the LEZ during periods of restriction, while unregistered trucks are banned during high pollution episodes. The project is being expanded to cover 22 further districts.

Bangkok has an operational air-quality monitoring network that combines national and city systems, and real-time dashboards underpin decisions about when to activate truck bans or pollution control zone measures. LEZ enforcement relies on vehicle registration through green accounts, CCTV monitoring, and legal penalties.

However, the city faces challenges in implementing a permanent CAZ that targets freight. Bangkok is not a monocentric transit city: while inner districts have dense transit coverage, many freight trips originate or terminate outside public transport corridors, such as those associated with warehousing, logistics hubs, and ports. This means freight operators often have few practical clean alternatives for last-mile distribution. As such, the LEZ in Bangkok has targeted larger trucks of six wheels and more, although the availability of low-emission heavy trucks across the fleet is still increasing. The affordability of clean heavy-vehicle options is constrained by capital costs, but subsidies, tax deductions and incentives are available for fleets that adopt zero-emission or Euro 5+ vehicles.¹⁴

In addition to the Green List Program and truck restrictions – and as seen in other examples in this study – BMA combines their LEZ with a range of additional measures such as roadside and source-based black smoke inspections, the promotion of electric vehicles within municipal fleets, the pilot deployment of diesel particulate filters, traffic demand-management measures, and temporary fare reductions or service enhancements to encourage modal shift.

There is no single explicit law for the LEZ measures. Instead, the BMA applies provisions from existing instruments such as the Disaster Prevention and Mitigation Act, which empowers provincial governors to take necessary actions to address causes of pollution within their jurisdiction.

JAKARTA

Jakarta employs tactical measures via a low-cost pilot to test feasibility and deliver valuable learning while improving streetscapes and mobility.

Jakarta is the largest city in Indonesia, with a land area of 661 square kilometers and a population of 10.67 million people. While the city has a well-established public transport system, just 11% of Jakarta's population currently use public transport for their daily mobility needs.

Private vehicles are a major contributor to particulate matter and black carbon emissions, with studies showing the transport sector contributes 44.7% of PM_{2.5} pollutants in the city. Motorcycle is Jakarta's predominant mode of transport, used for private transportation, ride-sharing, last-mile delivery, and as taxis. More than 17 million motorcycles were recorded in 2022.

In line with national commitments, Jakarta has developed the Climate Action Plan (CAP) and 'Ikhtiar Jakarta' as strategic documents and guidelines to achieve climate targets consistent with the Paris Agreement (limiting global temperature rise to 1.5°C). In addition, Jakarta has its own Air Quality Management Plan (SPPU). It functions as Jakarta's master plan for air pollution control, guiding all agencies and sectors. Actions are designed to reduce exposure to PM_{2.5}, NO_x, SO₂, CO, and O₃, and to improve governance, enforcement, and data quality.

In 2021, the Provincial Government of Jakarta implemented an LEZ in the Kota Tua area, largely to support the preservation of nearby cultural heritage sites. The low-cost, 'quick win' initiative

included the pedestrianization of six streets surrounding the inner Kota Tua area, covering a total intervention area of 0.14 square kilometers. Only Trans Jakarta buses and vehicles displaying special resident and business stickers are permitted to access the LEZ.

The initiative was implemented largely through traffic re-engineering, including pedestrianization of key streets, rerouting, and limiting through-traffic, with enforcement relying on traffic police officers at control points and patrolling to stop non-compliant vehicles. The relatively small size of the LEZ and defined physical layout of the area makes manual monitoring and pedestrianization feasible.

Launched amid COVID-19 mobility restrictions – and therefore lower traffic volumes – the scheme was implemented relatively quickly. Awareness campaigns, clear signage on permitted vehicle types, and the visible presence of municipal staff at entry points supported early compliance without significant capital investment. The intervention also enhanced the visitor experience by providing more space for walking and cycling, making the program well-received by tourists and the public.

