How Robust are Urban India's Clean Air Plans?

An Assessment of 102 Cities

Tanushree Ganguly, L. S. Kurinji, and Sarath Guttikunda

Report | June 2020

Adequate covering is necessary at construction sites to control fugitive emissions.

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Acknowledgments

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Tanushree Ganguly is a programme associate at CEEW. Her work focuses on assessing potential alternative methods for monitoring air quality, and understanding and addressing current regulatory challenges for the effective implementation of clean air policies. She has a master's degree in environmental engineering from the Georgia Institute of Technology and is a certified engineer-in-training under California law.

"Given that the availability of funds for air pollution mitigation activities in cities is contingent upon the performance of cities with regards to pollution control initiatives, state pollution control boards and local authorities need to develop implementable strategies with detailed cost estimates."

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Kurinji is a policy researcher at CEEW. At The Council, her research focuses on the crop residue burning using technologies like remote sensing in Northern India and also addresses regulatory challenges to implementing mitigation measures. She holds a bachelor's degree in Energy and Environmental Engineering from Tamil Nadu Agricultural University, Coimbatore. She is an Indian Green Building Council (IGBC) Accredited Professional.

"Solving for clean air across cities requires strategic planning and implementation of key measures with high pollution-reduction potential. Though cities are aware of their polluting sources and mitigating measures, the real challenge lies in ensuring coordination and stringent enforcement."
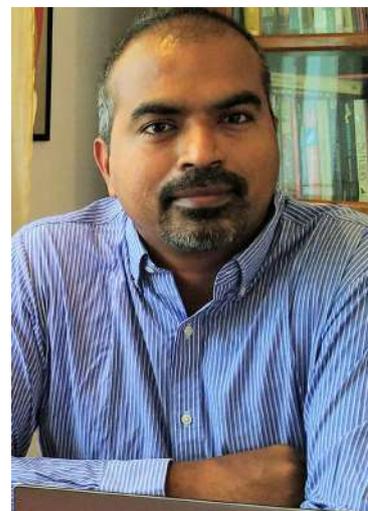
Sarath Guttikunda
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Sarath Guttikunda is a chemical engineer, an atmospheric scientist, a TED Fellow, and founder of Urban Emissions (India). His main research interest is air quality analysis and finding ways to bridge the gap between science and policy. He developed the SIM-air family of tools, which can assess air quality in multi-pollutant environments. In 2016, Sarath was part of the team to launch modelled air quality forecasts for all of India. He was a member of India's AQI formulation committee (2014) and the WHO's air quality guidelines development group (2016-2020).

"One thing is clear from going through 100+ action plans. We know the sources contributing to air pollution in every city and we need to find out how much. While we are waiting for the accounting studies to prioritise actions, known control measures must be prepped."

COMPLIANCE

TRANSPARENCY

RULES

LAW

POLICIES

STANDARDS

REQUIREMENTS

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Abbreviations

ApNA	Air Pollution Knowledge Assessment
AQMC	Air Quality Monitoring Committee
AAQD	Ambient Air Quality Directives
BSPCB	Bihar State Pollution Control Board
BTH	Beijing-Tianjin-Hebei
CAAQMS	Continuous Ambient Air Quality Monitoring Station
CEPI	Comprehensive Environmental Pollution Index
C&D	construction and demolition
CPCB	Central Pollution Control Board
EU	European Union
EPCA	Environment Pollution (Prevention & Control) Authority
FY	fiscal year
IIT	Indian Institute of Technology
IGB	Indo-Gangetic Basin
IHME	Institute of Health Metrics and Evaluation
HEI	Health Effects Institute
LPG	liquified petroleum gas
MEE	Ministry of Ecology and Environment
MoEFCC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MoRTH	Ministry of Road Transport and Highways
MSW	municipal solid waste
NAAQS	National Ambient Air Quality Standards
NCAP	National Clean Air Programme
NCR	National Capital Region
NGT	National Green Tribunal
NHAI	National Highway Authority of India
NO2	nitrogen dioxide
NOx	oxides of nitrogen
OCEMS	Online Continuous Emission Monitoring System
PM	particulate matter
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	piped natural gas
PWD	Public Works Department
RSPM	respirable suspended particulate matter
SIP	state implementation plans
SPCB	State Pollution Control Board
SO2	sulphur dioxide
US EPA	United States Environmental Protection Agency
USA	United States of America
ULB	urban local body
UPPCB	Uttar Pradesh Pollution Control Board

Ambient air pollution has been linked to 4.2 million deaths globally (WHO 2016).

Executive summary

Ambient air pollution is linked to 4.2 million deaths globally (WHO, 2016). A study led by researchers from the Indian Institute of Technology (IIT) Bombay, the Health Effects Institute (HEI), and the Institute of Health Metrics and Evaluation (IHME) found that in 2015, residential biomass fuel-burning contributed to nearly 268,000 deaths. Coal combustion in thermal power plants and industries contributed to 169,000 deaths; anthropogenic dust contributed to 100,000 deaths; agricultural burning contributed to 66,000 deaths; and transport, diesel, and kilns contributed to over 65,000 deaths in India (GBD Maps Working Group 2018). Mortality numbers associated with different polluting sectors establish the need for an emission mitigation strategy that addresses each of these sectors and any interlinkages that exist. Such a programme also warrants the participation of the relevant central ministries, state governments, local bodies, and other stakeholders to ensure a focus on all pollution sources. This was the ethos behind the formulation of the *National Clean Air Programme* (NCAP). While the Ministry of Environment, Forest and Climate Change (MoEF&CC) circulated a concept note for the NCAP in April 2018, the final NCAP document was released in January 2019.

The NCAP aims to achieve a 20–30 per cent reduction in particulate matter (PM) concentration by 2024 with 2017 as the base year (MoEFCC 2019). It proposes the implementation of city-specific air quality management plans for non-attainment cities i.e. cities that violate the National Ambient Air Quality Standty Standards (NAAQS). While the NCAP document released in January 2019 lists 102 non-attainment cities, an August 2019, National Green Tribunal (NGT) directed 20 additional cities to prepare clean air plans. These 20 cities await inclusion in the NCAP and the approval of their city-specific action plans. Although the clean air plans are meant to propose an actionable strategy with clear targets and timelines, the current plans have significant shortcomings that could potentially derail the implementation process. A review of the global literature on best practices for clean air planning helps establish the essential components of a clean air plan: a legal framework, sectoral reduction targets based on source contributions, the cost-effectiveness of the proposed measures, and a clear delineation of responsibilities among implementing agencies. We reviewed the 102 approved city clean air plans to assess whether the aforementioned components have been addressed. Our findings are summarised as follows.

There is no legal mandate for reviewing and updating plans

Unlike in the United States and the European Union, where states and member nations are legally mandated to periodically update clean air plans for regions that violate air pollution standards, the city clean air action plans in India were drafted in response to an order by the National Green Tribunal. Therefore, there is cause for concern that the preparation of plans

We reviewed the 102 approved city clean air plans to assess whether the aforementioned components have been addressed

might remain a one-time exercise. We recommend that preparing and periodically updating plans be mandated under the *Air (Prevention and Control of Pollution) Act (1981)*".

Actions in the plan cannot be prioritised without information on the contributions of different sources. State pollution control boards (SPCBs) can benefit from mapping out dispersed polluting sources in the cities and intensifying inspection in these areas.

Our review found that only 25 of the 102 city action plans contained data on emissions from different sources. This is despite the fact that the *Air Pollution Knowledge Assessment* (ApNA) maintains a database of the emission inventories of over 40 of the non-attainment cities. Even among the 25 action plans that contain data on sources, the information does not translate into timelines set for the execution of the action points listed in the plan. While 56 action plans clearly express the intention to carry out source apportionment studies in the coming years, in the meantime, a mapping of polluting activities in the city can be carried out. This could help in determining the spatial distribution of polluting sources and help identify areas where action should be prioritised.

Pollution control measures warrant inter-departmental coordination, which may result in fragmented accountability and overlap of responsibilities. Hence, for each measure, agencies should be assigned specific duties..

Another major concern that our review highlights is the absence of a single body or agency that could be held responsible for the implementation of each city's clean air plan. About 84 per cent of all activities have been assigned to pollution control boards (PCBs), municipal
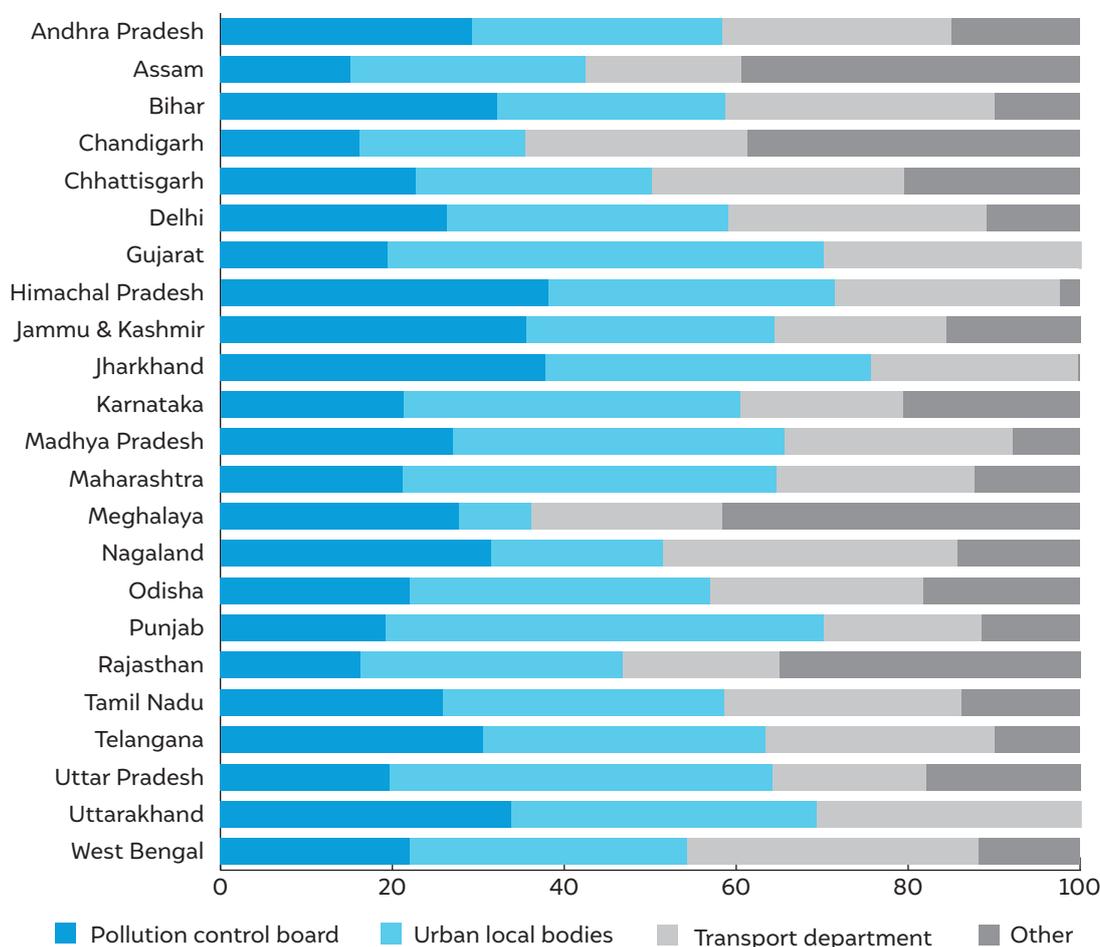
ES1

