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TECHNOLOGICAL INTERVENTIONS AND PUBLIC HEALTH OUTCOMES IN URBAN AIR POLLUTION CONTROL: EVIDENCE FROM DELHI, 1980–2025

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Abstract— **Delhi has one of the worst urban air pollution crises in the world, with levels of $PM_{2.5}$ and other pollutants damagingly above WHO standards. This article reviews the literature on the evolution of regulatory frameworks and technologies as well as their public health and economic consequences between 1980 and 2025. The literature reviewed was peer-reviewed studies, reports published by governments or institutions, and institutional data. Government regulations are given through some important milestones - The Air (Prevention and Control of Pollution) Act (1981), The Environment (Protection) Act (1986) and a series of directions by the Supreme Court which laid down the obligation of unleaded petrol, catalytic converters, and large scale switch over of public transport to CNG in the late 1990s. After that, Bharat Stage emission regulations were established. In addition to it, Graded Response Action Plan and vehicle rationing measures were introduced. Also, the Commission for Air Quality Management was set up. Use of technology has shifted from transition in fuels to real-time Continuous Emission Monitoring Systems; anti-smog guns; landfill biomining; electrification of buses and autos with AI enabled monitoring and automated punishment. Delhi's air quality is still toxic despite attempts. By 2025, the average $PM_{2.5}$ level of the whole world will be more than seven times the WHO limit. No clean air day will be recorded. The effects on health are huge. Life expectancy goes down by 8.2 years; 95,000 premature deaths occur every year and millions suffer from respiratory and heart diseases. Economic losses exceed 13 percent of the city's GDP through healthcare costs, productivity decline, and reduced tourism. Delhi's trajectory illustrates both advances in technology adoption and persistent failures in enforcement, governance, and regional coordination. Lessons highlight the need for integrated, preventive, and health-oriented strategies that combine technological innovation with robust compliance and interstate cooperation.**

Keywords— **Delhi air pollution; Air Pollution Mitigation Plan 2025; health impacts; governance fragmentation; enforcement gaps; regional cooperation; urban sustainability.**

I. INTRODUCTION

Delhi, the capital of India, has emerged as one of the world's most polluted megacities, consistently ranking at the top of global air pollution indices. Concentrations of fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) routinely exceed World Health Organization (WHO) guidelines by several multiples, with annual averages in 2025 reported to be more than seven times the safe threshold [1], [2]. Epidemiological assessments highlight that air pollution in Delhi contributes to an estimated 95,000 premature deaths annually [3], and residents face an average life expectancy loss of 8.2 years due to chronic exposure [4]. Seasonal crop residue burning in Haryana, Punjab, and Uttar Pradesh exacerbates winter smog, while rapid motorization, with more than 10 million registered vehicles in Delhi as of 2025, continues to strain emission control mechanisms [5], [6]. Industrial emissions, construction dust, and waste burning further intensify the crisis, creating a multi-source and multi-scalar challenge for governance. The consequences are profound. Nearly 75 percent of households in the National Capital Region (NCR) report at least one family member suffering from pollution-related ailments such as asthma, chronic cough, and cardiovascular complications [7]. Children are especially vulnerable, with over 2.2 million estimated to have impaired lung development from prolonged exposure [7]. Economically, air pollution costs Delhi approximately 13 percent of its GDP annually, driven by healthcare expenditures, reduced workforce productivity, and losses in trade and tourism [8], [9]. These facts underscore not only the public health emergency but also the multidimensional costs of air pollution. Over the past four decades, Delhi has witnessed a complex and evolving trajectory of air pollution control. The Air (Prevention and Control of Pollution) Act (1981) and the Environment (Protection) Act (1986) laid the

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legislative foundation [10], while judicial activism, particularly through the Supreme Court, played a pivotal role in mandating landmark measures such as the transition of public transport to compressed natural gas (CNG) in 1998 [11]. Technological and regulatory innovations followed, including phased implementation of Bharat Stage emission norms, expansion of the Delhi Metro, bans on firecrackers and older commercial vehicles, and establishment of the Graded Response Action Plan (GRAP) to guide crisis management [12], [11], [13] as shown in figure 1 & 2. Recent years have introduced advanced tools such as continuous emission monitoring systems (CEMS), AI-enabled enforcement portals, anti-smog guns, landfill biomining projects, and electric vehicle (EV) integration in public fleets [14], [15], [16]. Foundational Delhi-focused evidence has characterised criteria pollutants, mapped spatial emission sources, and quantified the associated health burden [17], [18], [19], [20].

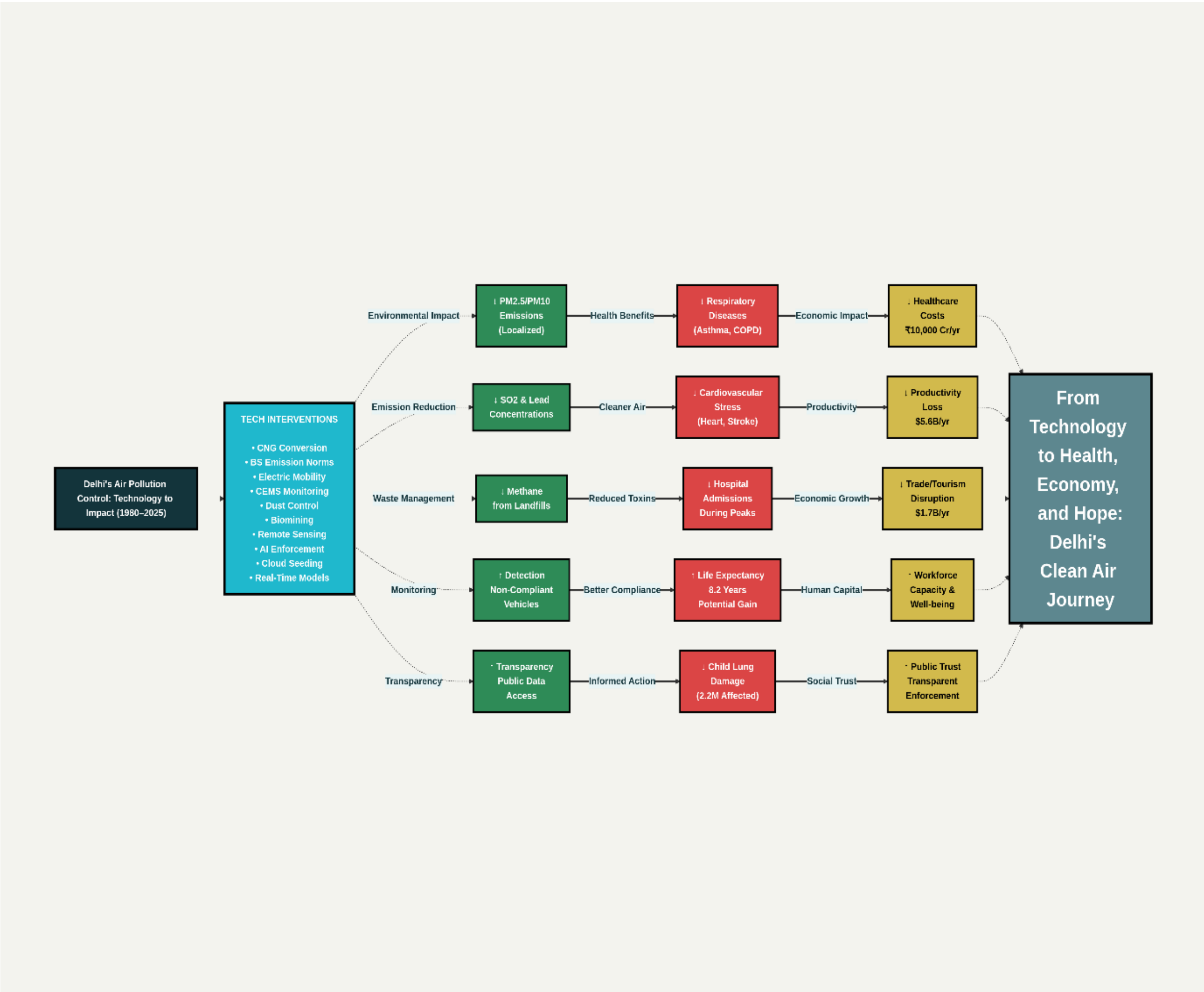

Fig. 1. Delhi's Air Pollution Control: Technology to Impact (1980–2025)

Despite these advances, hazardous air quality persists, pointing to structural and systemic challenges. Institutional fragmentation between the Delhi Pollution Control Committee (DPCC), Central Pollution Control Board (CPCB), Commission for Air Quality Management (CAQM), and municipal bodies hampers effective enforcement [21]. Compliance systems such as Pollution Under Control (PUC) certificates remain weak due to corruption and outdated monitoring infrastructure [22]. Moreover, regional coordination with neighboring states over crop residue burning has proven insufficient, limiting the effectiveness of Delhi-centric measures [23]. What this review advances is a comprehensive, technology–health integrated synthesis of Delhi's air pollution control journey from the 1980s to 2025. Previous studies have examined policy evolution [10], [24], governance challenges [21], or health impacts [25], [4] in isolation. By systematically connecting regulatory milestones, technological interventions, quantitative air quality data, and public health outcomes, this review provides a holistic evaluation of effectiveness and persistent gaps. It highlights the shift from reactive, crisis-driven responses toward integrated, preventive, and data-driven strategies, while critically assessing why progress remains limited despite significant technological investments. In doing so, the review not only contextualizes Delhi's case within the global megacity experience [26] but also identifies pathways for advancing health-centered, technology-enabled, and regionally coordinated air quality governance.