While the small scale of the LEZ means significant emissions reduction impacts are yet to be felt, the pilot has provided valuable learning and insight on early-stage implementation to Jakarta's Environment Agency, which has been mandated by government to identify further LEZ locations across the city. One such additional LEZ is designed under the Breathe Cities initiative in Jakarta.¹⁵



Car free day held every Sunday morning in the business district



Pedestrian only zones

PASIG

Low-cost, neighborhood-led People's Streets pilots deliver immediate liveability benefits and build public support for longer-term transport reforms.

The “People’s Streets” initiative of Pasig represents a transformative approach to urban mobility and public space management, rooted in the city’s broader vision of creating a greener, more livable, and people-centered city. Launched under the Pasig Green City Program, this initiative aims to reclaim streets for people, rather than vehicles, by restricting motorized traffic. As such, they are not technically considered a CAZ but traffic controlling measures that bring air quality benefits.

Its overarching objective is to reduce car dependency, improve air quality, enhance road safety, and promote active, low-carbon modes of transport such as walking and cycling. As of 2025, there are four active People’s Streets, covering four streets in four barangays.

People’s Streets are closed to private motor vehicles on certain days or during specified hours, transforming them into safe, car-free spaces for walking, cycling, and social activities. Enforcement is managed through road closures, physical barriers, and traffic marshals from the Pasig Traffic and Parking Management Office (TPMO), coordinated with the City Transportation Development and Management Office (CTDMO) and the City Environment and Natural Resources Office (CENRO).

Public participation is a defining feature of Pasig’s policymaking approach. The city’s transport and environmental reforms undergo extensive community consultations, especially with transport cooperatives, business owners, and residents in pilot corridors. In 2022, the city launched the ‘#PasigGreenCity’ communications campaign, which engages citizens through social media, local assemblies, and school-based environmental education. These efforts have built strong local awareness and support for clean air policies and sustainable transport – an essential foundation for social acceptance of CAZ-type measures.

Pasig’s initiative has encouraged a behavioral shift toward active and shared mobility. Surveys conducted by the Pasig Transport Office find foot and cycling traffic is up 40% in pilot areas, while the volume of short-distance motorized trips has declined. Traffic bottlenecks have eased in neighboring intersections due to improved circulation and reduced illegal parking. Local businesses report increased foot traffic and higher weekend sales in car-free corridors, consistent with international findings linking walkable streets to commercial revitalization. Informal vendors and micro-enterprises have also benefited from the additional public space, while improved air quality and safety conditions enhance social well-being and neighborhood cohesion.



Cycle lanes



Bicycle hire scheme



GOOD PRACTICE IN EQUITY, INCLUSION AND TRANSPORT IMPACTS

The implementation of CAZ measures tends to be more effective when cities offer affordable and viable mobility alternatives and targeted equity mitigation mechanisms – public acceptance is higher where affected trips had realistic alternative transport options.

In addition, the early identification and monitoring of equity impacts, supported by proper communication and engagement, allows equity risks to be anticipated and addressed during implementation, which contributes to greater social sustainability.

DELHI NATIONAL CAPITAL REGION

Phased implementation, exemptions, EV purchase incentives, and public transport support help to manage equity risks in a highly exposed megacity.

India's capital territory Delhi National Capital Region (NCR) is one of the country's most densely populated urban regions, with a population of over 34.66 million. Studies indicate that vehicles contribute between 20–39% of Delhi's PM_{2.5} levels,¹⁶ making transport one of the most significant local pollution sources.

Its transport ecosystem consists of formal modes such as the Delhi Metro, public and private bus services, registered taxis, and app-based ride-hailing; and informal modes, such as auto-rickshaws, e-rickshaws, cycle-rickshaws, and informal shared vans. These play a crucial role in last-mile connectivity.

Informal transport provides substantial employment opportunities for low-income workers, while formal transport services support a broad range of public- and private-sector jobs in operations, maintenance, and administration. This diverse and heavily used transport landscape forms a critical backdrop for implementing sectoral measures aimed at reducing vehicle emissions and improving overall urban air quality.