About 84 per cent of the mitigation activities have been allotted to PCBs, ULBs, and the transport department

Source: Authors' analysis

Legend: ■ Pollution control board   ■ Urban local bodies   ■ Transport department   ■ Other

corporations, or the state department of transport (ES 1). 40 per cent of all listed activities are shared among multiple agencies, including the respective SPCBs, urban local bodies (ULBs), and the state department of transport, which can result in fragmented accountability. To address this, we recommend that for each measure, agencies should be assigned specific roles, i.e., planning, implementing, enforcing, or monitoring.

Cities are affected by polluting sources both within the city and outside the city limits. Hence, the plans should propose an inter-city, cross-state coordination mechanism to ensure that regional sources are addressed.

Studies suggest that the contribution of sources outside a cities' boundary could range 15–50 per cent (ES 2). Despite this, the action plans establish no clear guidelines for coordination with other regions in the state, let alone addressing sources that impact multiple states. This can be addressed by setting up regional airshed management authorities that enjoy cross-state jurisdiction.

We also find that the states with multiple non-attainment cities such as Uttar Pradesh and Rajasthan have resorted to using the same set of action points in all their city plans. To address this, we recommend the preparation of a state action plan that would include state-wide emission control measures and city action plans that would address local sources.
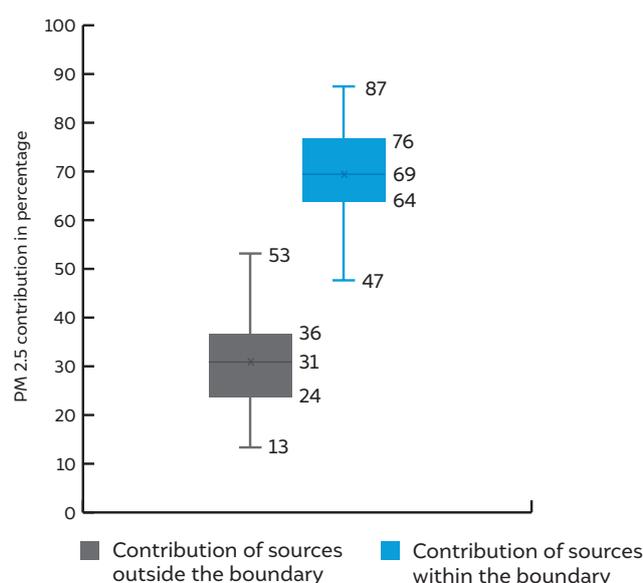
ES2

Sources outside the city boundaries contribute about 30 per cent of the PM 2.5 concentration

Source: Authors' compilation; Guttikunda, Sarath, K. A. Nishadh, and Puja Jawahar. n.d. "India – Air Pollution Knowledge Assessment (APnA) City Programme." http://www.urbanemissions.info/india-apna/

The feasibility of mitigation actions depends on their cost-effectiveness. Hence, the plans should budget for the execution of each action.

The most glaring shortcoming was the absence of cost estimates for the execution of the action points listed in the plans. Only 9 out of the 102 approved plans provided detailed budgets. State budgets need to account for the expenses that implementing clean air plans will incur, especially since some actions call for core infrastructural development and the purchase of expensive assets like mechanical street sweepers and real-time monitoring stations. Also, of all the agencies listed in the plans, the ULBs, including the municipal corporations and urban development authorities, are responsible for more than 35 per cent of all listed activities in the plans. Municipalities across India are infamous for underdeveloped finances. Hence, their ability to raise resources for air pollution mitigation

should be evaluated and suitable source of finance should be provided to enable them to act independently.

In the following years, clean air plans will guide pollution mitigation activities in cities. SPCBs and municipal corporations could use the recommendations listed in this report to update the plans.

1. Introduction

In January 2019, the Ministry of Environment, Forest and Climate Change (MoEFCC) launched the *National Clean Air Programme* (NCAP), which lists the preparation and implementation of 102 city-specific air quality management plans as a primary mitigation measure for fulfilling its objective of effecting a 20 to 30 per cent reduction in particulate concentration with 2017 as the base year (MoEFCC 2019).

In August 2019, the National Green Tribunal (NGT) directed 20 additional cities to develop clean air plans (NGT 2019). A clean air plan (CAP) aims to improve air quality and public health by identifying cost-effective measures to reduce emissions from sectors such as transport, industries, waste deposits, and residential burning, among others. Clean air plans are also collections of regulations, policies, and programmes for cleaner air (Clean Air Asia 2016).

The clean air plans submitted by State Pollution Control Boards (SPCB) in India list sector-specific interventions with predetermined timelines for implementation and the agency responsible for execution. A handful of the plans also include interim milestones and financial requirements for some of the listed action points. While these plans are meant to evolve with available scientific information from source apportionment studies, they are representative of the scale of ambition that Indian cities have with regard to air quality management.

This report reflects our evaluations of the 102 approved city action plans. Based on an extensive review of global literature on clean air planning, we identified the key components of a clean air plan and suggested ways in which these components can be integrated into the existing city action plans. Given that the current plans are preliminary, the SPCBs can use our recommendations to improve the plans.

Our review finds that the city-level clean air plans stand as a collection of measures without specified goals and priorities. With frugal resources to tackle persistent air pollution, there is an urgent need to identify time-bound goals, make the actions listed in the plans legally binding and increase accountability of all responsible agencies.

While city-wise clean air plans are meant to evolve with available scientific information from source apportionment studies, they are representative of the scale of ambition that Indian cities have with regard to air quality management

Transport is the most discussed sector in most plans, accounting for 38 per cent of all listed mitigation measures.

2. A brief history of clean air planning in Indian cities

While this is indeed the first time that the preparation of clean air plans has been taken up across India's states, this is definitely not the first time that polluted cities have been asked to draw up clean air strategies.

In 1997, the MoEFCC prepared an action plan for controlling pollution in Delhi. The plan warranted the implementation of a time-bound programme consisting of a coordinated inter-departmental strategy (MoEFCC 2016).

In 2003, the Supreme Court directed the states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu, and Uttar Pradesh to prepare plans for lowering the respirable suspended particulate matter (RSPM) level in the cities of Ahmedabad, Bengaluru, Chennai, Hyderabad, Lucknow, and Sholapur (EPCA 2003).

In 2009, the CPCB introduced the Comprehensive Environmental Pollution Index (CEPI) as a tool for the environmental assessment of industrial clusters. The CEPI aimed to identify critically polluted industrial areas and formulate action plans for prioritising interventions to improve environmental quality in these areas (LIFE 2017).

In 2015, the CPCB issued a comprehensive set of directions under Section 18 (1) (b) of the *Air (Prevention and Control of Pollution) Act, 1981* (henceforth, *Air Act 1981*) for the implementation of 42 measures to mitigate air pollution in major cities, including Delhi and the National Capital Region (NCR). The directions comprised action points for countering air pollution, including control and mitigation measures related to vehicular emissions, the re-suspension of road dust and other fugitive emissions, biomass/municipal solid waste (MSW) burning, industrial pollution, construction and demolition (C&D) activities, and other general steps. Containing 42 action points, the directions, which were initially issued for implementation in the NCR, were subsequently extended to other states for implementation in other non-attainment cities[1] (MoEFCC 2019).

In April 2018, the MoEFCC circulated a draft concept note that proposed several strategies for reducing air pollution (MoEFCC 2018). This document identified 94 non-attainment cities based on PM10 for the period 2011-2015. All 94 cities exceeded the PM10 standard, while five cities exceeded the No_2 standard for five years (WHO 2016). The total cost of carrying out all the activities listed in the draft (excluding the implementation of city-specific action

In 2009, the CPCB introduced the Comprehensive Environmental Pollution Index (CEPI) as a tool for the environmental assessment of industrial clusters

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[1] Non-attainment cities refer to polluted cities where the CPCB prescribed National Ambient Air Quality Standards (NAAQS) are violated.

plans) was estimated at INR 637 crore (2011-2015). The list was further extended to the 102 non-attainment cities based on the World Health Organisation's fourth ambient air quality database on the basis of PM2.5 in the final draft (MoEFCC 2019).