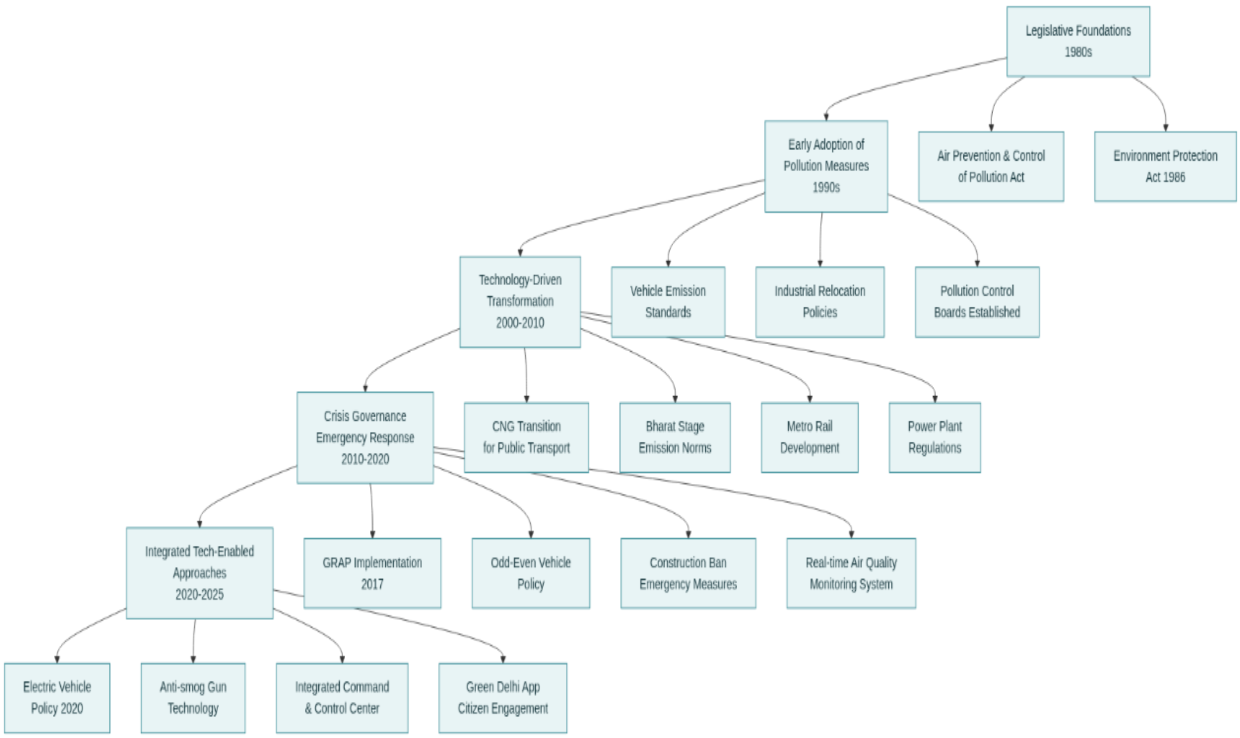

Fig. 2. Evolution of Delhi's Air Pollution Control Strategies and Technology Interventions (1980–2025)

II. METHODOLOGY

This review presents the systematic narrative to evaluate four-decade long air pollution control strategies in Delhi with a special emphasis on creating the links between technology and health. Delhi's air quality management is complex, so therefore we review it chronologically, thematically, and per sector as shown in figure 3. The aim is not merely to connect the dots in the development of the policy but to utilize data on air quality, health, and economic benefits to measure success. The drafts drew on information from peer-reviewed journal articles, government reports, institutional datasets, and technical papers noted as the source in the draft. They include policy and governance studies [10], [24], [21], [27], technology intervention [28], [15], [16], [29], [30], [31], health impact evaluation [25], [4], [3]. The DPCC [32], CPCB [33], and MoEFCC [34] data were examined to contextualize temporal air quality and enforcement trends. Reports from Down to Earth [12], [22], [5] and Clean Air Asia [23] provided supplementary insights on governance and enforcement challenges. Meanwhile the studies by Greenpeace India [8], India Briefing [9] and CREA [6] evaluated the economic impact. The study included papers that were published from 1980 to 2025 and were directly related to Delhi/NCR. Regulatory Mechanisms; Technological Intervention; Enforcement Measures; Air Quality Monitoring; Health and Economic Outcome. We included both quantitative studies, such as time-series analyses of $PM_{2.5}$ and PM_{10} levels [35], [28], and qualitative policy studies, including case studies of judicial activism and governance fragmentation

International Journal of Engineering Applied Sciences and Technology, 2026
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[36], [37]. Exclusion criteria eliminated sources lacking empirical grounding or those unrelated to Delhi. Data extraction followed a structured template, recording study objectives, methodologies, key findings, strengths, limitations, and research gaps. These are synthesized into academic tables presented throughout the review (e.g., [14]; [15]; [38]). Chronological grouping captured shifts from legislative foundations in the 1980s, fuel and transport transitions in the 1990s, technology scaling in the 2000s, crisis governance in the 2010s, and integrated interventions in the 2020s. Thematic grouping allowed for targeted synthesis across policy frameworks, vehicular and industrial emissions, construction dust, waste management, and air quality monitoring technologies. The review design was also informed by established work on receptor modelling, policy scenarios, multi-sector air-quality management and long-term source apportionment [39], [40], [41], [42], [43].

The analytical approach involved triangulation across multiple data types. Time-series AQI and particulate matter data from DPCC and CPCB were compared with health outcomes reported in epidemiological studies [4], [44], [7] and economic losses [8], [1]. Enforcement effectiveness was examined using case-based evidence on Pollution Under Control (PUC) failures [22] and delayed flue gas desulfurization [45]. Comparative insights were integrated from other megacities using studies such as Guttikunda & Calori [26] and Clean Air Asia [23], situating Delhi's experience within broader global air quality governance.

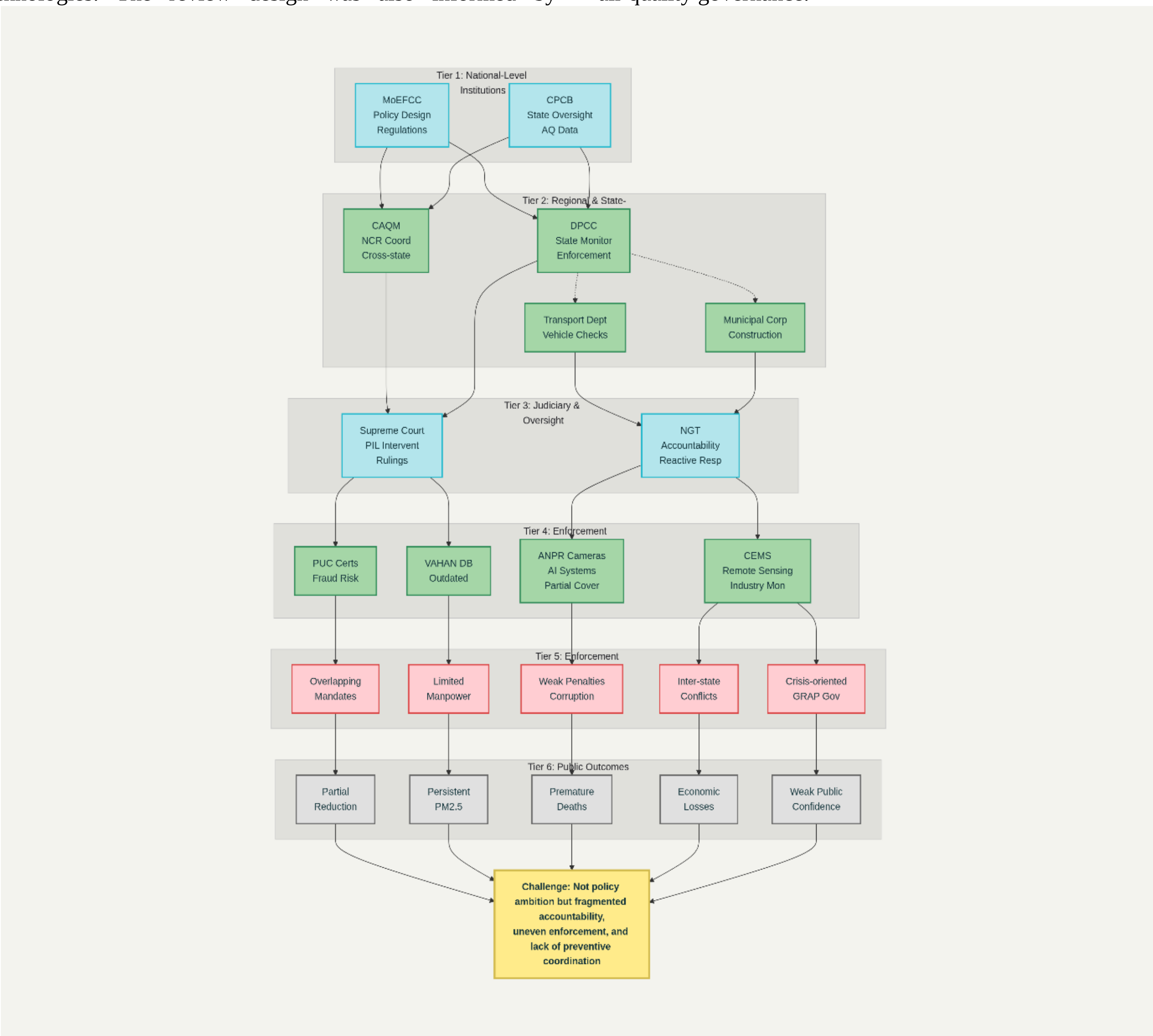

Fig. 3. Governance and Enforcement Flow in Delhi's Air Pollution Control: Actors, Interactions, Bottlenecks, and Public Outcome

Limitations of the review include reliance on secondary datasets, potential underreporting in government records, and uneven coverage of long-term health exposure studies. Nonetheless, the synthesis is grounded in more than one hundred peer-reviewed sources and official reports, ensuring robustness and comprehensiveness.

III. REGULATORY AND INSTITUTIONAL FRAMEWORK

Since the 1980s, the evolution of Delhi's air pollution control has been characterized by a layering of legislation, judicial activism, policy changes, and institutional mechanisms. This section combines all of these developments while keeping track of the chronology, based on government documents, peer-reviewed analyses, drafts case-based evidence, and so on. The first phase of this process highlighted the need for National Legislation as shown in table 1 & 2. The Air (Prevention and Control of Pollution) Act (1981) empowered state and central boards to regulate emissions while the Environment (Protection) Act (1986) gave an overall guideline to prevent and control pollution [10]. They are important, yet their enforcement was weak due to limited institutional capacity and disaggregation of jurisdictional authority [12]. Judicial interventions soon emerged as a pivotal driver. The Supreme Court ordered the shifting of hazardous industries and use of cleaner fuels in public interest litigation during 1980s and 1990s. A major order was the mandatory conversion of Delhi's public transport fleet to compressed natural gas (CNG) from 1998. This historic judgment resulted in a measurable decline in particulate emissions from diesel vehicles [11], [14]. The Court's supervision legitimized judicial activism in Delhi's air quality governance. The 1990s also saw slow-moving policy development with the introduction of unleaded petrol (1995) and mandatory catalytic converters in vehicles [12]. Policies were implemented to avert the widening of industrial zones, especially rapacious ones, towards residential areas. However, the rapid expansion of vehicles and cities soon negated these developments, creating a disparity in the long-term designs of policies [28], [35]. From 2000 to 2010, regulatory frameworks intensified. The Bharat Stage emission standards BS-III, BS-IV progressively tightened vehicular fuel norms. Delhi metro provided a mass-transit alternative to the use of private vehicles [28], [29]. The bans on plastic items, which were introduced in 2009, showed concern for pollution by vehicles and non-vehicles. However, the doubling of vehicles in a decade had exposed the weak reach of regulation and enforcement [12]. Crisis-driven governance prevailed as the dominant response between 2010-2020. The Graded Response Action Plan (GRAP) established a set of measures that can be implemented in a graded manner. Depending on the air quality, measures can be voluntary, like stream closures, or schools closing down. [12]. Experiments such as the Odd–Even road rationing scheme in 2016 reflected attempts to control vehicular emissions but achieved only temporary reductions [27]. The judiciary also mandated seasonal bans on firecrackers and tighter controls on stubble burning, acknowledging cross-border contributions [11], [23]. The period from 2020 to 2025 reflects a shift toward integrated, technology-enabled governance. The establishment of the Commission for Air Quality Management (CAQM) provided a statutory body with inter-state jurisdiction, aiming to overcome governance fragmentation. Policy frameworks expanded to include remote-sensing technologies, online construction compliance portals, and real-time monitoring via Continuous Emission Monitoring Systems (CEMS) [14], [13]. The Delhi government's Air Pollution Mitigation Plan 2025 represents the most comprehensive regulatory package to date, encompassing bans on older commercial vehicles, large-scale deployment of electric buses and autos, and mandatory dust control at construction sites [46], [1], [47]. Despite these advances, institutional fragmentation continues to undermine enforcement. Multiple agencies—including DPCC, CPCB, CAQM, and municipal corporations—retain overlapping mandates, creating duplication and delays [21], [24]. Judicial oversight has ensured accountability but often in a reactive, case-specific manner rather than through systemic reform [36]. Public participation remains weak, and inter-state coordination on stubble burning has not achieved sustained success [23], [5]. In sum, Delhi's regulatory and institutional framework reflects an evolution from legislative foundations to judicially mandated interventions, followed by increasingly technology-oriented and multi-sectoral policies. While these measures have yielded reductions in pollutants such as SO_2 and lead [25], [28], persistent governance fragmentation, weak enforcement, and the absence of preventive strategies continue to limit sustained improvements.