Delhi's CAZ mechanism is focused on controlling the use of older diesel and petrol vehicles, while promoting cleaner alternatives such as electric vehicles. This impacts an estimated 3.5 million BS-III petrol and 1.3 million BS-IV diesel vehicles¹⁷ – a total of 27% of all vehicles in Delhi.¹⁸ Restrictions cover commercial vehicles that fail to meet Bharat Stage VI emission norms,¹⁹ and during high pollution events, petrol and diesel-powered four-wheel vehicles are included.²⁰

In specific high-density and heritage zones such as Chandni Chowk, a permanent ban on polluting vehicles remains in effect year-round, promoting pedestrianization and the use of electric and non-motorized transport alternatives.

As informal vehicle owners – such as auto-rickshaw, e-rickshaw, and small freight operators – often rely on older vehicles for their livelihoods and face financial barriers to transitioning to cleaner options, it has been critical for the city to account for equity risks. Implementation has taken a phased approach, enabling affected individuals to become familiar with the scheme, while the city has introduced scrappage incentives and tax concessions for end-of-life vehicles.

Delhi is also actively promoting clean mobility as a complement to its CAZ measures, with the upcoming Delhi EV Policy 2.0 aiming to ensure some 95% of new vehicle registrations are electric by 2027. The campaign targets auto-rickshaws, taxis and light commercial vehicles with purchase incentives and subsidies offered to help mitigate the financial burdens felt by informal vehicle owners.



Electric scooters

ULAANBAATAR

Sequenced restrictions alongside public transport upgrades reduce social backlash while gradually building institutional capacity.

Ulaanbaatar is Mongolia's capital, with a population of 1.7 million. The metropolitan economy is concentrated in administration, industry, and services, attracting sustained rural-urban migration that has expanded peri-urban "ger" (yurt) settlements. These ger districts are characterized by informal housing, low-insulation dwellings, and reliance on small stoves, which, combined with the city's bowl-like topography, produces severe seasonal air pollution, especially in winter when PM2.5 levels routinely exceed WHO guidelines. The city also faces issues around rapid urbanization and spatial inequality.

Despite these challenges, Ulaanbaatar has articulated an ambitious vision through Ulaanbaatar 2040 and Vision 2050, which emphasize sustainable mobility, climate resilience, and inclusive growth. These policy frameworks underpin the city's ongoing efforts to modernize its transport systems through data-driven, equitable, and integrated approaches.

Ulaanbaatar's key CAZ intervention is its Ulaanbaatar Sustainable Urban Transport Project (USUTP), financed by a US\$100 million loan from World Bank. The project aims to develop a comprehensive sustainable urban mobility framework for the city and to reduce congestion, improve road safety, and increase climate resilience on selected transport corridors. The rationale links congestion and inefficient public transport to high vehicle emissions and poor accessibility, while aiming to shift travel to higher-capacity, lower-emission public transport and safer walking and cycling conditions.

Components of the project include corridor upgrades – such as dedicated bus lanes, sidewalks, cycleways, and intelligent transport systems – as well as diesel particulate filter retrofits for buses, and incentives and tax exemptions for electric vehicle uptake.

Efforts toward implementing these measures intersect significantly with issues of equity, social inclusion, and public acceptability. Some incentives in Ulaanbaatar explicitly aim to reduce cost barriers for cleaner vehicles: Mongolia offers VAT and customs exemptions for electric vehicles concessional financing, and other fiscal measures.

The city also benefits from a structured Stakeholder Engagement Plan under World Bank standards, with consultations, public surveys, and formalized grievance mechanisms. For example, surveys were carried out to assess public sentiment to license plate age restrictions and vehicle caps. When odd/even license plate rules were introduced for weekday traffic control during the new school year, the city suspended the restriction for a day to gather public comments. Underpinning these measures is a proactive and well-planned communications drive around traffic rules and environmental regulation, ensuring all affected parties are familiar with the USUTP and its avenues for feedback.



Electric buses



GOOD PRACTICE IN INFORMAL TRANSPORT DYNAMICS AND INTEGRATION

In cities with informal transport, the implementation of CAZ measures is challenging but more workable when informal transport is explicitly recognized as part of the urban transport system, rather than treated as an afterthought.