An NGT order dated 8 October 2018 directed non-attainment cities to submit clean air plans by 31 December 2018 (NGT 2018). The NGT order directed a state-level six-member committee called the Air Quality Monitoring Committee (AQMC), comprising Directors of Environment, Transport, Industries, Urban Development, Agriculture and the Member Secretary, State Pollution Control Board (or Committee) of the concerned state for the purposes of preparing these plans. A central committee, comprising Dr Prashant Gargava (Member Secretary, CPCB), Dr Mukesh Khare (Professor, IIT Delhi) and Dr Mukesh Sharma (Professor, IIT Kanpur) reviewed the plans. The Chairman, CPCB approved the plans on the recommendations of the said Committee (NGT 2018).

On 10 January 2019, the MoEFCC launched the finalised NCAP with an initial budget of 300 crore for the first two years. The NCAP listed the preparation and implementation of 102 city-specific air quality action plans as a mitigation measure (MoEFCC 2019). On 6 August 2019, another NGT order added an additional 20 cities to the list, bringing the tally of non-attainment cities, and hence required city action plans, to 122 (NGT 2019). The order directed non-attainment cities to prepare their action plans within three months of the order's issue date. Figure 1 visualises the location of these 122 non-attainment cities. Figure 2 ranks the states on the basis of the number of non-attainment cities they house.

It is important to note that out of the 122 designated non-attainment cities, 102 are included under the NCAP while the remaining 20 cities await NCAP inclusion and the approval of their city-specific action plans. The approved plans have been uploaded to a public portal (CPCB 2019).

Figure 1
Locations of 122 non-attainment cities in India
Source: Authors' compilation

Non-attainment cities
- ● Cities included in draft NCAP (94)
- ● Additional cities included in the final NCAP (8)
- ● Additional cities directed to be added under NCAP by NGT (20)
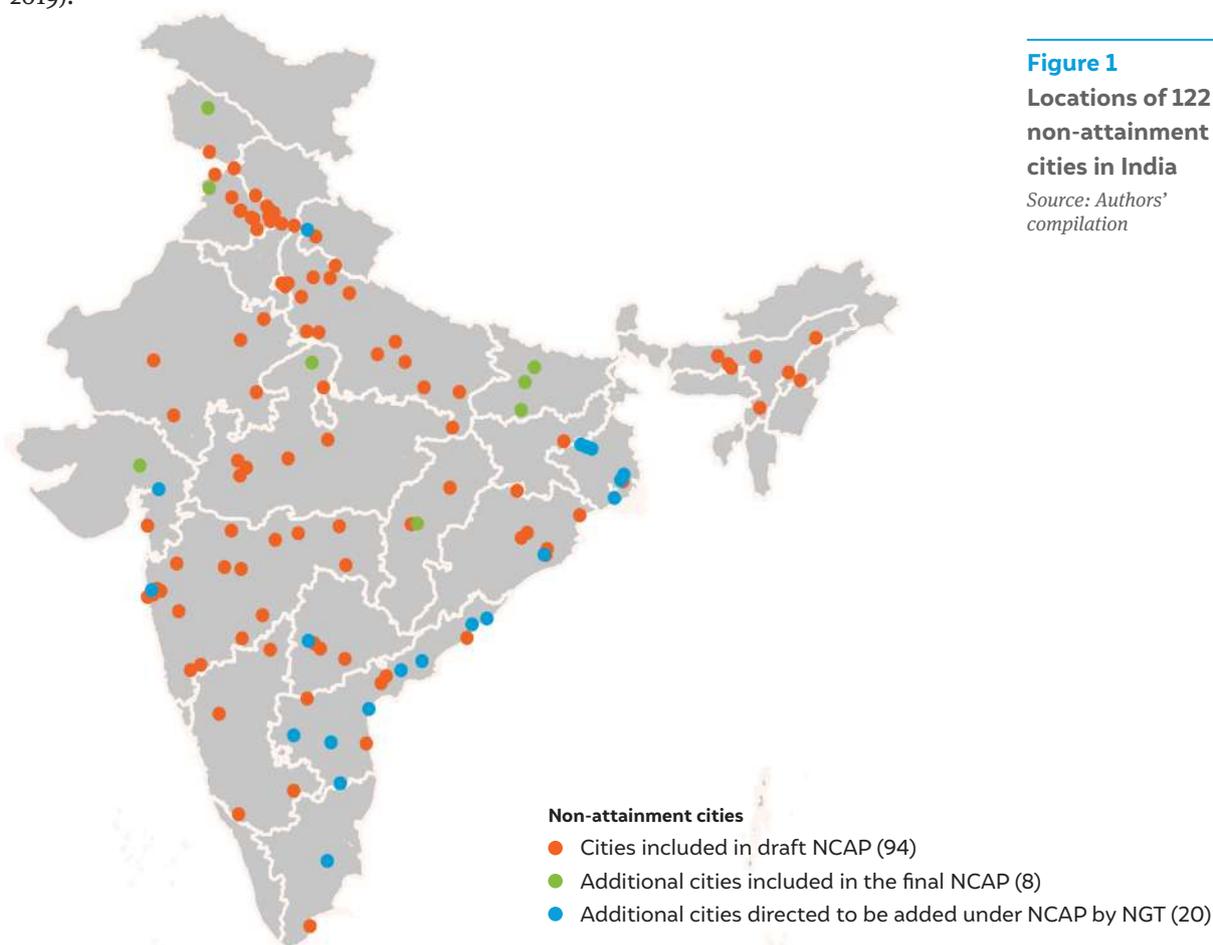
A timeline of clean air planning in India

1997

The MoEFCC prepared an action plan for controlling pollution in Delhi.

2003

In order to reduce RSPM levels, the Supreme Court issued directives ordering the preparation of clean air plans for the cities of Ahmedabad, Kanpur, Sholapur, Lucknow, Bangalore, Chennai, and Hyderabad.

2009

The CPCB introduced the *Comprehensive Environmental Pollution Index* as a tool for the environmental assessment of industrial clusters.

2015

The CPCB issued directives under the *Air Act, 1981* for the implementation of 42 action points containing control and mitigation measures for major cities, including Delhi and the NCR.

April 2018

The MoEFCC circulated a draft concept note of the *National Clean Air Programme* that proposed multiple time-bound strategies for reducing air pollution.

8 October 2018

The NGT directed the states and the union territories with non-attainment cities under the NCAP to prepare action plans.

10 January 2019

The MoEFCC launched the *National Clean Air Programme* as a time-bound national strategy to tackle increasing air pollution.

31 January 2019

A three-member central committee examined and approved the clean air plans.

6 August 2019

Following the NGT's intervention, 20 new non-attainment cities were added.

Source: Authors' compilation

A glimpse at the mitigation measures

Transport

- Plying electric vehicles for public transport
- Establishment of charging stations
- Construction of expressways/bypasses/peripheral roads
- Arrangement of multi-level parking facilities
- Development of cycling zones
- Retrofitting diesel vehicles with particulate filters
- Use of bio-ethanol
- Widening roads
- Installation of remote sensor-based PUC systems

Industry

- Adoption of zig-zag technology in brick kilns
- Monitoring industrial emissions through the Online Continuous Emission Monitoring System (OCEMS)
- Shifting air pollution industries to conforming zones
- Installation of webcams and OCEMS in gross polluting industries

Waste burning

- Launching an extensive drive against open burning
- Proper collection of horticultural waste
- Door to door collection of segregated waste
- Establishment of compost pits
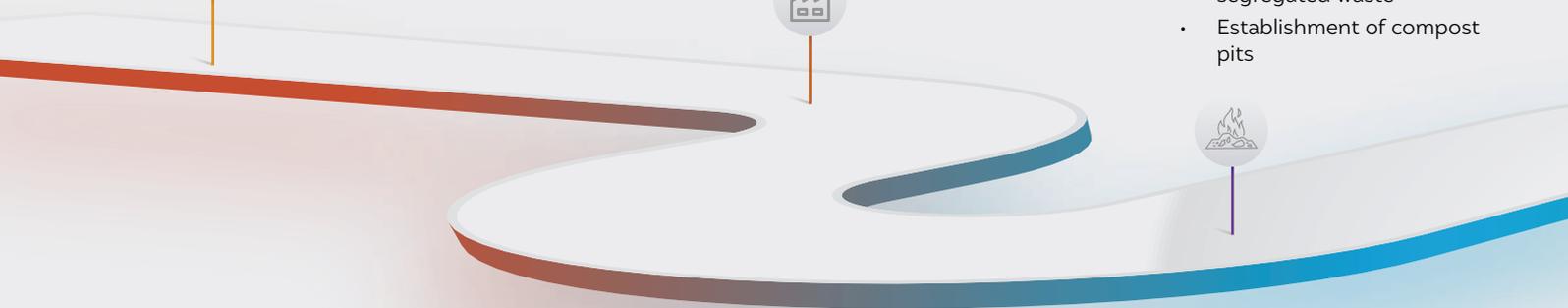
Number of non-attainment cities across states