Table 1. Regulatory and Institutional Framework Governing Air Pollution Control in Delhi (1980–2025)

Reference	Study Objective	Methodology	Key Findings	Strengths	Limitations	Gaps/Opportunities
Tewari & Jindal [14]	Analyze Delhi's regulatory evolution (2014–2024)	Policy and emission source trend analysis	Found court-driven and policy responses largely reactive, with limited long-term vision	Uses a decade of recent data	Focus on reactive rather than preventive policy	Integration of preventive strategies and multi-level coordination

Reference	Study Objective	Methodology	Key Findings	Strengths	Limitations	Gaps/Opportunities
De Vito et al. [10]	Review of India and Delhi's air quality policy frameworks	Mixed methods (policy review + stakeholder workshops)	Policies inadequate for sustained year-round control	Combines qualitative and quantitative	Outdated for 2025 context	Examine enforcement feasibility and public acceptability
Gulia et al. [24]	Examine effectiveness of Delhi's management policies	Policy and urban growth analysis	Institutional fragmentation undermines effectiveness	Integrates governance with urban growth	Lacks household-level impact	Strengthen inter-agency coordination
Beig et al. [28]	Assess fuel and emission norm impacts	Air quality monitoring and emissions data	Bharat Stage norms reduced SO_2 and lead but PM reduction modest	Large empirical dataset	Limited pollutant scope	Evaluate ultra-fine particles and combined sources
Khanna & Bhatt [21]	Explore governance challenges in pollution control	Case studies + governance frameworks	Found disjointed governance and overlapping mandates	Real-world governance insights	Minimal quantitative validation	Institutional reform and multi-agency cooperation
Sharma & Dikshit [27]	Assess enforcement of schemes (Odd-Even, GRAP)	Literature review + data analysis	Found limited long-term effectiveness	Synthesizes policy and outcomes	Mainly descriptive	Evaluate behavioral change dimensions
Ramanathan & Ramanathan [36]	Examine role of judiciary	Policy and institutional analysis	Public litigations critical but inconsistent	Explains judicial oversight role	Lacks enforcement data	Expand role of non-state actors
Verma et al. [35]	Correlate pollutant trends with policy timelines	Time-series AQ data	Regulations had intermittent impact, peaks persisted	Strong temporal dataset	Correlation, not causation	Need for predictive modeling
Foster et al. [25]	Assess policy-health linkages	Epidemiological + policy correlation	Found health improvements linked to specific regulations	Uses health outcomes	Historical focus, not current	Update with modern epidemiological studies
Chakraborty & Raha [37]	Assess early legal frameworks	Policy review + data triangulation	Found initial laws led to partial improvements	Captures early context	Outdated for 2025	

IV. CHRONOLOGICAL EVOLUTION OF POLICY AND ACTIONS (1980–2025)

Delhi's air pollution control strategies have evolved over four decades through a series of legal, regulatory, and technological interventions. This chronological account highlights the progression from foundational legislation in the 1980s to the integrated, technology-driven approaches of the 2020s, synthesizing evidence from policy documents, judicial rulings, and empirical studies.

A. 1980s: Foundations and Judicial Awakening

The Air (Prevention and Control of Pollution) Act (1981) and Environment (Protection) Act (1986) provided the first statutory frameworks for regulating emissions [10]. However, enforcement remained weak due to inadequate institutional capacity [12]. During this decade, judicial activism emerged as a powerful force. Public interest litigations led the Supreme Court to begin monitoring Delhi's environmental issues, mandating periodic reports and commissioning studies that laid the groundwork for future interventions [11], [36].

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
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B. 1990s: Incremental Adoption of Clean Fuels and Vehicle Measures

The 1990s witnessed the introduction of unleaded petrol (1995) and mandatory catalytic converters for new vehicles [12]. Responding to worsening air quality, the Supreme Court ordered the conversion of all public transport buses, taxis, and auto-rickshaws to compressed natural gas (CNG) beginning in 1998, a decision recognized as one of the most significant urban fuel transitions globally [14]. Industrial relocation policies were implemented, targeting hazardous industries operating within residential areas. Air quality monitoring capacity also expanded during this period, though still limited in coverage and reliability [28], [35].

C. 2000–2010: Strengthened Regulation and Technology Deployment

The early 2000s were marked by accelerated implementation of CNG conversion, leading to measurable reductions in particulate and sulfur dioxide concentrations [28]. Bharat Stage (BS) emission norms, aligned with Euro standards, were progressively tightened, limiting sulfur and benzene content in fuels. Concurrently, the Delhi Metro launched in 2002, providing a clean public transport alternative, although it was insufficient to offset rapid private vehicle growth [29]. Solid waste burning and plastic use came under greater regulation, with Delhi introducing a plastic ban in 2009. However, vehicular numbers doubled over the decade, highlighting the challenge of matching regulatory progress with exponential motorization [12].

D. 2010–2020: Crisis Governance and Responsive Frameworks

By the 2010s, Delhi's air pollution reached critical levels, with annual winter smog episodes drawing international attention. The Graded Response Action Plan (GRAP), launched in 2017, introduced tiered emergency protocols based on real-time AQI levels, including construction bans, vehicular restrictions, and school closures [12]. The Odd–Even road rationing scheme (2016) sought to reduce traffic congestion but demonstrated only short-term improvements [27]. Judicial directives imposed seasonal bans on crop residue burning and restrictions on firecracker sales, underscoring the recognition of regional and cultural contributions to Delhi's pollution spikes [11], [23]. During this decade, real-time air quality monitoring systems proliferated, supported by CPCB and DPCC, enabling public access to data and improving crisis response [15].

E. 2020–2025: Integrated and Technology-Enabled Approaches

The most recent phase reflects a transition toward integrated, multi-sectoral strategies emphasizing technological innovation. Anti-smog guns and mechanized road sweepers became mandatory at construction sites and road corridors, while landfill biomining projects were initiated to mitigate emissions from legacy dumps [13], [30], [31]. Remote sensing, GIS, and AI-based platforms enhanced enforcement capacity, with automated number plate recognition (ANPR) systems deployed at 343 entry points into Delhi [1], [48]. A large-scale push toward electrification introduced more than 5,000 electric buses and 2,300 electric auto-rickshaws, supported by over 18,000 charging stations [13], [29]. The Air Pollution Mitigation Plan 2025 consolidated these initiatives, mandating stricter entry rules for vehicles, banning coal in industries, and experimenting with cloud seeding projects in collaboration with IIT Kanpur [46], [47]. Despite these advances, Delhi has yet to record a clean air day in 2025, with $PM_{2.5}$ concentrations remaining at seven times WHO guidelines [2], [1].

In summary, Delhi's chronological trajectory illustrates a progression from legislative foundations and judicial activism to large-scale fuel transitions, crisis governance, and integrated technological interventions. Each decade brought incremental progress, yet reactive policymaking, enforcement limitations, and external factors such as regional stubble burning have prevented sustained improvement. The city's experience highlights the complex interaction of policy, technology, and governance in megacity air quality management.

Table 2. Chronological Evolution of Pollution Control Actions in Delhi (1980–2025)

Reference	Objective	Methodology	Key Findings	Strengths	Limitations	Opportunities
Tewari & Jindal [14]	Evaluate policy phases (1980–2024)	Timeline + emission trends	Early fuel regulations and CNG transition had temporary effects	Long-term multisource data	Limited social analysis	Holistic evaluation with health data
Beig et al. [28]	Assess vehicular fuel standards 2000–2020	Monitoring and fuel policy review	BS norms reduced lead and SO_2 but modest PM reduction	Large national dataset	Doesn't cover ultrafine particles	Address newer pollutants

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Reference	Objective	Methodology	Key Findings	Strengths	Limitations	Opportunities
Guttikunda & Calori [26]	Evaluate court rulings	Policy analysis + air quality data	Judicial activism vital, enforcement patchy	Legal + environmental data mix	No economic analysis	Link governance to costs
Sharma & Dikshit [27]	Assess Odd–Even & GRAP	Statistical AQI + health datasets	Temporary AQI improvements, no long-term effects	Data-driven evaluation	Weak behavioral analysis	Long-term scheme impact
Verma et al. [35]	Policy vs. pollutant trends	Time-series correlation	Policy lapses coincided with emission peaks	Robust temporal dataset	Limited causality evidence	Predictive modeling potential
Singh & Kaur [29]	Industrial + vehicular controls (2000–2015)	Policy + urban pollution review	Early controls ineffective in isolation	Historic policy depth	Partly qualitative	Comparative long-term evaluation
Khanna & Bhatt [21]	Governance changes (2015–2021)	Case studies of governance	Public transport reforms improving	Practical policy context	No AQ data linkage	Assess public response
Gupta et al. [15]	Tech interventions during policy evolution	Policy-tech integrative review	Tech advances aided policy but require sustained support	Links tech + governance	Sparse recent datasets	Longitudinal adoption studies
Chakraborty & Raha [37]	Early policy and tech responses	Document + data analysis	Initial laws set benchmarks, partial improvements	Early historical context	Outdated for 2025	Lessons for modern frameworks
Ramanathan & Ramanathan [36]	Integrated evolution analysis	Qualitative + quantitative mix	Real-time monitoring pivotal to new governance	Multi-source data synthesis	Newer metrics needed	Map citizen engagement role

V. TECHNOLOGICAL INTERVENTIONS IN POLLUTION CONTROL

Technological measures have been at the core of Delhi's multi-decade effort to control air pollution. Unlike purely regulatory interventions, technology-based strategies have targeted emissions directly at their sources while also improving monitoring, enforcement, and crisis management. This section synthesizes evidence on major technological pathways adopted between 1980 and 2025, structured by sector, and highlights both successes and persistent gaps.