Proper recognition of informal operators as legitimate stakeholders creates a vital platform for engagement and reduces immediate resistance during implementation stages.

KATHMANDU

The city has pursued the partial integration of informal operators through cooperatives and route reallocation, minimizing livelihood disruption rather than relying solely on bans.

Kathmandu Valley is a geographical region in Nepal with an area of 722 square kilometers, which includes approximately 85% of the Nepalese capital, 50% of Lalitpur, and Bhaktapur districts. The Valley's rapid economic growth has spurred economic opportunities that have attracted many rural Nepalese to migrate into its urban areas. However, residential development without sufficient infrastructure development has created significant urban sprawl, and a corresponding lack of efficient, high-capacity mass transport systems, such as metro rail or bus rapid transit systems, has contributed to increased motorization in the Valley.

Kathmandu does not have a formal CAZ or LEZ, but it applies citywide emission enforcement, temporary traffic restrictions, and pollution control standards that resemble early building blocks of a CAZ. This includes the Kathmandu Sustainable Transport Project (which ran from 2011 to 2018), and since 2022 the Kathmandu Valley Air Quality Management Action Plan. This enables random emission testing on the road, which found that 80% of diesel vehicles and 30% of petrol vehicles emit black smoke beyond permissible levels. Since 2025, the most polluting vehicles have been banned.

Given the sprawling nature of Kathmandu – and a lack of comprehensive public transport options – the commuting public primarily prefer private vehicles, including informal modes, which play a critical role in city-wide mobility. Without informal operators, many journeys around the city would be unfeasible.

As such, Kathmandu has taken steps to recognize informal operators as legitimate stakeholders in the city's transport agenda, integrating this transport mode into wider CAZ plans. This is partly supported by the city's relatively few institutional constraints, which allows it to explore and pursue partial informal transport integration.

Through proactive engagement, dialogue and feedback with informal operators, the city has instigated informed measures such as consolidating operator associations, reallocating routes for displaced operators, forming cooperatives to operate high-capacity buses, and providing training and other support. These interventions are inclusive and context sensitive, helping to reduce gaps in enforcement while protecting livelihoods and ensuring continuity of travel for populations that rely on informal transport.



Electric buses

COMMON CHALLENGES AND LESSONS LEARNED

This report highlights CAZ measures and frameworks across 10 Asian cities. However, it must be noted that no city has implemented CAZ initiatives without challenge, and even those that report positive outcomes continue to mitigate risks and barriers. Below, we draw attention to key lessons learned in implementing CAZ measures, highlighting where approaches fall short and which measures are better positioned to drive expected outcomes.

1. Successful Initiatives Report Similar Obstacles

Despite geographical, economic, and social differences between cities, several recurring constraints limit the feasibility of CAZ schemes: an absence of strong and clear legal basis, mandate, or backing; inconsistent enforcement and enforcement gaps when manual controls are not paired with strong evidence chains; data gaps that weaken design and impact evaluation; and procedural bottlenecks in subsidy verification that slow implementation. These constraints are most pronounced when CAZ objectives are introduced (ahead of or) without corresponding strengthening of legal mandates, enforcement capacity, data, and monitoring systems. Overall, solutions will depend on the capacity parameters of each location.

2. Successful Initiatives Report Consistent Enablers

Despite geographical, economic, and social differences between cities, consistent enablers of CAZ schemes emerge, including: clear ordinances and policy mandates; cross-agency teams with defined escalation paths; and monitoring backbones that integrate air-quality and traffic data. The success of CAZ measures increases when access rules are paired with public transport connectivity, as seen in Agra, and when support is sequenced, from maintenance and retrofits to partial upgrades, under transparent targeting. Cities can start by managing vehicle activity (such as restrictions, rerouting, and scheduling) while incrementally clarifying policies and upgrading monitoring for before and after evaluation. The scale and implementation of these interventions will again depend on the unique strengths and weaknesses of each location.