State	Number
Maharashtra	18
Uttar Pradesh	15
Andhra Pradesh	13
Punjab	9
West Bengal	7
Odisha	7
Himachal Pradesh	7
Madhya Pradesh	6
Rajasthan	5
Assam	5
Telangana	4
Karnataka	4
Uttarakhand	3
Gujarat	3
Chhattisgarh	3
Bihar	3
Tamil Nadu	2
Nagaland	2
Jammu & Kashmir	2
Meghalaya	1
Jharkhand	1
Delhi	1
Chandigarh	1
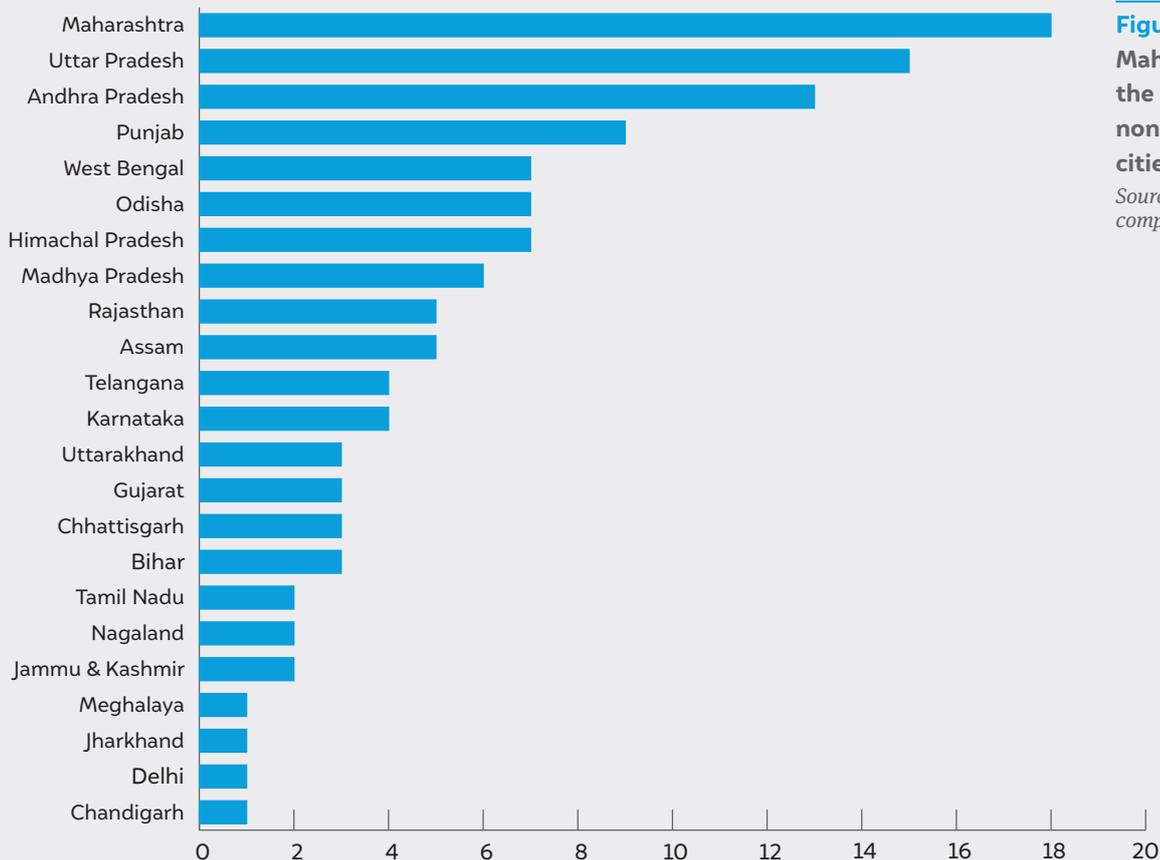
Figure 2:

Maharashtra tops the list with 18 non-attainment cities

Source: Authors' compilation

Construction

- Implementation of control measure for fugitive emissions
- Covering all construction areas to avoid dispersion of particulate matter
- Ensuring that construction material is carried in closed/covered vessels

Residential

- Maintaining continuous engagement with the concerned authorities to maximise LPG/PNG coverage for domestic and commercial cooking with a target of 100 per cent coverage

Dust

- Maintenance of 33 per cent forest cover
- Creation of green buffers
- Maintain pothole-free roads
- Introduction of water fountains
- Implementing wall-to-wall pavement
- Blacktopping metallic roads

Source: Authors' compilation

City action plans target only the wider LPG coverage and neglects the adoption of LPG as a primary fuel. Targeted awareness programmes are necessary for the sustained use of LPG and its adoption as primary fuel.

3. Methodology

Through this evaluation, we attempt to assess the 102 existing clean air plans and suggest ways to improve them. Since the current plans are preliminary, the SPCBs can use these suggestions to strengthen future versions.

We established the key components of a clean air plan using existing literature on clean air planning in combination with Clean Air Asia's prescribed clean air plans format[2]. The components described below could significantly affect the implementation of clean air plans.

Legislative framework: Legislation is absolutely critical for effective implementation of clean air plans because it can designate an area as an air pollution control area, set ambient air quality limits and target values for air quality, ensure the implementation of emission mitigation controls, set vehicle emission standards for reducing transport-related emissions, set fuel quality standards, encourage the use of renewable fuels, and outline implementing agencies' roles, among other measures. Without legally-mandated targets, procedures, and responsibilities, any failures on the part of responsible agencies to prepare and execute clean air plans cannot be questioned (Acosta 2018; US EPA 2015).

Accountability: Air quality issues span widely across sectors and departments. A variety of stakeholders have an interest in, or may be affected by, air quality issues (European Commission 2020). Studies have often cited the lack of coordination and integration in planning across concerned agencies and departments as the reason state- and central government-introduced schemes have failed in the past (AIGGPS 2018). Since Indian cities are also affected by pollution from neighbouring regions, states, and countries (Guttikunda, Nishadh, and Jawahar 2020), air pollution's cross-sectoral and regional nature calls for cross-state and cross-departmental participation and coordination. Delineating responsibility and establishing a coordination mechanism thus becomes absolutely essential to ensuring that plans are effectively implemented.

Source information: A quantitative understanding of pollution sources and their contribution is critical for planning emission control interventions in non-attainment regions. Source information is meant to be available via emission inventories and source apportionment (SA)[3] studies (Clean Air Asia 2016; Belis et al. 2014). Such studies intend to

Delineating responsibility and establishing a coordination mechanism is absolutely essential to ensuring that plans are effectively implemented

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2   The recommended clean air action plan outline was developed following a review of nine international cities' and seven Chinese cities' action plans. Table A1 (in the Annexure) presents the outline.

3   Source apportionment (SA) is the identification of ambient air pollution sources and the quantification of their contribution to pollution levels. This task can be accomplished using the following approaches: emission inventories and source- or receptor-oriented models.

give policymakers and other stakeholders a scientific basis for formulating strategies and prioritising actions towards improving air quality. They help with setting sector-specific emission reduction targets.

Cost of measures: It is critical to estimate the costs associated with the proposed measures as this would help evaluate the cost-effectiveness of competing control options, thereby helping prioritise action. Estimating measures' cost can also help cities and states determine their required air pollution prevention and control expenditure as well as whether additional revenue streams will be needed in addition to conventional funding avenues.

We examined the 102 existing city action plans to assess the presence of each of the above components. In order to understand variances among different cities' clean air plans, we also compared the plans to one another based on each component.

4. Results and discussion
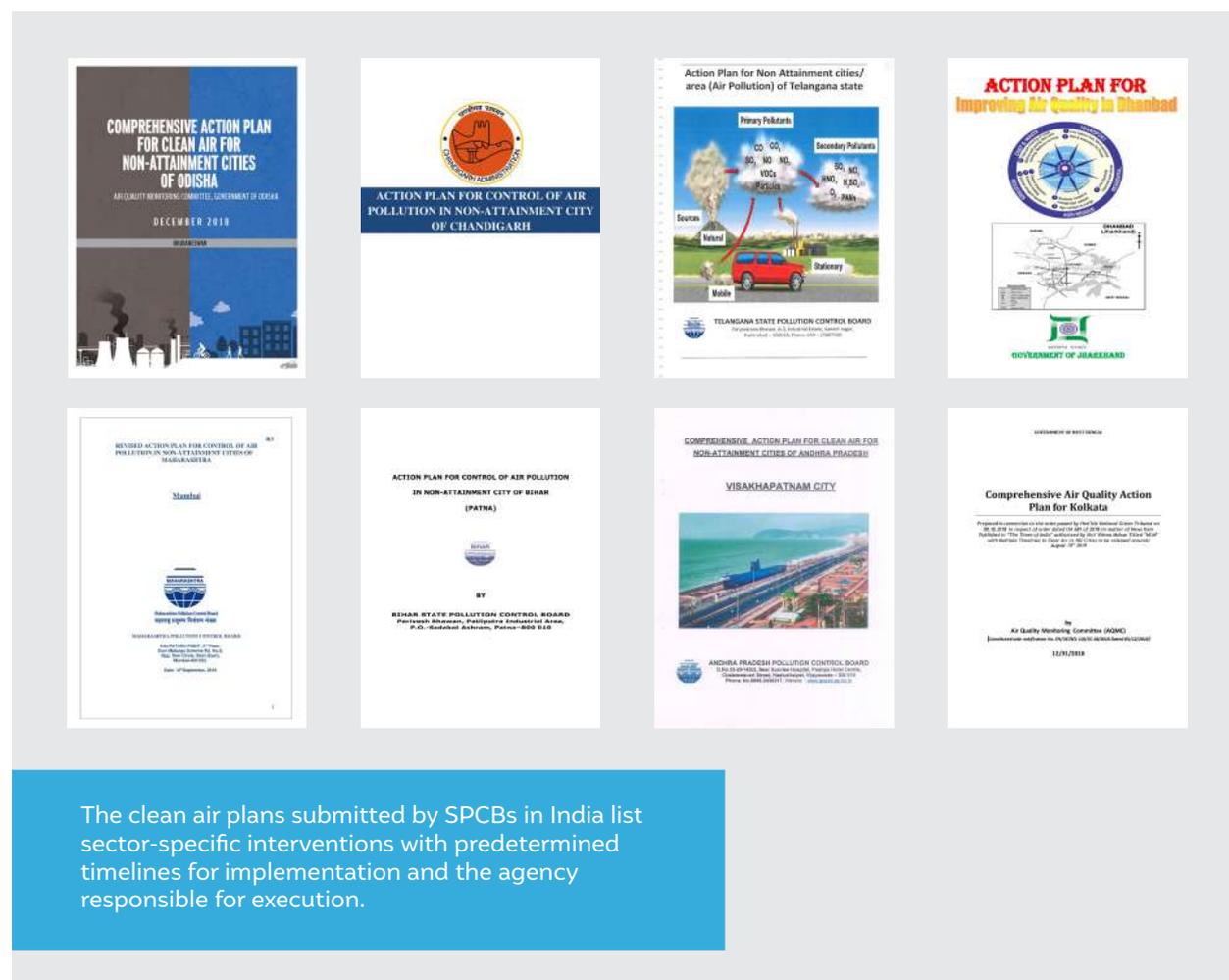
The clean air plans submitted by SPCBs in India list sector-specific interventions with predetermined timelines for implementation and the agency responsible for execution.