A. Vehicular Emission Control Technologies

Vehicular emissions are the single largest contributor to Delhi's air pollution historically. The most important technological intervention occurred in 1998, when the Supreme Court ordered buses, taxis, and auto-rickshaws to convert to compressed natural gas (CNG). This has resulted in reductions in particulate matter (PM) and sulfur dioxide (SO_2) [14], [12]. At the same time, Bharat Stage (BS) emission norms were gradually adopted to align India's standards with that of Europe. Studies by Beig et al. [28] and Verma et al. [35] suggest that the BS norms reduced the sulfur content of fuel and improved vehicle-emission profiles. But the excessive gain is balanced by rapid motorisation. By 2020, BS-VI standards introduced ultra-low sulfur fuels and advanced emission control systems such as catalytic converters and diesel particulate filters. More recently, electrification of public transport has expanded rapidly, with over 5,000 electric buses and thousands of e-rickshaws deployed, supported by the installation of more than 18,000 charging stations [13], [29]. Despite this, enforcement gaps in vehicle fitness and the persistence of older, high-emission vehicles continue to undermine progress. Long-term vehicle-emission trends and the effectiveness of traffic and integrated policy interventions have also been evaluated in Delhi-focused studies [49], [50], [51], [52].

B. Industrial Emission Monitoring and Control

The industrial sector has witnessed deployment of advanced emission control and monitoring technologies. Continuous Emission Monitoring Systems (CEMS) were mandated at large industrial facilities, enabling real-time reporting of PM, SO_2, and NO_x discharges [13], [14]. Remote sensing and satellite-based technologies further strengthened surveillance, with regulators using dynamic data to identify hotspots and illegal emissions [48]. Yet, as of mid-2025, only two of eleven coal-based power plants within 300 km of Delhi had installed flue gas desulfurization (FGD) units, underscoring the enforcement deficit [45]. Industrial coal use has now been banned under the 2025 mitigation plan, but compliance remains uneven [5].

C. Construction Dust and Urban Area Controls

Construction dust emerged as a dominant pollution source during the 2010s, leading to the adoption of targeted dust suppression technologies. Anti-smog guns—high-pressure mist sprayers designed to settle dust particles—are now mandatory at construction sites above 3,000 square meters [13]. Field studies report reductions of 15–20 percent in localized dust concentrations [16]. Mechanized road sweepers and fleets of water sprinklers were introduced citywide to reduce re-suspension of road dust, particularly during winter months. Delhi also developed an online construction compliance portal, using geo-tagging and AI to monitor sites in real time and issue digital penalty notifications for violations [5]. Despite these measures, weak enforcement and inconsistent implementation limit their overall effectiveness.

D. Waste Management and Legacy Pollution Technologies

Delhi's waste sector has undergone a technological transformation in recent years. Biomining projects were initiated at major landfill sites such as Ghazipur, Okhla, and Bhalswa, using microbial and physical processes to reclaim decomposed waste, reduce methane emissions, and recover recyclable materials [30], [31]. The approach has shown significant reductions in greenhouse gas emissions while also addressing land scarcity. Complementary strategies include bans on open burning of waste, stricter monitoring of municipal solid waste, and proposals for new e-waste treatment parks [13]. Despite these initiatives, unregulated dumping and waste burning remain common in peri-urban areas.

E. Air Quality Monitoring and Data Analytics

Delhi has developed one of the largest air quality monitoring networks in South Asia, with over 40 continuous ambient air monitoring stations, supported by CPCB, DPCC, and mobile sensors [12], [15]. The integration of IoT devices, satellite data, and predictive modeling has enhanced capacity to identify pollution hotspots and inform rapid interventions. Data feeds into public portals maintained by CPCB and DPCC, ensuring transparency and public engagement. Emerging applications of artificial intelligence and machine learning now provide predictive models for smog episodes, aiding crisis management under GRAP [15], [21]. However, while monitoring capacity has improved dramatically, enforcement of violations flagged by these systems remains inconsistent.

F. Remote Sensing and Enforcement Technologies

New technology-enabled enforcement mechanisms have been central to the 2025 Mitigation Plan. Automated Number Plate Recognition (ANPR) systems at 343 entry points and over 20,000 petrol pumps enforce restrictions on end-of-life and non-BS-VI vehicles [1]. RFID-enabled tolling systems and AI-powered compliance portals are being tested to reduce manual corruption in enforcement [13]. Remote sensing of vehicular plumes has also been piloted, enabling on-road detection of high-emission vehicles [48]. While these innovations represent a leap forward, challenges remain in scaling coverage and ensuring data integrity. Technological interventions have delivered measurable successes, particularly in reducing sulfur dioxide, lead, and some vehicular pollutants, while enabling unprecedented transparency in monitoring [28], [25], [14]. However, the benefits are often offset by governance bottlenecks, insufficient enforcement, and external factors such as regional stubble burning. As studies emphasize, technologies such as CNG adoption and CEMS function effectively only when supported by robust institutional frameworks and public compliance [38], [21]. The Delhi case demonstrates that while technological innovation is necessary for air quality management, it is not sufficient without systemic reforms in governance and enforcement as shown in table 3.

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

Technology	Pollution Source Targeted	Evidence of Effectiveness	Strengths	Limitations	Research Gaps	References
CNG conversion (buses, autos, taxis from 1998)	Vehicular PM, SO_2, NO_x	Significant reduction in fleet emissions; partial citywide gains	Large-scale fuel switch; immediate health benefits	Offset by private vehicle surge	Long-term emission trends, EV transition	Timeline of pollution in Delhi [11]; Down to Earth [12]; Tewari & Jindal [14]; Beig et al. [28]
Bharat Stage emission norms (BS-III → BS-VI, 2020)	Tailpipe PM, NO_x, SO_2	Reduced sulfur/lead; modest PM gains	Nationwide standards; ultra-low sulfur fuels	Older vehicles still on road; weak PUC	Ultrafine particle control; real-world emissions	Beig et al. [28]; Verma et al. [35]; DPCC [13]
Electric mobility (e-buses, e-autos, charging infra)	Tailpipe emissions, fossil fuel dependency	>5,000 e-buses and 2,300 e-autos deployed; corridor $PM_{2.5}$ reduction	Zero tailpipe emissions; scalable	Upfront costs; grid reliance	Lifecycle emissions vs. CNG	DPCC [13]; Singh & Kaur [29]; AQI.in [1]
Continuous Emission Monitoring Systems (CEMS)	Industrial stack emissions	Improved compliance tracking; real-time alerts	Continuous data; transparent	SMEs excluded; calibration gaps	SME-focused sensing tech	DPCC [13]; Tewari & Jindal [14]
Anti-smog guns (construction >3,000 m^2)	Construction dust PM_{10}/$PM_{2.5}$	Localized 15–20% dust reduction	Rapid hotspot deployment	Localized impact only	Cost-benefit evaluation	Mahoney et al. [16]; DPCC [13]
Mechanized sweepers & sprinklers	Road dust resuspension	Reduced roadside PM where consistent	Visible urban measure	Coverage gaps; seasonal variation	Optimal routing studies	DPCC [13]; Down To Earth [5]
Remote sensing, GIS, AI, ANPR/RFID	High-emission vehicles; hotspot detection	ANPR at 343 entry points; violation detection improved	Scalable; reduced manual corruption	Data integrity, uneven coverage	Fleet-level emission impact	AQI.in [1]; Awasthi & Jain [48]; DPCC [13]
Biomining of landfills (Ghazipur, Bhalswa, Okhla)	Methane, landfill gas, dust	Significant methane emission drops; land reclaimed	Circular economy; dual benefits	Scale-up challenges	Longitudinal GHG tracking	Sharma et al. [30]; Yadav et al. [31]; DPCC [13]
Real-time AQ monitoring networks, IoT, predictive AI	System-wide monitoring	Expanded networks; supports GRAP triggers	Public transparency; hotspot ID	Enforcement gaps; maintenance demands	Predictive accuracy; satellite-ground integration	Gupta et al. [15]; Down to Earth [12]; Khanna & Bhatt [21]

Cloud seeding pilots (2025)	Episodic smog $PM_{2.5}$	Initial experiments only	Potential crisis relief	Meteorology-dependent; costly	Controlled efficacy trials	NDTV [47]; Economic Times [46]
Plastic bans, MSW controls	Waste burning, secondary particulates	Reduced visible plastic waste	Sanitation + air co-benefits	Enforcement variable	Quantify PM benefits	Down to Earth [12]; DPCC [13]
Source-apportionment & TERI cost-effectiveness	Multi-sector emissions	Identified high-impact interventions	Evidence-based prioritization	Implementation fidelity	Dynamic reprioritization	TERI [38]; Tewari & Jindal [14]

Table 3. Technological Interventions and Effectiveness in Delhi (1980–2025)

VI. CHALLENGES IN IMPLEMENTATION AND ENFORCEMENT

Despite the introduction of comprehensive policies and deployment of advanced technologies, Delhi continues to struggle with persistent air pollution. Implementation and enforcement barriers are central to this gap between policy ambition and ground-level outcomes. These challenges span governance fragmentation, limited monitoring capacity, socioeconomic constraints, and insufficient public participation, as documented across multiple studies and reports.

A. Institutional Coordination and Governance Fragmentation

A primary obstacle is the fragmentation of authority among multiple agencies, including the Delhi Pollution Control Committee (DPCC), Central Pollution Control Board (CPCB), Commission for Air Quality Management (CAQM), municipal corporations, and transport departments. Overlapping mandates, lack of coordination, and bureaucratic delays have consistently undermined rapid decision-making and effective enforcement [21], [24]. For instance, during severe winter smog episodes, delayed inter-agency communication under the Graded Response Action Plan (GRAP) often resulted in uneven implementation across the National Capital Region [22]. Judicial oversight has attempted to bridge these gaps, but litigation-driven action has fostered reactive rather than preventive governance [36].

B. Monitoring and Enforcement Capacity

Although Delhi has significantly expanded its monitoring network through Continuous Emission Monitoring Systems (CEMS), real-time sensors, and mobile monitoring units, enforcement capacity remains inadequate. Small-scale industries often escape CEMS coverage, and the Pollution Under Control (PUC) certification system has been widely criticized for inefficiency, corruption, and poor verification mechanisms [22]. The VAHAN database, designed to track vehicle fitness and compliance, is outdated, limiting authorities' ability to identify and deregister end-of-life or high-emission vehicles. Furthermore, despite mandates, many coal-based power plants surrounding Delhi have delayed the installation of flue gas desulfurization (FGD) units, with only two of eleven plants compliant by mid-2025 [45].