3. Pilot Schemes are Critical Starting Points

The clearest quick wins tend to be low-cost pilots, evidence baselining, and measures that leverage existing infrastructure. Where legal authority and operational systems are already in place, these actions can often be deployed within few weeks to several months by using current staff, cameras/sensors, and temporary operating rules. These actions validate compliance dynamics early and de-risk later scale-up without large capital outlays. For example, pedestrianization pilots such as Pasig's "People's Streets" or corridor-focused truck controls, such as Bangkok's use of its CCTV/LPR network, demonstrate how cities can rapidly test compliance and behavior change without major new investments.



4. Measures are Most Effective When Sequenced

Transitional measures across Asian cities are most effective when sequenced. Start with evidence-led quick pilots that leverage existing systems, then layer supported maintenance/ retrofits to reduce emissions per vehicle, and only scale to capital-intensive fleet replacement once institutions and equity safeguards are ready. Overall, feasibility rises when cities match ambition to capacity, moving from “manage activity fast” to “reduce emissions per vehicle” and finally to “replace fleets equitably,” while continuously validating impacts and refining design to maintain feasibility and public acceptance. Sequencing support and pairing pilots with real-time monitoring tend to sustain compliance and build public acceptance, as seen in Seoul’s initiative with added bus routes and fare adjustments.

5. Data Systems are the Foundation of Success

Data systems that are fragmented and not integrated limit the ability of cities to verify compliance and monitor performance effectively. Many of the cities noted in this report still work with disconnected datasets across transport, environment, traffic police, and vehicle registries. Even in the strongest-performing cities such as Chengdu, systems still require active management and coordination across agencies.

6. Equity Risks are a Critical Consideration

Common equity risks center on income and access losses for small fleet owners, freight and construction vehicle operators, and informal transport providers when restrictions or compliance costs outpace support and connectivity. In some of the Asian cities researched, informal transport plays a significant role. For example, the informal transport sector in Agra plays a major role in last-mile connectivity, with an estimated 30–40% of urban trips relying on it.

Without safeguards, vulnerable commuters can face disrupted trips, while operators with limited capital struggle to adopt cleaner technologies. Without safeguards, restrictions can unintentionally exclude those with the least capacity to transition. Ulaanbaatar’s structured stakeholder engagement plan demonstrates successful mitigation action in this area.

7. Large Scale Initiatives Require a Sustained, Coordinated Approach

Measures that require stronger institutions typically involve sustained financing, complex program delivery, and system-wide coordination, most notably non-low-cost support schemes (such as subsidies, scrappage and replacement schemes). These depend on budgeted capacity, credible clean alternatives, public transport readiness, and robust targeting with equity safeguards. Large-scale transitions such as Seoul’s multi-channel subsidies or Shanghai’s targeted truck replacement program work when cities can manage disbursement, authenticate beneficiaries, and align enforcement with upgrade pathways.



Cycle path through park in Bangkok, Thailand

LOOKING AHEAD

The implementation of CAZ measures across Asian cities reflects the region's wide diversity in urban form, economic development, governance capacity, and air pollution challenges. While some cities benefit from strong public transport networks, advanced monitoring systems, and regulatory enforcement, others face challenges such as rapid urbanization, high reliance on informal transport, limited fiscal resources, or competing development priorities. These differing conditions mean that the opportunities presented by CAZ schemes – such as improved public health, reduced emissions, and enhanced urban liveability – are not uniform, and neither are the barriers to successful implementation.



Cities can draw on a range of measures tailored to their specific strengths and weaknesses, from low-emission vehicle standards and congestion pricing to freight management, public transport investment, and non-motorized mobility improvements. By aligning CAZ measures with local contexts, cities can maximize effectiveness while minimizing social and economic disruption.

However, as this report demonstrates, there are recurring implementation themes across cities, and the varied approaches to these common challenges provide a valuable source of insight to city planners and leaders across Asia considering their own CAZ initiatives. We hope this report acts as a springboard for further discussion as cities work towards achieving cleaner air and more sustainable urban futures across the region.



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CLEAN AIR FUND

Clean Air Fund is a global philanthropic organisation that works with governments, funders, businesses and campaigners to create a future where everyone breathes clean air. We fund and partner with organisations across the globe that promote air quality data, build public demand for clean air and drive action. We also support decision makers to act on air pollution.



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