This section presents and discusses various findings based on the key components covered in the assessment, namely, legislative framework, accountability, source contributions, and the cost of measures.

4.1 Legislative framework

Apart from Delhi's clean air plan, which the Supreme Court partially notified for implementation in January 2018, no other clean air plan has a legal mandate for implementation. The CPCB approved the plans and directed the SPCBs to implement them, but without a mandated timeline for implementation, any failure or delay to implement these plans cannot be questioned.

It is critical to note that it was not the NCAP but rather an NGT order that mandated the preparation of the clean air plans (NGT 2018). This stems from the fact that the NCAP is itself a programme that cannot legally bind cities to draft clean air plans. The NCAP set 2019 as the deadline for preparing the plans. Meanwhile, the NGT order that was issued on 8 October 2018 sets 31 December 2018 as the deadline for preparing and submitting the plans, giving cities only two months to comply.

It is critical to note that it was not the NCAP but rather an NGT order that mandated the preparation of the clean air plans (NGT 2018)

Interestingly, Section 16, Clause 2(a) of the Air Act, 1981 lists the planning and execution of a nationwide programme for the prevention and control of air pollution as one of the CPCB's main functions (*The Air (Prevention And Control of Pollution) Act*, 1981). Similarly, Section 17, Clause 1(a) lists planning a comprehensive programme for the prevention and control of air pollution and securing its execution as an SPCB function. Despite these provisions, this was the first time that SPCBs across the country attempted to draft plans.

By contrast, in the United States, state implementation plans (SIPs) are considered the backbone of efforts to attain better air quality (Mathias 2007). The *United States Clean Air Act* requires a general plan for all areas of the country and specific plans for all non-attainment areas.

Similarly, the *EU Ambient Air Quality Directives* (AAQDs) oblige EU member states to divide their territories into zones and agglomerations for the purposes of air quality assessment and management. Air quality assessment and management should be carried out in all zones and agglomerations, and each zone and agglomeration should be classified in relation to the assessment thresholds for ambient concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) or nitrogen oxides (NO_x), particulate matter ($PM10$, $PM2.5$), lead, and benzene or carbon monoxide, as specified in the AAQDs.

The above cases from the USA and the EU demonstrate that non-attainment regions are legally mandated to frame clean air plans for regions that exceed national air quality standards. This legal binding is currently—and sorely—missing from India's air quality management framework.

4.2 Accountability

All the clean air plans list responsible agencies for each action points. But, over 40 per cent of the listed activities are shared by multiple agencies thereby resulting in fragmented accountability. This is in addition to the fact that none of the plans propose a regional coordination mechanism despite approximately 30 per cent of pollution coming from sources outside the city boundaries.

Multiple agencies

Our analysis has indicated that only 24 per cent of activities have been allotted to the pollution control boards. Approximately 60 percent of activities lie with the urban local bodies (ULBs), including municipal corporations and development authorities, and the transport department, including traffic police (Figure 3). The remaining 16 percent lies with miscellaneous agencies, as listed in Table 1.
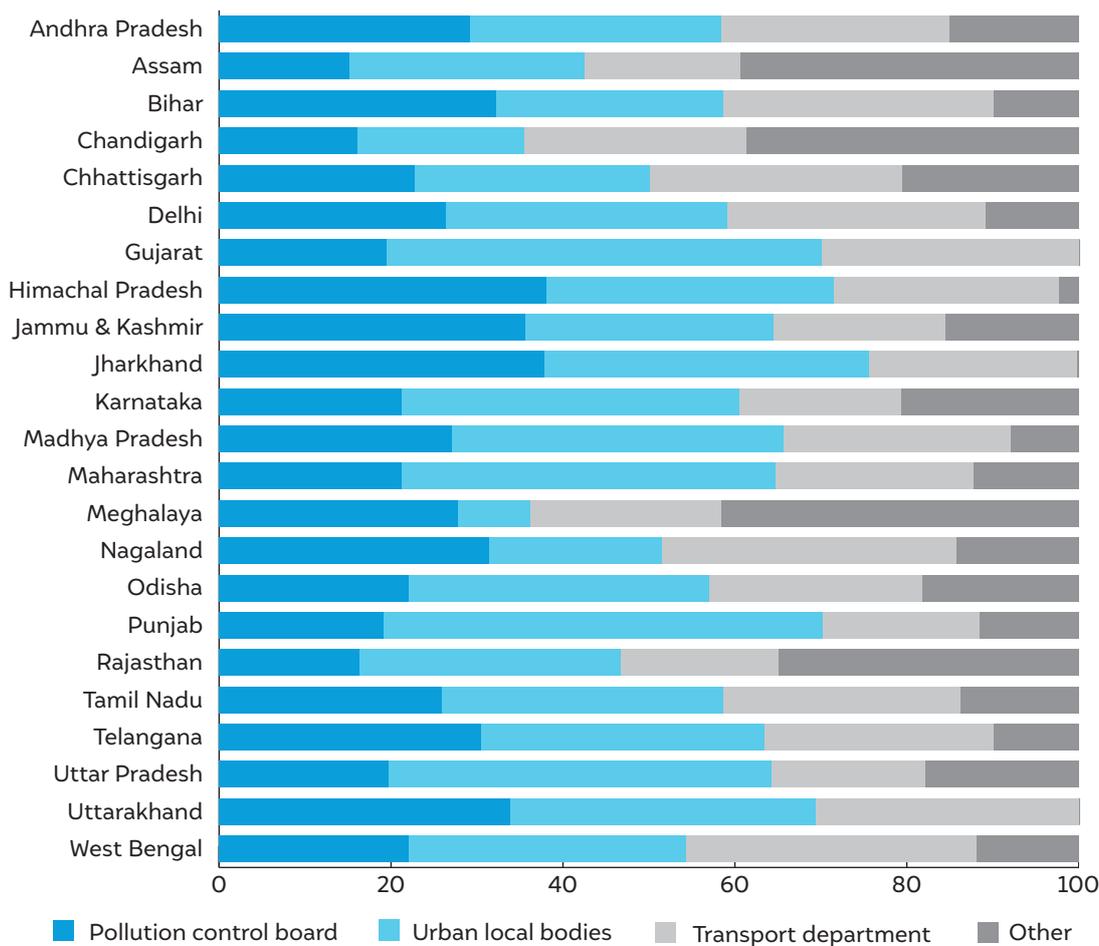
S. No	Responsible agency
1	National Highway Authority of India (NHAI)
2	Public Works Department (PWD)
3	Vehicle manufacturing companies
4	Ministry of Road Transport and Highways (MoRTH)
5	Food and civil supply
6	Oil companies
7	Forest department
8	Irrigation department
9	Agriculture department
10	Urban development department
11	District Industries Centre
12	Housing companies

In more than half of the cities, approximately 37 per cent of the responsibilities lie with the ULBs. This disproportionate allocation of activities to ULBs is problematic due to the country's underdeveloped municipal finances (Ahluwalia et al. 2019). The 74th Amendment Act that formally recognized urban local bodies as the third tier of the government defines the range of possible expenditure assignment but leaves it to the states to notify devolution from the range identified. The Act also vests the responsibility of identifying potential revenue sources of the urban local bodies entirely with the state government thereby leaving the local bodies with limited fiscal autonomy.

Distinguishing between planning, monitoring, and enforcement roles

The NCAP lays down the institutional framework for implementation in cities in the form of a state-level review and monitoring committee under the chief secretary of the state, a district-level committee under the district collector, and a city-level review committee under the municipal commissioner; however, these the composition and strength of these committees have not been elaborated, making it difficult to assess the enforcement powers of these committees.

Interestingly, the pollution control action plan that concerns Uttar Pradesh's 15 non-attainment cities identifies the Uttar Pradesh Pollution Control Board (UPPCB) as the nodal agency for monitoring the implementation of the plans (UPPCB 2019).This highlights an apparent overlap between the state-level monitoring committee and the responsibility that the plan allocates to the UPPCB. Alternatively, there is also the possibility of an arrangement wherein one committee enforces and the other monitors. Unfortunately, the existing plans lack such a clear delineation of responsibility. As the *Handbook on the Implementation of EU Environmental Legislation* points out, "It may be useful to separate the technical inspection function of the competent authority from an enforcement function. This will help to allow the technical inspectors to maintain a good working relationship with the operator and to avoid the strain on the relationship that the inspectors' being directly responsible for a closure notice or for a prosecution might cause" (European Commission 2020).

With regard to industrial pollution management in India, PCBs play both monitoring and enforcement roles. PCBs are empowered to issue directions requesting compliance, but they cannot levy penalties in the event of non-compliance. Only criminal courts can levy penalties, and this significantly limits the PCB's powers of enforcement since the absence of a credible threat of enforcement due to limited powers of enforcement deters compliance (Ghosh 2015).

The National Capital Region (NCR) has been privileged to have a dedicated authority called the Environment Pollution Control Authority (EPCA), which has a specific mandate to protect and improve its environment. However, despite this privilege, Delhi's air quality issues persist, again because the EPCA is only empowered to issue directions and initiate legal proceedings against violators (Dutta 2018).

Environmental protection agencies should have the legal authority to penalise and prosecute violators. For instance, the US EPA has a dedicated enforcement and compliance cell that can choose to take non-judicial or judicial action against violators as it deems fit (US EPA 2018). While judicial action involves formal lawsuits, non-judicial action can take the form of a notice of violation or an order that involves penalties for directing a non-compliant entity to do its duty.