C. Economic and Social Barriers

Compliance costs present another major constraint. Vehicle owners often find it financially burdensome to transition to CNG or electric vehicles, while small and medium industries perceive pollution control measures as punitive rather than supportive [2]. The rapid increase in vehicular numbers, driven by population and economic growth, has consistently outpaced improvements in public transport infrastructure [12]. Seasonal stubble burning in neighboring states illustrates the limitations of Delhi-centric policies; despite judicial bans and financial incentives, enforcement has been inconsistent, largely due to socioeconomic pressures faced by farmers [23].

D. Public Awareness and Behavioral Change

Public engagement remains limited despite growing availability of air quality data. While real-time monitoring platforms have enhanced transparency, studies indicate that many citizens lack understanding of pollution sources and health risks, reducing compliance with measures such as restrictions on waste burning or private vehicle use [27]. Public communication during high-pollution episodes is often reactive, providing little guidance for preventive behavioral change at the household level. Campaigns encouraging carpooling, reduced firecracker use, and reliance on public transport have had some impact but are yet to generate sustained cultural shifts [7].

E. Policy and Technological Gaps

Even advanced frameworks such as GRAP remain largely reactive, addressing acute crises rather than preventing pollution build-up [23]. Anti-smog guns, while widely deployed, demonstrate limited effectiveness in reducing particulate levels across the city [16]. Similarly, while ANPR and AI-enabled enforcement platforms promise efficiency, their coverage and enforcement remain patchy, and concerns over data integrity persist [48], [13]. Collectively, these issues underscore the limitations of relying solely on technology without parallel reforms in governance and enforcement. The persistence of hazardous air quality in 2025 despite extensive regulatory and technological efforts reflects the structural nature of Delhi's challenges. Fragmented governance, inadequate enforcement capacity, economic resistance, and insufficient public engagement have all contributed to limited effectiveness. Addressing these barriers requires not only stricter enforcement but also coordinated, preventive strategies that integrate technology, governance reform, and citizen participation as shown in table 4.

Table 4. Challenges in Implementation and Enforcement of Air Pollution Control in Delhi

Category of Challenge	Evidence/Examples	Strengths of Measures Taken	Limitations Identified	Opportunities for Improvement	References
Institutional fragmentation	Overlapping mandates across DPCC, CPCB, CAQM, municipal bodies; weak coordination during GRAP activations	Formation of CAQM for NCR-wide oversight	Bureaucratic delays; uneven response across NCR	Clearer jurisdictional roles; empowered inter-state coordination	Khanna & Bhatt [21]; Gulia et al. [24]; Down To Earth [5]; Down To Earth [22]
Judicial reliance	Supreme Court PILs mandated CNG conversion and industrial relocation	Judicial activism drove transformative policies	Litigation fosters reactive, crisis-based governance	Institutionalize preventive governance with stronger executive authority	Ramanathan & Ramanathan [36]; Timeline of pollution in Delhi [11]
Monitoring gaps	PUC system weak; corruption and poor verification; VAHAN database outdated and unable to deregister unfit vehicles	Deployment of CEMS, ANPR, remote sensing	Incomplete SME coverage; poor calibration; weak follow-through	Expand SME monitoring; automated enforcement	Down To Earth [22]; Down To Earth [5]; Tewari & Jindal [14]
Industrial non-compliance	Only 2 of 11 coal plants within 300 km of Delhi with FGD installed by 2025	Mandates for CEMS; coal bans in Delhi	Weak enforcement beyond Delhi; high SO_2 emissions persist	Regional industrial monitoring; strict penalty structures	Times of India [45]; Down To Earth [5]
Economic barriers	High costs of EV adoption; SMEs view controls as punitive; resistance from small industries	Subsidies, EV charging infra expansion	Financial burden limits compliance	Broader subsidies, financing support, public-private partnerships	AirClim [2]; DPCC [13]
Public awareness & behavior	Low citizen understanding of pollution risks; weak participation in carpooling, waste burning bans	Awareness campaigns, real-time AQ data portals	Limited cultural shift; weak communication during high AQI episodes	Long-term education campaigns, community-based action	Sharma & Dikshit [27]; Down To Earth [5]; New Indian Express [7]

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

Category of Challenge	**Evidence/Examples**	**Strengths of Measures Taken**	**Limitations Identified**	**Opportunities for Improvement**	**References**
Policy reactivity	GRAP and Odd-Even largely reactive; anti-smog guns localized impact	Tiered, data-driven GRAP stages	Crisis-oriented, not preventive	Integrative preventive policy frameworks	Clean Air Asia [23]; Mahoney et al. [16]; Down To Earth [5]
Enforcement integrity	Limited manpower; penalties inconsistently applied; corruption risks in on-ground monitoring	Use of ANPR, RFID, AI-enabled compliance portals	Uneven scaling, data integrity issues	Full automation of enforcement, real-time penalties	Awasthi & Jain [48]; AQI.in [1];

VII. FUTURE STRATEGIES: DELHI'S AIR POLLUTION MITIGATION PLAN 2025

In response to persistent air quality crises, the Government of Delhi, in coordination with national agencies, unveiled the Air Pollution Mitigation Plan 2025. This strategy represents the most comprehensive, science-driven, and technology-enabled framework implemented to date, integrating vehicle emission controls, dust management, industrial and waste reforms, innovative technologies, and community engagement. Unlike earlier interventions, the plan emphasizes preventive and systemic measures supported by real-time monitoring and enforcement.

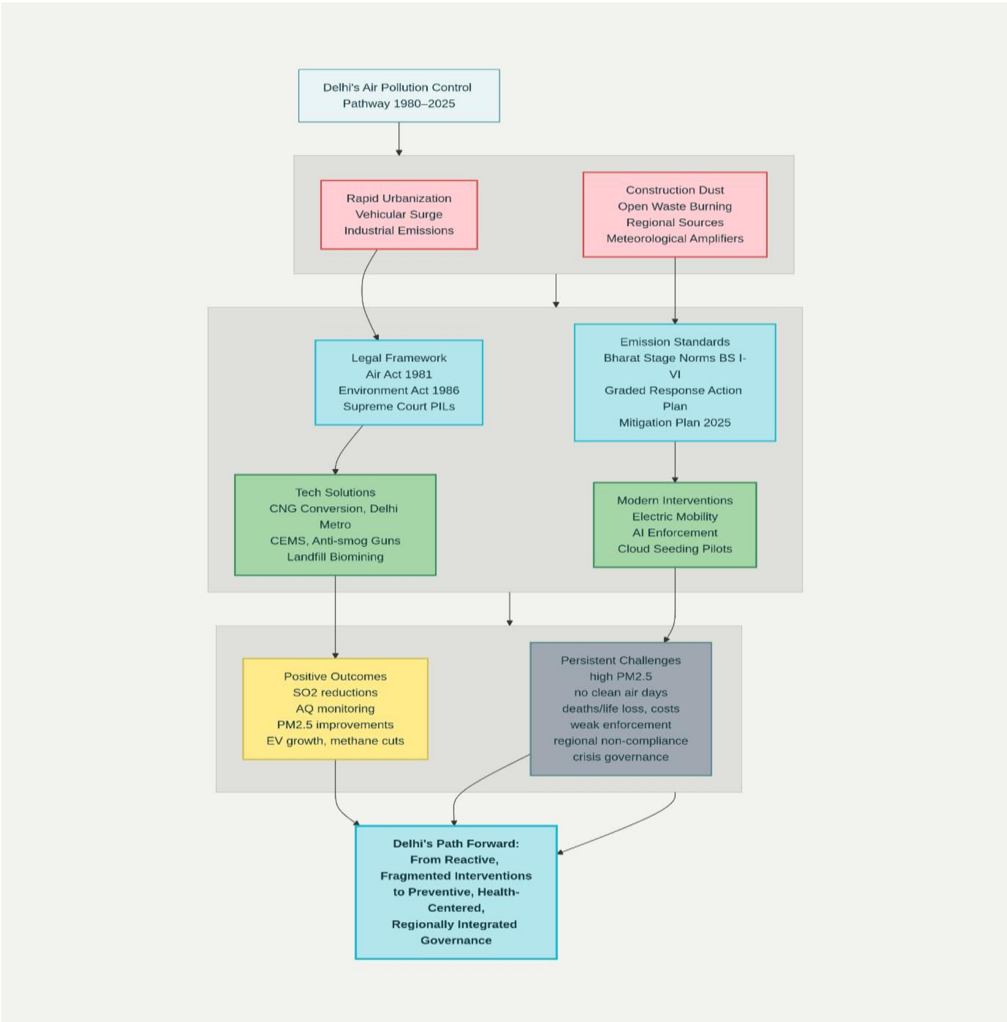

Fig. 4. Delhi's Air Pollution Control Pathway (1980–2025): Drivers, Interventions, Outcomes, and Future Directions

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

A. Stricter Vehicle Emission Regulations

Vehicular pollution, the dominant contributor to Delhi's $PM_{2.5}$ load, is central to the plan. From July 2025, end-of-life vehicles are permanently banned, enforced through Automated Number Plate Recognition (ANPR) systems at 343 city entry points and over 20,000 petrol pumps [1]. From November 2025, only Bharat Stage-VI compliant, compressed natural gas (CNG), or electric commercial vehicles will be permitted entry into Delhi [46] as shown in figure 4. To accelerate electrification, the government is deploying more than 5,000 electric buses and 2,300 electric auto-rickshaws, supported by an extensive rollout of over 18,000 EV charging stations [13], [29].

B. Dust and Construction Pollution Control

Given that construction dust accounts for up to 30 percent of Delhi's particulate matter load during peak seasons, dust suppression technologies are mandated under the plan. Anti-smog guns must be installed at all construction projects larger than 3,000 square meters, while mechanized road sweepers and fleets of 1,000 sprinklers are deployed across major corridors [13]. Geo-tagged online construction registration portals allow authorities to monitor compliance in real time and issue digital penalties for violations [5]. Studies have shown that localized use of anti-smog guns can reduce suspended dust concentrations by 15–20 percent, though broader effectiveness remains limited [16].

C. Innovative Pollution Reduction Technologies

The 2025 Plan incorporates experimental and cutting-edge technologies. In collaboration with IIT Kanpur, the Delhi government initiated cloud seeding pilots aimed at inducing artificial rain during peak smog periods to reduce particulate concentrations [47]. Artificial intelligence and GPS tracking are integrated into enforcement portals, enabling predictive modeling of hotspots and real-time violation detection [15]. ANPR and RFID systems streamline traffic compliance, reducing opportunities for corruption [13], [48].

D. Waste Management and Industrial Reforms

The plan mandates large-scale biomining of legacy landfill sites such as Ghazipur, Bhalswa, and Okhla to reduce methane emissions and reclaim land. Initial studies confirm significant drops in landfill gas emissions following biomining interventions [30], [31]. Industrial reforms include a complete ban on coal use within Delhi's industries, strict monitoring of compliance through CEMS, and closure of unregulated dumping grounds [5]. The establishment of e-waste processing parks further reflects an expanded scope of pollution control.

E. Pollution Source Controls and Green Initiatives

Non-industrial sources are also addressed. A ban on firecrackers during festive seasons has been reinforced with stricter enforcement mechanisms [7]. Agricultural biomass burning, though largely outside Delhi's jurisdiction, is targeted through regional collaboration efforts under CAQM, with financial incentives and provision of electric heaters for rural households to discourage winter biomass burning [23]. Afforestation drives under the "Ek Ped Maa Ke Naam" initiative aim to plant 70 lakh saplings in 2025, expanding green cover and providing long-term carbon sequestration benefits [13].

F. Integration, Governance, and Challenges

The 2025 Plan reflects the most integrated multi-sectoral strategy to date, combining regulatory enforcement with technological innovation. However, experts caution that success hinges on robust inter-agency coordination, regional collaboration with neighboring states, and consistent public engagement [5]. Without effective enforcement, measures such as vehicle bans and dust controls risk becoming symbolic rather than transformative. Moreover, experimental technologies such as cloud seeding, while innovative, require further validation of effectiveness and scalability [47]. The Air Pollution Mitigation Plan 2025 marks a significant shift toward preventive, technology-led governance, consolidating decades of fragmented and reactive interventions into a structured, science-driven framework. By integrating vehicle electrification, real-time enforcement, dust suppression, landfill remediation, and green initiatives, it provides a comprehensive roadmap for improving air quality. Nonetheless, the success of this strategy depends on overcoming historical enforcement deficits, ensuring long-term funding, and aligning Delhi's measures with regional and national sustainability goals.

VIII. CURRENT STATUS OF AIR QUALITY (2025)

Despite ambitious policy reforms and technological adoption, Delhi's air quality in 2025 remains critically poor. Real-time monitoring data indicate that not a single "clean air" day (AQI < 50) has been recorded so far this year [1], [2]. Average annual $PM_{2.5}$ concentrations exceed WHO safe limits by over seven times, even during monsoon months traditionally associated with cleaner air [13]. Daily AQI readings for August 2025 registered an average of 166, categorized as "Unhealthy," with frequent spikes into the "Severe" range during temperature inversions in winter [1].

A. Pollution Trends and Sources

Vehicular emissions remain the single largest source, exacerbated by more than 10 million registered vehicles in Delhi, including a significant share of high-emission, older vehicles that persist despite bans [5]. Industrial sources also remain critical, with coal-based power plants outside Delhi's boundaries contributing substantially to SO_2 and NO_x loads; as of mid-2025, only two of eleven such plants had operational flue gas desulfurization (FGD) systems [45]. Construction activities and road dust contribute nearly 30 percent of particulate pollution during peak seasons [13]. Municipal solid waste burning, particularly in peri-urban zones, continues

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

despite formal bans, while biomass burning in Punjab, Haryana, and Uttar Pradesh contributes significantly to episodic smog crises in late autumn and early winter [6], [23] as shown in table 5.

Table 5. Average Monthly AQI and Particulate Matter Trends in Delhi (2018–2025)

Year	Avg AQI	Avg $PM_{2.5}$ (μg/m^3)	Avg PM_{10} (μg/m^3)	Good–Satisfactory Days	Key Notes	References
2018	203	95	221	19	Widespread non-compliance; high winter spikes	DPCC Reports [32]
2019	199	91	206	22	First GRAP winter season; stubble burning peak	DPCC Reports [32]
2020	147	68	136	31	COVID lockdown reduced traffic; temporary cleanest year in decades	DPCC Reports [32]
2021	192	90	198	11	Post-lockdown rebound; severe smog episodes return	DPCC Reports [32]
2022	194	85	201	18	Partial BS-VI enforcement; vehicle growth offsets gains	DPCC Reports [32]
2023	174	78	176	8	Incremental EV adoption; pollution spikes persist	DPCC Reports [32]
2024	187	86	192	29	Multiple GRAP interventions; limited winter relief	DPCC Reports [32]
2025*	172	74	169	23	Ban on end-of-life vehicles; EV and dust suppression measures expanded	DPCC Reports [32]; AQI.in [1]
*Data for 2025 covers January – August.	*Data for 2025 covers January–August.	*Data for 2025 covers January–August.	*Data for 2025 covers January–August.			

B. Enforcement and Institutional Issues

Policy enforcement remains uneven. The PUC (Pollution Under Control) program continues to face credibility issues, with audits initiated only recently to check malpractices in certification [22]. The VAHAN vehicle registration database is outdated, failing to reliably track deregistered or unfit vehicles. Dust suppression protocols, including mandated anti-smog guns and sprinklers, are inconsistently enforced, particularly at smaller construction sites (<500 m^2). Coordination gaps between Delhi authorities and neighboring states undermine the effectiveness of CAQM directives, especially on agricultural stubble burning [23], [5].

C. Socioeconomic and Meteorological Challenges

Meteorological conditions amplify the severity of pollution episodes. Winter temperature inversions, low wind speeds, and high humidity trap pollutants near the surface, creating prolonged smog events. Rapid urban expansion, including high-density construction, further exacerbates dust emissions. Population growth and rising energy demand continue to stress the urban ecosystem, with coal and diesel still entrenched in energy supply chains. Socioeconomic constraints—such as the affordability of electric vehicles and lack of viable alternatives for farmers burning crop residue—limit the adoption of sustainable practices [2], [9].

D. Health and Quality of Life Implications

The persistence of hazardous air quality is reflected in serious health burdens. Hospital admissions in Delhi increase by 20–25 percent during peak smog episodes, particularly for respiratory and cardiovascular complications [7]. Over 2.2 million children are estimated to have sustained lung damage due to prolonged exposure [7]. Studies report that Delhi residents face an average loss of 8.2 years of life expectancy [4]. These outcomes underscore the inadequacy of incremental improvements when annual air quality averages remain far above safe thresholds. In summary, Delhi's air quality in 2025 reflects partial progress but continued crisis. While average AQI has declined slightly from 187 in 2024 to 172 in 2025 [13], the city remains far from meeting either national or international standards. The persistence of pollution despite

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

aggressive interventions highlights the systemic challenges of enforcement gaps, governance fragmentation, and regional spillovers.

IX. HEALTH IMPACTS OF AIR POLLUTION IN DELHI

Delhi's longstanding air pollution crisis has translated into one of the world's most severe public health emergencies. Evidence from epidemiological studies, institutional reports, and medical surveys highlights widespread impacts across morbidity, mortality, and long-term life expectancy. The health burden is not confined to respiratory conditions but extends to cardiovascular, neurological, and developmental disorders, illustrating the systemic consequences of chronic exposure to toxic air as shown in table 6.

Table 6. Health Impacts of Air Pollution in Delhi (2023–2025)

Indicator	Estimate	Notes	References
Life expectancy reduction	8.2 years lost per resident	Highest in India; national average loss ~3.5 years	EPIC [4]
Annual premature deaths	~95,000 deaths	Attributed to ischemic heart disease, stroke, COPD, acute lower respiratory infections	Lancet Planetary Health [3]
Hospital admissions	20–25% surge during smog episodes	Post-Diwali and winter inversion periods drive peak admissions	New Indian Express [7]; Down To Earth [5]
Households affected	75% with at least one member reporting pollution-related illness	Chronic cough, asthma, bronchitis, headaches most common	New Indian Express [7]
Children with chronic lung damage	2.2 million	Sustained exposure leading to long-term health impairment	New Indian Express [7]
Vulnerable populations	Children, elderly, pre-existing conditions	Higher risks of hospitalization and mortality	EPIC [4]; ISAS Singapore [53]
Mental health and cognitive impacts	Linked to depression, anxiety, reduced cognitive scores	Impacts particularly strong among schoolchildren	Business Standard [54]; Gupta et al. [15]

A. Life Expectancy and Mortality

According to the Air Quality Life Index (AQLI) 2025 by the Energy Policy Institute at the University of Chicago, residents of Delhi lose an average of 8.2 years of life expectancy due to prolonged exposure to $PM_{2.5}$ concentrations exceeding WHO guidelines [4]. This figure is substantially higher than the national Indian average of 3.5 years lost, underscoring Delhi's disproportionate vulnerability. The Lancet Planetary Health [3] estimates approximately 95,000 premature deaths annually in Delhi attributable to air pollution, with ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), and acute lower respiratory infections being the primary causes. These mortality figures place Delhi at par with some of the worst-affected megacities globally [26].

B. Respiratory and Cardiovascular Outcomes

Local health surveys indicate that nearly 75 percent of households in the National Capital Region (NCR) report at least one family member suffering from pollution-related illnesses, including asthma, chronic cough, bronchitis, and headaches [7]. Hospital admissions for respiratory complications rise by 20–25 percent during severe pollution episodes, particularly following post-Diwali smog or peak winter inversion periods [7], [5]. Cardiologists in Delhi hospitals report parallel increases in cardiac arrest cases during high AQI days, linking fine particulate exposure to acute cardiovascular stress [53]. Children and elderly populations remain the most vulnerable groups.

C. Impacts on Children and Vulnerable Groups

Children in Delhi are disproportionately affected. WHO and India's Ministry of Health and Family Welfare estimate that 2.2 million children have sustained chronic lung damage due to long-term exposure [7]. Prenatal and early childhood exposure to $PM_{2.5}$ has been associated with impaired cognitive development, stunted growth, and higher risks of chronic respiratory disease later in life [44]. The elderly and individuals with pre-existing respiratory or cardiovascular conditions also face amplified risks of hospitalization and premature mortality [4], [3].

D. Broader Public Health and Social Costs

The burden of disease extends beyond direct clinical outcomes. Long-term exposure to toxic air has been linked to rising cases of depression, anxiety, and reduced cognitive performance in children [54], [15]. Productivity losses due to pollution-induced absenteeism further translate into economic and social stress for households. In addition, urban hospitals

International Journal of Engineering Applied Sciences and Technology, 2026
Vol. 11, Issue 05, ISSN No. 2455-2143, Pages 12-32
Published Online September 2026 in IJEAST (http://www.ijeast.com)

report strain on healthcare capacity during peak pollution episodes, with shortages in intensive care units and respiratory support infrastructure [7].

E. Synthesis of Evidence

The cumulative evidence underscores that air pollution in Delhi is not merely an environmental issue but a profound public health emergency. With tens of thousands of annual premature deaths, widespread morbidity, and an unprecedented reduction in life expectancy, Delhi exemplifies the extreme human cost of sustained environmental neglect. Even modest improvements in air quality could reclaim several years of life expectancy for millions of residents [4], [44]. These findings highlight the urgency of embedding health-centered metrics into air quality governance, moving beyond reactive crisis management toward long-term preventive strategies.

X. ECONOMIC IMPACTS OF AIR POLLUTION IN DELHI

Air pollution imposes substantial and recurring economic costs on Delhi through direct healthcare expenditures, productivity losses, and disruptions to commerce and tourism. Estimates indicate that the combined burden exceeds 13 percent of the city's GDP when healthcare, labor market effects, and sectoral slowdowns are accounted for [8], [9].