Regional coordination

The NCAP's third chapter outlines the need for institutionalising an air quality management framework with mitigation strategies at different levels, i.e., local, city, state, regional, and transboundary, in the interest of effectively controlling pollution (MoEFCC 2019). Furthermore, Section 7.4 of the NCAP clearly lists regional mitigation measures including the implementation of pollution abatement policies such as the auto fuel policy to ensure stringent vehicle and fuel norms, strict industrial emission standards, the widening of the LPG network, and control over agricultural burning through regional-level inter-state coordination for the Indo-Gangetic Plain (IGP) in particular. It also recommends

A clear delineation of responsibility between enforcement and monitoring is needed in the plans

Environmental protection agencies should have the legal authority to penalise and prosecute violators

a comprehensive regional plan that incorporates the results of a regional source apportionment study.

In order to understand the contribution of outside sources to particulate concentration in cities, we reviewed the summary of modelled source contributions to PM2.5 across 50 cities that were covered by the Air Pollution Knowledge Assessment (ApNA) programme (see Table A3 in the Annexure). Our review found that the contribution of outside sources in these 50 cities ranges from 15 to 50 per cent of the total burden (Guttikunda, Nishadh, and Jawahar 2020).
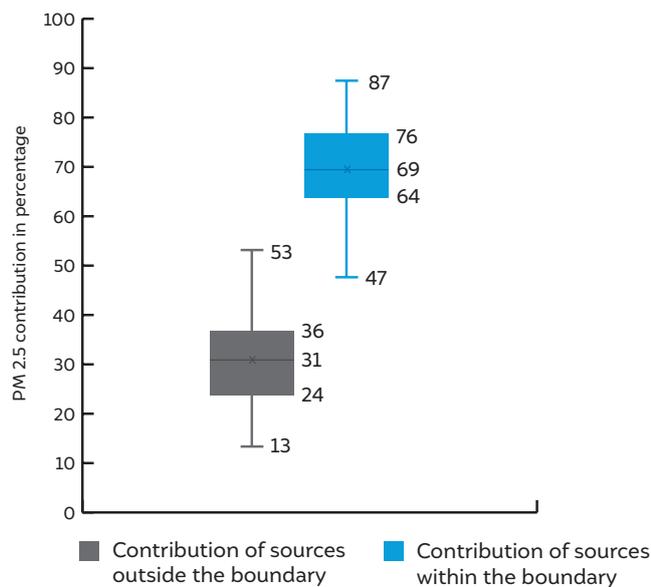

Figure 4
Sources outside the city boundaries contribute about 30 per cent of the PM$_{2.5}$ concentration
Source: Authors' compilation; Guttikunda, Sarath, K. A. Nishadh, and Puja Jawahar. n.d. "India – Air Pollution Knowledge Assessment (APnA) City Programme." http://www.urbanemissions.info/india-apna/

While most city plans include the recommended measures, there are no clear guidelines on establishing regional coordination across state boundaries. For example, Delhi's action plan lists three action points for mitigating pollution from regional sources. The governments of the National Capital Region (NCR) states and the Punjab state government have been made responsible for implementing these action points; however, there is no clear delineation of responsibilities nor are there any guidelines for institutionalising coordination between the state governments.

On the other hand, China's State Council has supported the establishment of the *Mechanism for Coordinated Prevention and Control of Air Pollution Beijing–Tianjin–Hebei (BTH) and Surrounding Areas* to ensure regional coordination and achieve alignment among pollution control measures (UNEP 2019). The government also set up the Office of the BTH and Surrounding Areas Air Pollution Control Coordination Group (Coordination Group), which is chaired by a vice premier and joined by key central government agencies including the Ministry of Finance, the National Development and Reform Commission, and the Ministry of Environmental Protection (re-designated in 2018 as the Ministry of Ecology and Environment [MEE]) as well as the seven provincial governments (ADB 2019).Through coordinated planning, common emission standards, and information sharing, the average annual PM2.5 concentrations in the Beijing–Tianjin–Hebei region and its surrounding areas has decreased by nearly 25 per cent during 2013-2017 (UNEP 2019).

While most city plans include the recommended measures, there are no clear guidelines on establishing regional coordination across state boundaries

Based on the 102 existing clean air plans, it is evident that the first stage of clean air planning has focused primarily on city-level interventions. As the planning process evolves, protocols for the regional alignment of mitigation measures should be established.

4.3 Source information

Only 25 cities' clean air plans contain collated information about emission sources; however, even in cases where the information was included, it has not been used to prioritise mitigation measures. About 56 cities' clean air plans include source apportionment studies among their action points.

Section 7.6 of the NCAP mentions that city-based clean air action plans are to be dynamic and evolve based on the available scientific evidence, including the information available through source apportionment studies (MoEFCC 2019). Our analysis found that only 25 clean air plans contain source information. A few Indian cities that lacked source apportionment studies have mapped emission activities through asset details such as the number of registered vehicles, the types and number of industries, the number of traffic intersections, etc. However, even the city action plans that include this information fail to effectively integrate insights from scientific studies and source compilations. Consequently, the end product turns out to be a mere compilation of activities without specific emission reduction and interim targets.

The absence of source information has resulted in plans being replicated. Our review indicated that nine states with multiple non-attainment cities have used the same set of action points and timelines across all cities. For example, Uttar Pradesh has 15 non-attainment cities, which is the second highest number after Maharashtra, and with the exception of Anpara, all have identical plans, each with the same 56 actions for transport, road dust, vehicles, waste burning, industries, and construction and demolition—and without any interim targets. Similarly, Rajasthan has five non-attainment cities and identical plans for all five. Only 48 cities within eight states have made clean air plans with distinct actions and interim targets, as shown in Table A2 in the Annexure.

Moreover, a clear understanding of sources will eliminate the tendency to over- or under-emphasise certain sectors or, conversely, ignore others (Guttikunda and Jawahar 2011). For instance, studies have identified that addressing residential emissions, such as biomass for cooking, and space- and water-heating, in India will help with achieving the National Ambient Air Quality Standards (NAAQS) (Chowdhury et al. 2019). Despite various government schemes regarding subsidising LPG and launching *Pradhan Mantri Ujjwala Yojana* (PMUY) in 2016, studies have demonstrated that the number of households across six Indian states[4] that use LPG as a primary fuel is still low at about 37 per cent as of 2018 (Jain et al. 2018). In spite of this situation, most action plans have targeted LPG coverage while neglecting the wider adoption of LPG as a primary fuel. This is an example of how the residential sector has not received much attention despite its sizeable contribution to air pollution.

Figure 5 illustrates the number of actions that have been planned across sectors in all the non-attainment cities. Approximately 38 per cent of all planned activities are aimed at reducing emissions from the transportation sector. Furthermore, more than 70 per cent are mentioned as involving overseeing, planning, proposing, preparing, investigating, identifying, ensuring, strengthening, training, studying, and engaging. Meanwhile, less than 30 per cent of the interventions call for physically manifested control options

Our analysis found that only 25 clean air plans contain source information

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4   These six study states include Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal.
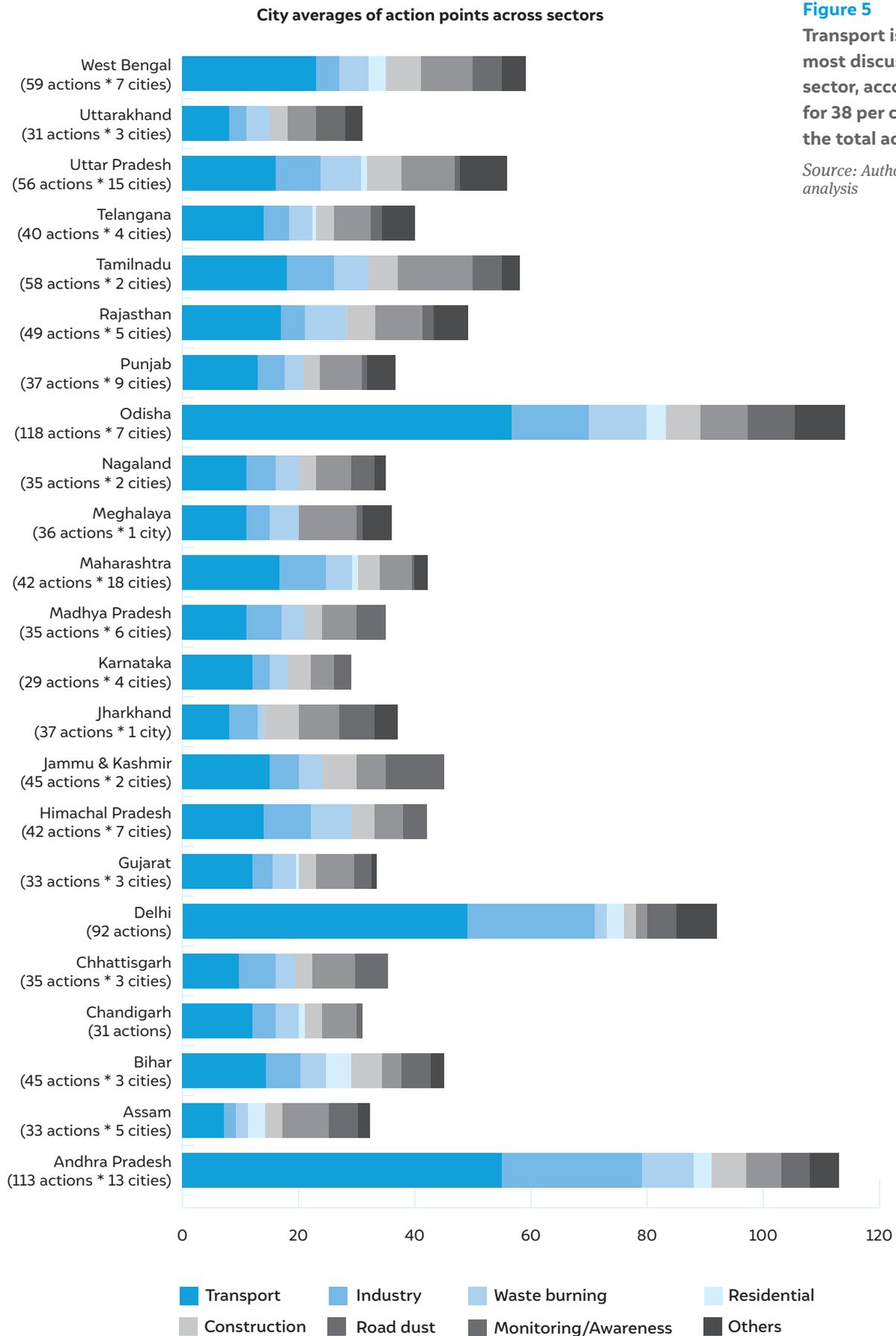
## City averages of action points across sectors