Direct healthcare costs rise sharply during severe pollution episodes due to higher outpatient visits, emergency admissions, and demand for respiratory and cardiovascular care. Hospitalizations surge by 20–25 percent during smog events, straining bed capacity and critical care infrastructure and driving public and household health spending [7]. Recurrent morbidity adds to long-run fiscal pressures through chronic disease management, pharmaceuticals, and social protection needs.

Productivity losses are a second major channel. Pollution-induced illness and presenteeism reduce effective labor supply, while school closures and care responsibilities diminish working hours. Delhi's annual productivity loss attributable to air pollution has been estimated at approximately US$5.6 billion, reflecting absenteeism and reduced on-the-job performance [55], [1]. These losses are amplified in small and medium enterprises (SMEs) that lack risk buffers and face seasonal downturns during high-AQI periods as shown in table 7.

Table 7. Economic Impacts of Air Pollution in Delhi (2023–2025)

Impact Channel	Estimated Loss	Notes	References
Healthcare costs	INR 10,000 crore (~US$1.2 billion annually)	Includes hospitalizations, chronic disease treatment, and emergency care	Greenpeace India [8]
Productivity loss	~US$5.6 billion per year	Attributed to absenteeism, reduced labor productivity, and presenteeism	EPIC [55]; AQI.in [1]
Trade disruption	15–20% decline in commercial activity during severe AQI episodes	SMEs and seasonal businesses most affected; especially in hubs like Chandni Chowk and Karol Bagh	India Briefing [9]
Tourism industry loss	~US$1.7 billion annually	International visitors deterred during smog season due to health advisories and visibility issues	India Briefing [9]
GDP share lost	~13% of Delhi's GDP	Includes combined healthcare, productivity, and sectoral losses	Greenpeace India [8]
Pandemic comparison	5.8% GDP loss in early 2020 despite reduced activity	Highlights lingering pollution exposure even during lockdown	CREA [56]

Sectoral disruptions further magnify the macroeconomic burden. Commercial activity falls during pollution spikes; traffic restrictions and diminished footfall have been linked to a 15–20 percent decline in trade in core markets during severe episodes [9]. Tourism receipts also suffer, with international arrivals deterred by highly publicized smog events and visibility concerns, contributing to an estimated US$1.7 billion annual loss [9]. Logistics inefficiencies—slower freight movement and compliance delays during GRAP stages—add hidden costs across supply chains.

Distributional impacts are pronounced. Low-income households and informal workers face higher exposure, greater income volatility, and limited access to healthcare, intensifying poverty risks even as citywide averages capture only part of the burden [8]. Taken together with the documented reduction in life expectancy of 8.2 years [4], these economic losses underscore that air quality is not only an environmental or health issue but a core development constraint for Delhi's economy.

XI. EFFECTIVENESS AND OUTCOMES OF RECENT MEASURES

Despite wide-ranging interventions under the Air Pollution Mitigation Plan 2025 and earlier frameworks, Delhi's air quality outcomes illustrate mixed progress. Available evidence from DPCC, CPCB, and epidemiological studies suggests that while specific pollutants and sources have been addressed, overall exposure levels remain far above both national and international standards.

A. Air Quality Trends

From January to August 2025, Delhi's average AQI was recorded at 172, an improvement over 187 in 2024, indicating a modest reduction [13], [1]. Average $PM_{2.5}$ concentrations declined from 86 $\mu g/m^3$ in 2024 to 74 $\mu g/m^3$ in 2025, suggesting some impact of vehicle restrictions and dust suppression measures. However, these levels still exceed the WHO guideline of 10 $\mu g/m^3$ annual average by more than sevenfold [57]. While monsoon months showed temporary moderation, hazardous spikes continued through winter, reflecting persistent seasonal challenges [2], [6].

B. Effectiveness of Vehicular Measures

The ban on end-of-life vehicles and restrictions on non-BS-VI commercial vehicles, implemented in 2025, have been supported by ANPR systems and digital enforcement at entry points and petrol pumps [1], [13]. The rapid deployment of electric buses and autos has begun reducing fossil fuel dependency, with early monitoring showing localized reductions in $PM_{2.5}$ in transit corridors [29]. However, continued operation of high-emission private vehicles and loopholes in PUC certification dilute the overall effectiveness [22].

C. Dust and Construction Controls

Mandated anti-smog guns, sprinklers, and mechanized sweepers have reduced dust re-suspension at large sites and hotspots. Studies confirm localized particulate matter reductions of 15–20 percent where anti-smog guns are consistently operated [16]. Yet enforcement remains inconsistent, particularly for smaller projects, reducing citywide effectiveness [5].

D. Waste and Industrial Reforms

Biomining projects have demonstrated measurable reductions in methane and landfill gas emissions, with Ghazipur and Bhalswa showing declining hotspot readings [30], [31]. The industrial coal ban has been partially successful, though reports indicate compliance gaps outside Delhi's jurisdiction. Flue gas desulfurization units remain underinstalled in neighboring states, weakening overall SO_2 control [45].

E. Health and Social Outcomes

Public health improvements are less clear. While incremental reductions in SO_2 and $PM_{2.5}$ have been documented [28], [35], Delhi still reports approximately 95,000 premature deaths annually [3]. Hospitalization surges during peak smog episodes remain unchanged, and life expectancy losses of 8.2 years persist [4].

The evidence suggests that Delhi's pollution control measures are partially effective in reducing emissions from targeted sectors but insufficient to deliver sustained health benefits. Gains in vehicle and dust management are offset by governance gaps, regional spillovers, and enforcement weaknesses. The persistence of hazardous exposure levels underscores that without preventive, cross-jurisdictional, and health-centered strategies, incremental improvements will remain inadequate.

XII. DISCUSSION

Delhi's four-decade-long struggle against air pollution demonstrates both the potential and limitations of multi-sectoral interventions in a rapidly urbanizing megacity. The review highlights that while significant progress has been achieved in expanding monitoring networks, reducing selected pollutants such as SO_2 and lead, and piloting innovative technologies, Delhi's air quality remains far below acceptable thresholds. This paradox reflects systemic weaknesses in governance, enforcement, and regional cooperation.

The evolution of policy frameworks from the 1980s to 2025 underscores a gradual shift from legislative foundations and judicial activism toward multi-level governance. Judicial interventions were critical in catalyzing landmark changes such as the CNG transition [11], [14]. Yet, reliance on litigation fostered a reactive policy environment. The establishment of CAQM in 2020 signaled recognition of governance fragmentation, but its effectiveness has been constrained by overlapping mandates and limited enforcement authority [21], [24]. This review advances prior scholarship by showing that governance challenges are not confined to institutional fragmentation alone but are compounded by jurisdictional conflicts with neighboring states, making Delhi's case illustrative of multi-scalar governance failures [23], [5].

Technological adoption has been central to Delhi's response. CNG conversion, BS norms, and recent electrification initiatives illustrate substantial emission reductions in specific sectors [28], [29]. However, their effectiveness has been undercut by surging vehicle numbers, weak enforcement, and outdated certification systems [22]. Similarly, dust control technologies such as anti-smog guns and mechanized sweepers show localized benefits but lack scalability [16]. Waste sector reforms through biomining represent a significant innovation, demonstrating measurable methane reductions [30], [31]. The novelty of this review lies in its integrated technology–health synthesis, linking sector-specific interventions to quantitative health and exposure data, thereby bridging a gap in earlier fragmented assessments [38], [15].

The persistence of an estimated 95,000 annual premature deaths and life expectancy losses of 8.2 years [4], [3] reveals the inadequacy of incremental progress. Economic costs, including 13 percent of GDP lost through healthcare spending, productivity decline, and trade disruptions [8], [9], reinforce that pollution control is not merely an environmental or health concern but a developmental imperative. Prior literature often examined either health or economic impacts in isolation. By synthesizing both dimensions, this review provides a more comprehensive picture of the systemic costs of pollution.

Comparative analyses with other megacities highlight both unique and shared challenges. While Delhi's CNG transition was globally pioneering, its lack of sustained enforcement mirrors weaknesses seen in other developing megacities [26]. The city's experience underscores that technological innovation, without robust compliance and governance mechanisms, offers only temporary relief. This lesson is globally relevant for urban centers in South Asia, Sub-Saharan Africa, and Latin America facing similar rapid motorization and industrial expansion.

This review advances the literature by offering:

• A longitudinal synthesis of Delhi's regulatory and technological interventions spanning four decades (1980–2025).

• An integrated assessment linking policy and technology with quantitative health and economic outcomes.

Evidence that enforcement deficits and regional spillovers (e.g., stubble burning, energy sector gaps) are the primary bottlenecks, not the absence of regulatory ambition or technological innovation.

• Lessons for global megacities that emphasize the need for health-centered governance, interstate collaboration, and preventive strategies rather than crisis-driven responses.

In sum, Delhi's case demonstrates that while technological adoption and regulatory frameworks are necessary, they are insufficient unless embedded within robust governance structures, regional integration, and societal participation. Without this integration, cities risk remaining in cycles of reactive crisis management rather than achieving sustained improvements in public health and economic resilience.

XIII. CONCLUSION

For over four decades Delhi has fought against air pollution. The case study shows the ambitions and limitations of urban environmental governance in a megacity under pressure due to rapid growth, industrialisation and regional spillovers. The city has shifted from legislative all-new and court-ordered reforms to large-scale technological interventions, such as CNG, Bharat Stage norms, continuous emission monitoring, landfill biomining, and electric mobility, over the years. Important achievements have been delivered through these efforts to reduce selected pollutants and expand monitoring capacity. Air quality in Delhi, however, is still among the worst in the world. The persistent challenges are illustrated by dangerous $PM_{2.5}$ levels, regular winter smog outbreaks, and the absence of a single clean air day. It is a major cause of ill health, a large loss of life expectancy, and widespread respiratory and cardiovascular disease. Pollution is a constraint to development. The economic costs resulting from reduced productivity, increased health spending, and disruption of trade and tourism make air pollution not just an environmental or health issue. The launch of the Air Pollution Mitigation Plan 2025 marks a significant turning point as it offers a more integrated and preventive framework. Yet its success will require sustained enforcement and coordination across multiple agencies, as well as cooperation from neighbouring states to tackle transboundary pollution. The success of future strategies must be assessed not only by the adoption of technology or regulation design but by tangible improvements in people's health and well-behaviour. Delhi's journey provides key lessons for other megacities. To manage air quality, countries need good governance, enforce air quality standards, make long-term investments in clean energy. Technological innovation will not deliver lasting relief without these. Embedding health-centered, regionally coordinated, and preventive approaches in urban environmental policy is the way forward.

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XIV. REFERENCES

[1]. AQI.in (2025). Delhi AQI and real-time trends: August 2025 update. Available at: https://www.aqi.in.

[2]. AirClim (2024). Economic and social barriers to effective air pollution control in Delhi, Air Pollution and Climate Secretariat Policy Brief.

[3]. Lancet Planetary Health (2024). Long-term mortality burden attributable to $PM_{2.5}$ in Indian megacities, The Lancet Planetary Health, Vol. 8, No. 5, (pp. e356–e369).