Legend:
- Transport
- Industry
- Waste burning
- Residential
- Construction
- Road dust
- Monitoring/Awareness
- Others

In the context of creating city air action plans, cities in China, the European Union (EU), and the United States (US) have realised the importance of having scientific studies as a guiding principle for setting emission reduction targets and prioritising plans (European Commission 2004; CAI-Asia 2012; Clean Air Asia 2016). By contrast, in India, although the NCAP has mentioned that source information should be used to develop clean air plans, SPCBs have charted actions without properly mapping various sources, owing to the two-month limit for preparing plans. Such a time constraint is insufficient for source apportionment studies, which are resource intensive, requiring about one year to accurately capture source contribution across seasons (Guttikunda and Jawahar 2011). However, since the ApNA emission database has city-specific emission inventories for 50 Indian cities (Guttikunda, Nishadh, and Jawahar 2020), SPCBs can use this resource as a starting point to identify and target high-priority sources.

Capitalising on the asset mapping exercise

In both the US and the EU, the SIPs require setting of emission ceilings to achieve air quality targets (Kuklinska, Wolska, and Namiesnik 2015). In light of the fact that insights from the National Emission Inventory (NEI) are used to determine emission targets (European Commission 2004), the US EPA has mandated that states keep the inventory up to date by submitting periodic emission inventories every three years (US EPA 2017). By contrast, in India, SA studies are mostly outdated. The lack of a national emission inventory coupled with the absence of a standard protocol for air pollution emission reporting across Indian states hinders the setting of emission reduction targets.

Cities that have no emission inventory, whether dated or recent, should capitalise on asset mapping exercises for targeted, localised interventions. The asset mapping exercise could also help with designing a reporting protocol for line agencies, which technical partners can use to create emission inventories for cities.

4.4 Cost of measures

Only nine cities' clean air plans have listed budgetary requirements for executing all the action points listed in the plans. Across these nine cities, the cost of execution of the plans ranges from 89 crore in Dimapur, which is the least densely populated city, to 16,780 crore in Mumbai, which is the most densely populated city.

Section 10.1 of the NCAP states that the programme is one of the sub-schemes of India's Pollution Abatement Scheme[5] (MoEFCC 2019). In fiscal year (FY) 2019-2020, the government of India set aside INR 460 crore for all pollution control activities. In FY 2019-2020, out of the 102 non-attainment cities, the MoEFCC disbursed INR 10 crore for 28 cities with populations of one million plus and PM10 greater than 90 μg/m³ for various components, including installing and commissioning continuous ambient air quality monitoring stations (CAAQMS); creating green buffer zones along roads; acquiring mechanical street sweepers, mobile enforcement units, and water sprinklers; and funding public awareness and capacity building activities, among other things. It is worth noting that a CAAQMS alone costs approximately 1.5 crore. The MoEFCC, therefore, needs to reconsider the funds that are being disbursed to cities. The remaining non-attainment cities were allocated INR 10 or INR 20 lakh per city for populations that were less than 500,000 or within the range of 500,001-1,000,000, respectively.

The lack of a national emission inventory coupled with the absence of a standard protocol for air pollution emission reporting across Indian states hinders the setting of emission reduction targets

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5   A central scheme, with an expected contribution from the state government as its outcome, would be contingent upon state investments.

Our assessment found that of the 102 cities' action plans, only nine (six cities in Maharashtra, two cities in Nagaland, and one city in Telangana) provided budgetary requirements for executing the listed actions. For instance, the total budget for successfully implementing all the activities in Dimapur's three-year action plan has been estimated as INR 89.64 crore. The budget also earmarks approximately INR 77 crore for core infrastructural activities like improving flexible pavement and repairing roads and drains, and another INR 5 crore for developing a multi-layer parking structure (Nagaland Air Quality Monitoring Committee 2019).

Recently, the Bihar State Pollution Control Board (BSPCB) released a revised action plan for the city of Patna (BSPCB et al. 2019) that differs from the one that is available on the CPCB portal. This version of the plan compares execution costs for three scenarios, namely high-pollution reduction (involving a 69 per cent decrease in PM2.5 emissions), medium-pollution reduction (involving a 48 per cent decrease), and low-pollution reduction (involving a 30 per cent decrease). The estimated cost ranges from 2,600-3,800 crore over eleven years (2019-2030). In all three scenarios, given Patna's currently inefficient public infrastructure, interventions in the transport sector will account for approximately one-third of the total execution cost. State budgets need to account for the expenses that implementing clean air plans will incur since some actions call for core infrastructural developments and the purchase of expensive assets like mechanical street sweepers and CAAQMS.

Twenty other cities in Telangana, Maharashtra, and Himachal Pradesh, as well as Chandigarh, have listed the financial requirements that are associated with some of the activities included in the plans.

Interestingly, the NCAP lists the preparation of state action plans that include detailed funding mechanisms for the effective implementation of city plans as an action point. While the deadline for preparing preliminary city action plans was 2019, the deadline for developing the funding mechanism is 2020; however, the two should have been carried out together. The effective implementation of city action plans can prove to be a very expensive exercise that will be contingent upon the availability of funds. Central assistance can partially cover the expenditure, but state governments and municipalities will need to identify clear revenue streams to fully implement the plans.

State budgets need to account for the expenses that implementing clean air plans will incur since some actions call for core infrastructural developments and the purchase of expensive assets like mechanical street sweepers and CAAQMS

Identify key indicators for each action point to track their impact on pollution reduction.

5. Recommendations to strengthen clean air planning in cities

The existing 102 clean air plans are representative of the clean air planning process in Indian cities. Based on our assessment of the plans, we recommend the strategies listed below for strengthening cities' clean air planning.

Legal mandate

Once a city has been designated as non-attainment, the preparation of plans should be mandated by law. This calls for an amendment to the existing Air Act, 1981. As mentioned earlier, Section 17, Clause 1(a) of the Air Act empowers state boards to plan and execute a comprEhensive programme for the prevention, control, and abatement of pollution. An additional sub-clause should make state boards responsible for biennially reviewing cities' non-attainment statuses and developing and updating plans for attainment. Mandatory plan components should be identified, and guidelines should be issued to SPCBs.

State- versus city-level plans

It is not productive for cities within a state to have the same set of activities with the same timelines since pollution in cities is affected by both local and regional sources. While regional plans can include state-wide emission control measures, city-specific plans should address local sources. For instance, in Amritsar and Ludhiana, outside sources contribute more than 40 per cent of the PM2.5 concentration (Guttikunda, Nishadh, and Jawahar 2020). Both Amritsar and Ludhiana are designated as non-attainment cities in Punjab. Given the significant contribution from outside sources, sole reliance on city-level interventions will not yield considerable reductions in air pollution levels.

Regional coordination mechanism

As highlighted in the NCAP, the states on the Indo-Gangetic Plain are particularly susceptible to regional pollution. Hence, the establishment of an inter-state coordination mechanism is crucial. This mechanism can be facilitated by setting up regional airshed management authorities that enjoy cross-state jurisdiction.

There are already agencies and bodies whose jurisdiction spans across states. For instance, in 1988 the Planning Commission divided the country into 15 agro-climatic zones to regionalise agricultural planning (Bansal, n.d.). Similarly, five regional power committees have been set up to plan for national power transmission (MoP 2019).

While regional plans can include state-wide emission control measures, city-specific plans should address local sources

Based on dominant source contributions, four airsheds, namely dust, coal, residential biomass, and open fire, can be defined in India (Brauer et al. 2019). Parts of the Indo-Gangetic Plain fall in the residential biomass and open fire airsheds. Therefore, the IGP could very well be managed by the same airshed management authority.

Integrating source information to prioritise concrete actions

Effective urban air quality management requires the use of information about the sources that contribute to ambient pollution levels so that actions can be prioritised accordingly. An action plan's overall success depends on the ability to monitor and model a city's spatial and temporal pollution trends, accounting for both local and non-local contributions. Having conducted studies in 2010, the CPCB presented source apportionment results for six cities and established protocols for conducting similar work in other cities (Aggarwal, Gargava, and Pathak 2010). These scientific studies combine local knowledge about pollution sources with an understanding of the chemical nature of pollution and should be further developed towards the continuous documentation of emission strength. When faced with limited resources, emission information should be used to prioritise specific actions that are suitable for helping cities produce tangible outcomes.

Budgeting for actions

Each action plan should account for its financial requirements. Municipal corporations and SPCBs should identify potential revenue streams when listing potential action points in plans. Given that more than 37 per cent of the responsibility lies with the ULBs, they should be granted greater fiscal autonomy. The primary responsibilities of ULBs include increasing the green cover, reducing road dust, and improving solid waste management in cities. Taken alone, a single mechanical street sweeper for eliminating road dust costs approximately 70 lakh.

Tracking progress

Plans should report interim milestones and sectoral emission reduction targets. The responsible agencies should identify key indicators that could be tracked to monitor the impact of their interventions. Constantly documenting progress could be beneficial in terms of identifying the strategies that work and those that need to be modified to yield better results. The PMUY scheme's progress, for instance, is tracked by the number of districts that have been covered and the number of connections that have been released. A similar tracking mechanism could be set up across sectors wherein the ULBs maintain a dashboard of the ward-wise number of households that segregate waste. In addition, the PCBs could maintain a dashboard of the number of inspections that have been carried out per industry as well as improvements that have been discerned through subsequent inspections.

The responsible agencies should identify key indicators that could be tracked to monitor the impact of their interventions

Clearly delineating responsibilities

Plans should clearly delineate participating agencies' responsibilities. In the interest of eliminating responsibility overlap, the existing plans' single column for identifying a responsible agency should be split into four so that, for each recommended measure, agencies can be identified per necessary duty, i.e., planning, implementing, enforcing, or monitoring.

Establishing an institution for overseeing the execution of clean air plans

At present, PCBs and ULBs have limited enforcement authority. As the country's only regional airshed management authority, the ECPA is also limited to issuing directions. However, without enforcement, these agencies' directives will always lack actual impact unless legal aid is sought. To remedy this, PCBs should be empowered to directly impose penalties on violators. A regional airshed management authority with a mandate to improve the country's air quality should also be created under the *Air Act*. This authority should have significant enforcement powers, allowing it to exert its influence across polluting sectors in the event of non-compliance.

Around 37 per cent of the mitigation activities lie under the responsibilities of municipal corporation and urban local bodies (ULBs). This disproportionate allocation of activities to ULBs is problematic due to the country's underdeveloped municipal finances (Ahluwalia et al. 2019)

Image: iStock

6. Conclusion

In the coming years, city action plans will guide air pollution mitigation interventions. Although the existing plans are ambitious, they are not devoid of shortcomings. Action planning in cities should be a continuous process rather than a one-time exercise that is undertaken in response to a court order. Hence, the process should be standardised and institutionalised. Furthermore, SPCBs should identify both state-wide and city-specific measures for implementation, and clean air plans should reflect this distinction. This model could also be helpful in determining the budget for clean air initiatives across different cities within a state. Moreover, the various responsible agencies need to acknowledge their roles in the clean air planning process. To encourage this, plans should specify each agency's role in the successful execution of each action.

In a sense, the future of India's clean air action can find its guiding force in the following Confucian adage: "*When it is obvious that the goals cannot be reached, don't adjust the goals, adjust the action steps.*" Simply put, in order to achieve the NCAP target of a 20-30 per cent reduction in particulate concentration by 2024, the existing plans require considerable improvement.

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Annexure

Key components of a plan
Executive summary
Introduction and background
Legal framework/Legislative and policy context
Roles and responsibilities (national/provincial/municipal)
Current status and challenges of air quality baseline assessment

– Current status, API, and comparisons to objective/standard
    – Emissions inventory and key pollutants
    – Causal analysis of effects and attribution to individual sources
    – Air pollution trends and tendencies analysis
    – Impact on public health and the environment

Guiding principles
Target and goals
Development of the action plan

– Process of development
    – Focus areas and main tasks
    – Expected impacts

Implementation of the action plan

– Analysis of costs and feasibility
    – Institutional arrangements (enforcement procedures)/Roles and responsibilities
    – Steps, working periods, and timeline

Supporting policies
– Monitoring and evaluation
Resource commitment (institution, financing, policy, technology, social)
Key projects
– Analysis of costs and feasibility   – Expected impacts

Table A1

The key components of a plan, as prepared by the Clean Air Initiative for Asian Cities Centre

Source: CAI-Asia. 2012. "Clean Air Action Planning in Chinese Cities: Hangzhou and Jinan Cases." Pasig City, Philippines: Clean Air Initiative for Asian Cities. https://cleanairasia.org/wp-content/uploads/portal/files/Report_on_Clean_Air_Action_Plans_Preparation.pdf.

States with similar plans	States with distinct plans
• Andhra Pradesh • Assam • Himachal Pradesh • Jammu and Kashmir • Nagaland • Odisha • Rajasthan • Uttar Pradesh • Uttarakhand	• Bihar • Chandigarh • Chhattisgarh • Delhi • Gujarat • Jharkhand • Karnataka • Madhya Pradesh • Maharashtra • Meghalaya • Punjab • Telangana • Tamil Nadu • West Bengal

Table A2
Categorisation of states with non-attainment cities on the basis of the nature of clean air plans, either distinct or similar

Source: Authors' compilation

Table A3: Compilation of source contribution to PM$_{2.5}$ in 50 cities from the ApNA city programme

City	Year	Transport	Residential	Industries	Dust	Waste	DG sets	Brick kilns	Sea salt	Outside
Agartala	2018	0.175	0.149	0.043	0.153	0.083	0.027	0.021		0.349
Ahmedabad	2018	0.149	0.066	0.124	0.177	0.084	0.065	0.007		0.328
Allahabad	2018	0.186	0.125	0.062	0.149	0.04	0.041	0.032		0.366
Asansol	2018	0.125	0.071	0.085	0.162	0.049	0.042	0.139		0.327
Aurangabad	2018	0.108	0.043	0.187	0.107	0.12	0.067	0.019		0.349
Dharwad-Hubli	2018	0.216	0.056	0.092	0.147	0.085	0.017	0.007		0.38
Dhanbad	2018	0.122	0.041	0.125	0.292	0.026	0.03	0.043		0.322
Gaya	2018	0.231	0.1	0.009	0.173	0.036	0.044	0.047		0.361
Guwahati-Dispur	2018	0.365	0.068	0.052	0.27	0.068	0.017	0.008		0.151
Gwalior	2018	0.127	0.093	0.122	0.129	0.048	0.025	0.042		0.414
Hyderabad	2018	0.165	0.048	0.148	0.186	0.129	0.068	0.002		0.253
Jamshedpur	2018	0.195	0.066	0.258	0.15	0.03	0.037	0.022		0.241
Jodhpur	2018	0.199	0.061	0.066	0.255	0.038	0.021	0		0.36
Kolkata	2018	0.135	0.086	0.176	0.125	0.128	0.094	0.067		0.19
Kota	2018	0.167	0.08	0.195	0.125	0.047	0.014	0.005		0.366
Lucknow	2018	0.13	0.243	0.043	0.139	0.075	0.033	0.035		0.301
Madurai	2018	0.234	0.035	0.136	0.19	0.15	0.036	0		0.22
Mumbai	2018	0.164	0.032	0.15	0.126	0.038	0.019	0.023	0.121	0.326
Nashik	2018	0.121	0.066	0.158	0.132	0.087	0.036	0.009		0.391
Panjim	2018	0.226	0.006	0.045	0.126	0.028	0.026	0	0.17	0.373
Puducherry	2018	0.097	0.012	0.278	0.067	0.089	0.078	0.006	0.073	0.3
Rajkot	2018	0.19	0.051	0.209	0.164	0.069	0.022	0		0.296
Shimla	2018	0.174	0.118	0.002	0.118	0.055	0.01	0		0.522
Srinagar	2018	0.098	0.413	0.008	0.082	0.064	0.074	0.018		0.244
Surat	2018	0.164	0.017	0.314	0.103	0.098	0.033	0.003	0.056	0.212

City	Year	Transport	Residential	Industries	Dust	Waste	DG sets	Brick kilns	Sea salt	Outside
Thiruvanan-thapuram	2018	0.37	0.055	0.094	0.174	0.066	0.054	0	0.032	0.154
Tiruchirapalli	2018	0.19	0.039	0.282	0.162	0.079	0.044	0		0.205
Vadodara	2018	0.208	0.047	0.08	0.172	0.076	0.058	0.006		0.354
Vijayawada	2018	0.227	0.035	0.117	0.197	0.093	0.059	0.014		0.258
Visakhapatnam	2018	0.193	0.033	0.235	0.109	0.081	0.023	0	0.048	0.278
Agra	2015	0.14	0.238	0.003	0.107	0.124	0.028	0		0.36
Amritsar	2015	0.105	0.107	0.073	0.071	0.062	0.032	0.022		0.528
Bengaluru	2015	0.265	0.099	0.021	0.23	0.161	0.04	0.026		0.157
Bhopal	2015	0.141	0.103	0.028	0.171	0.088	0.05	0.001		0.418
Bhubaneswar	2015	0.171	0.16	0.006	0.209	0.057	0.036	0.041		0.321
Chandigarh	2015	0.106	0.115	0.014	0.127	0.09	0.026	0.014		0.509
Chennai	2015	0.246	0.036	0.128	0.235	0.156	0.016	0.031	0.018	0.133
Coimbatore	2015	0.183	0.065	0.112	0.138	0.141	0.025	0.011		0.326
Dehradun	2015	0.143	0.143	0.013	0.044	0.196	0.038	0.005		0.417
Indore	2015	0.27	0.081	0.024	0.227	0.079	0.02	0.021		0.278
Jaipur	2015	0.241	0.135	0.024	0.176	0.085	0.022	0.018		0.299
Kanpur	2015	0.138	0.339	0.065	0.09	0.089	0.041	0.012		0.225
Kochi	2015	0.202	0.096	0.041	0.164	0.038	0.046	0.038	0.165	0.21
Ludhiana	2015	0.164	0.079	0.08	0.123	0.092	0.027	0.029		0.407
Nagpur	2015	0.172	0.068	0.267	0.11	0.116	0.019	0.033		0.215
Patna	2015	0.148	0.146	0.113	0.122	0.13	0.055	0.093		0.193
Pune	2015	0.241	0.059	0.098	0.234	0.065	0.029	0.027		0.248
Raipur	2015	0.173	0.119	0.229	0.116	0.063	0.028	0.014		0.259
Ranchi	2015	0.212	0.18	0.012	0.142	0.122	0.014	0.032		0.285
Varanasi	2015	0.135	0.209	0.003	0.083	0.162	0.034	0.062		0.313

Source: Authors' compilation; Guttikunda, Sarath, K. A. Nishadh, and Puja Jawahar. n.d. "India – Air Pollution Knowledge Assessment (APnA) City Program." http://www.urbanemissions.info/india-apna/.

Waste burning and garbage dumping is a serious environmental concern in urban India. Proper waste collection and scientific solid waste management should be established to solve the pollution-crisis resulting from ad-hoc measures.