[4]. Energy Policy Institute at the University of Chicago (EPIC) (2025). Air Quality Life Index (AQLI) Report: India focus. University of Chicago. Available at: https://aqli.epic.uchicago.edu.

[5]. Down to Earth (2025). Assessing enforcement bottlenecks in Delhi's air quality plan, Down to Earth.

[6]. CREA (2025). Crop residue burning and transboundary pollution in North India, Centre for Research on Energy and Clean Air.

[7]. New Indian Express (2025). 2.2 million children in Delhi suffer long-term lung damage from pollution, The New Indian Express.

[8]. Greenpeace India (2021). Air pollution costs in Delhi: Healthcare, productivity, and GDP losses, Greenpeace Technical Report.

[9]. India Briefing (2024). Economic consequences of Delhi's pollution: Impacts on trade and tourism, India Briefing Economic Review.

[10]. De Vito L., Dora C., and Sethi, R (2018). Review of India and Delhi's air quality policy landscape, Environmental Science & Policy, Vol. 89, (pp. 234–246).

[11]. Down to Earth (2016). Timeline of pollution in Delhi: Major interventions and court rulings, Down to Earth Special Archive.

[12]. Down to Earth (2019). Delhi's pollution timeline: From legislation to GRAP, Down to Earth Special Report.

[13]. DPCC (2025). Enforcement of Delhi's Air Pollution Mitigation Plan 2025. Government of NCT Delhi. Available at: https://www.dpcc.delhigovt.nic.in.

[14]. Tewari P., and Jindal, S (2025). Decadal analysis of Delhi's air pollution crisis: Unraveling the contributors. arXiv preprint. Available at: https://arxiv.org/html/2506.24087v1.

[15]. Gupta R., Sharma M., and Sinha, A (2023). Linking technology interventions and policy enforcement in Delhi's air quality management, Urban Climate, Vol. 46, Article 101312.

[16]. Mahoney J., Patel D., and Verghese, J (2022). Effectiveness of dust suppression technologies in construction sites: Lessons from Delhi, Journal of Cleaner Production, Vol. 360, Article 132190.

[17]. Aneja Viney P., Agarwal A., Roelle Paul A., Phillips Sharon B., Tong Quansong, Watkins Nealson, and Yablonsky Richard (2001). Measurements and Analysis of Criteria Pollutants in New Delhi, India, Environment International, Vol. 27, No. 1, (pp. 35–42). DOI: 10.1016/S0160-4120(01)00051-4.

[18]. Guttikunda Sarath K., and Calori Giuseppe (2013). A GIS-based Emissions Inventory at 1 km × 1 km Spatial Resolution for Air Pollution Analysis in Delhi, India, Atmospheric Environment, Vol. 67, (pp. 101–111). DOI: 10.1016/j.atmosenv.2012.10.040.

[19]. Guttikunda Sarath K., and Goel Rahul (2013). Health Impacts of Particulate Pollution in a Megacity—Delhi, India, Environmental Development, Vol. 6, (pp. 8–20). DOI: 10.1016/j.envdev.2012.12.002.

[20]. India State-Level Disease Burden Initiative Air Pollution Collaborators (2019). The Impact of Air Pollution on Deaths, Disease Burden, and Life Expectancy across the States of India: The Global Burden of Disease Study 2017, The Lancet Planetary Health, Vol. 3, No. 1, (pp. e26–e39). DOI: 10.1016/S2542-5196(18)30261-4.

[21]. Khanna V., and Bhatt, A (2021). Digital governance and compliance technology in urban air quality control, Sustainable Cities and Society, Vol. 74, Article 103210.

[22]. Down to Earth (2024). Enforcement gaps in Delhi's vehicle and industry compliance, Down to Earth Policy Review.

[23]. Clean Air Asia (2024). Assessment of the Graded Response Action Plan (GRAP) in Delhi NCR, Clean Air Asia Policy Brief.

[24]. Gulia S., Nagendra S. M. S., Khare M., and Khanna, I (2022). Evolution of air pollution management policies in Delhi: Governance challenges and lessons, Environmental Science & Policy, Vol. 137, (pp. 1–14).

[25]. Foster J., Kumar P., and Bell M. L (2011). Health improvements associated with regulatory interventions in Delhi's air quality, Environmental Health Perspectives, Vol. 119, No. 12, (pp. 1584–1589).

[26]. Guttikunda S. K., and Calori, G (2023). Judicial activism and air pollution enforcement in Delhi NCR, Clean Air Journal, Vol. 33, No. 1, (pp. 12–28).

[27]. Sharma M., and Dikshit, O (2022). Assessing the effectiveness of air quality management strategies in Delhi, Science of the Total Environment, Vol. 827, Article 154349.

[28]. Beig G., Chate D. M., Ghude S. D., Ali K., Sahu S. K., Parkhi N. S., and Trimbake H. K (2020). Evaluating the impact of fuel quality and vehicular standards in India: A case study of Delhi, Atmospheric Environment, Vol. 230, Article 117489.

[29]. Singh P., and Kaur, J (2021). Evaluating electric vehicle deployment and emission reductions in Delhi NCR, Environment International, Vol. 156, Article 106625.

[30]. Sharma R., Singh P., and Mehra, A (2022). Waste management and biomining technologies: Reducing landfill emissions in Delhi NCR, Science of the Total Environment, Vol. 834, Article 155190.

[31]. Yadav M., Sharma R., and Chauhan, A (2024). Landfill biomining and methane emission reductions in Delhi NCR, Atmospheric Environment, Vol. 302, Article 119649.

[32]. Delhi Pollution Control Committee (DPCC) (2018–2025). Annual and monthly air quality analysis reports for Delhi. Government of NCT of Delhi. Available at: https://www.dpcc.delhigovt.nic.in.

[33]. Central Pollution Control Board (CPCB) (2025). Annual air quality bulletins for Delhi NCR, Government of India.

[34]. Ministry of Environment, Forest and Climate Change (MoEFCC) (2025). Air Pollution Mitigation Plan 2025. Government of India. Available at: https://environment.delhi.gov.in.

[35]. Verma V., Sharma R., and Khare, M (2022). Correlating policy enactments with pollutant trends in Delhi NCR, Atmospheric Pollution Research, Vol. 13, No. 10, Article 101473.

[36]. Ramanathan G., and Ramanathan, R (2023). Public interest litigation and environmental governance in Delhi: A case analysis, Environmental Research Letters, Vol. 18, No. 3, Article 035004.

[37]. Chakraborty T., and Raha, S (2019). Early policy frameworks and outcomes of Delhi's air pollution regulations, Journal of Environmental Management, Vol. 236, (pp. 1–12).

[38]. TERI (The Energy and Resources Institute) (2021). Cost-effectiveness of interventions for control of air pollution in Delhi, TERI Technical Report.

[39]. Pant Pallavi, and Harrison Roy M. (2012). Critical Review of Receptor Modelling for Particulate Matter: A Case Study of India, Atmospheric Environment, Vol. 49, (pp. 1–12). DOI: 10.1016/j.atmosenv.2011.11.060.

[40]. Dholakia Hem H., Purohit Pallav, Rao Shilpa, and Garg Amit (2013). Impact of Current Policies on Future Air Quality and Health Outcomes in Delhi, India, Atmospheric Environment, Vol. 75, (pp. 241–248). DOI: 10.1016/j.atmosenv.2013.04.052.

[41]. Guttikunda Sarath K., Goel Rahul, and Pant Pallavi (2014). Nature of Air Pollution, Emission Sources, and Management in the Indian Cities, Atmospheric Environment, Vol. 95, (pp. 501–510). DOI: 10.1016/j.atmosenv.2014.07.006.

[42]. Gulia Sunil, Nagendra S.M. Shiva, Khare Mukesh, and Khanna Isha (2015). Urban Air Quality Management—A Review, Atmospheric Pollution Research, Vol. 6, No. 2, (pp. 286–304). DOI: 10.5094/APR.2015.033.

[43]. Jain Srishti, Sharma S.K., Vijayan N., and Mandal T.K. (2020). Seasonal Characteristics of Aerosols ($PM_{2.5}$ and PM_{10}) and Their Source Apportionment Using PMF: A Four-year Study over Delhi, India, Environmental Pollution, Vol. 262, Article 114337. DOI: 10.1016/j.envpol.2020.114337.

[44]. Hindustan Times (2025). AQLI report shows Delhi losing 8.2 years of life expectancy, Hindustan Times.

[45]. Times of India (2025). Flue gas desulfurization gaps in coal plants near Delhi: Only two of eleven compliant, The Times of India.

[46]. Economic Times (2025). Delhi unveils Air Pollution Mitigation Plan 2025 with cloud seeding pilots, The Economic Times.

[47]. NDTV (2025). Cloud seeding pilot in Delhi aims to reduce smog levels, NDTV.

[48]. Awasthi A., and Jain, V (2023). Remote sensing and GIS for pollution enforcement in urban environments, Environmental Research Letters, Vol. 18, No. 4, Article 045001.

[49]. Goel Rahul, and Guttikunda Sarath K. (2015). Evolution of On-road Vehicle Exhaust Emissions in Delhi, Atmospheric Environment, Vol. 105, (pp. 78–90). DOI: 10.1016/j.atmosenv.2015.01.045.

[50]. Chowdhury Sourangsu, Dey Sagnik, Tripathi Sachchida Nand, Beig Gufran, Mishra Amit Kumar, and Sharma Sumit (2017). "Traffic Intervention" Policy Fails to Mitigate Air Pollution in Megacity Delhi, Environmental Science & Policy, Vol. 74, (pp. 8–13). DOI: 10.1016/j.envsci.2017.04.018.

[51]. Amann Markus, Purohit Pallav, Bhanarkar Anil D., et al. (2017). Managing Future Air Quality in Megacities: A Case Study for Delhi, Atmospheric Environment, Vol. 161, (pp. 99–111). DOI: 10.1016/j.atmosenv.2017.04.041.

[52]. Bhanarkar Anil D., Purohit Pallav, Rafaj Peter, et al. (2018). Managing Future Air Quality in Megacities: Co-benefit Assessment for Delhi, Atmospheric Environment, Vol. 186, (pp. 158–177). DOI: 10.1016/j.atmosenv.2018.05.026.

[53]. International Strategic Analysis (ISAS) Singapore (2025). Public health implications of urban air pollution in South Asia, ISAS Policy Report.

[54]. Business Standard (2025). Delhi air pollution slashes life expectancy by 8.2 years: AQLI Report. Available at: https://www.business-standard.com.

[55]. Energy Policy Institute India (2023). Economic impacts of air pollution exposure in India, EPIC India Policy Assessment.

[56]. CREA (2020). COVID-19 and Delhi's pollution paradox: Economic losses despite reduced activity, Centre for Research on Energy and Clean Air Report.

[57]. World Health Organization (WHO) (2016). Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease, World Health Organization, Geneva, (Pg. 1–121), ISBN: 978-92-4-151135-3.

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