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Decarbonizing the Urban Fleet: Analyzing Beijing's Past as a Policy Blueprint for Hanoi's Vehicle Emissions Challenge

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Abstract

Despite significant economic progress, Vietnam faces a critical environmental challenge rooted in urban air pollution, common to many developing nations. The capital, Hanoi, a vital political and economic hub, has experienced persistent air quality degradation, with transportation identified as a primary contributor. This situation invites comparison with Beijing, a well-documented case of long-term air pollution control through sustained regulatory interventions. This study provides a systematic comparative analysis of the evolution of transport-related air pollution policies in Beijing and Hanoi, employing a targeted review of scholarly and official sources. Copernicus Atmosphere Monitoring Service Near Real-Time Particulate Matter 2.5 (CAMS NRT PM2.5) data during 2016-2024 are collected, then processed through unit conversion, spatial averaging, and monthly aggregation. To enable an equitable cross-city comparison, both absolute and population-normalized concentrations are evaluated. Results show that while Beijing's absolute PM2.5 levels remain higher, its aggressive policy framework has driven a steep, sustained decline. In contrast, Hanoi's lower baseline levels have shown stagnation, indicating that its more recent and less comprehensive policy approach has yet to alter its pollution trajectory significantly. Some of Beijing's policies are concluded to be suitable for Hanoi's adoption, such as low-emission zones (LEZs) establishment, scrappage programs, and camera-based law enforcement. Other strategies like the license-plate lottery or last-digit bans, however, appear impractical. Ultimately, these findings are intended to offer actionable insights for Hanoi's policymakers to tackle air pollution more effectively.

Keywords: urban air pollution, PM2.5, transport emissions, vehicle emissions standards, low-emission zones, transport policy, comparative policy analysis, Beijing, Hanoi

1. Introduction

Despite its current relatively low urban population, Southeast Asia has been experiencing rapid urban growth (Das & Paul, 2021). This trend is reflected in the case of Vietnam: in 1986, Vietnam's urban population was under 12 million, but by 2019, it reached nearly 37 million (World Bank, 2024). Vietnam's national transport structure, which is characterized by space constraints and inadequate infrastructure, is conducive to personal vehicle use (Nicolaisen, 2023). Consequently, growth in population likely increases private vehicle ownership, specifically cars and motorbikes (World Bank, 2008). In 2024, the numbers of registered cars and motorbikes in Hanoi were estimated at 1.1 million and over 6.7 million, respectively (Vo Hai, 2024). Considering the city's geographical area of over 3,359.8 km^2 and a population of 8.7 million in 2024, this translates to around 2,322 vehicles per km^2 and 897 vehicles per 1000 inhabitants (National Statistics Office, 2025).

Due to Hanoi's rapid growth rates of vehicle ownership (22.8% for cars and 13.1% for motorbikes, annually) (Bray & Holyoak, 2015), local traffic emissions of CO, NOx, Particulate Matter (PM), and Volatile Organic Compounds (VOCs) in the city have increased such that they became the primary factor behind the deterioration in Hanoi's air quality (Sakamoto et al., 2018). Therefore, it is important that the municipal government address air pollution with a focus on transportation, particularly through policy implementation. Otherwise, public health as well as the sustainability of urban environments may be put at risk. This growing concern raises the question of how comparable cities have addressed similar challenges.

Vietnam and China share a number of historical and cultural connections, as well as broadly similar socialist governance led by their respective Communist parties. Despite these similarities, a divergence emerges when it comes to present air quality. On one hand, China has made substantial progress in tackling air pollution through enforcement since its 2014 declaration of a "war against air pollution". Statistics have shown sharp declines in PM2.5 (particulate matter with a diameter of 2.5μm or less), NO2 (Nitrogen Dioxide), SO2 (Sulfur Dioxide) and CO (Carbon Monoxide) nationwide (Silver et al., 2025). On the other hand, Vietnam was listed as the second most polluted country in Southeast Asia in 2023 by IQAir (IQAir, 2024). Its capital, Hanoi, was named the eighth most polluted city in the world (IQAir, 2024).

Importantly, this contrast should not be understood solely in terms of absolute pollution levels. Beijing's experience is better describe as a case of substantial improvement from a highly polluted baseline, rather than the achievement of consistently lower PM2.5 concentrations. By contrast, Hanoi's challenge lies in the persistence of moderate yet stagnant pollution levels, which highlights the importance of policy direction and rate of improvement, rather than pollution severity at a single point in time.

Despite the urgency of this issue, existing literature primarily examines air quality issues in China and Vietnam separately, with no comprehensive research covering both nations for direct policy lessons. Hence, this paper addresses that gap by providing the first comparative analysis of transport-related air pollution policies in Beijing and Hanoi. The objective is to identify which of Beijing's successful policies are adaptable to Hanoi's context, therefore offering potential regulatory insights while accounting for certain limitations in policy transfer between cities.

2. Study Area

Table 1 below presents a brief comparative overview of the two study areas: Beijing (the capital of China) and Hanoi (the capital of Vietnam) in terms of key socioeconomic aspects.

Overall, Hanoi is smaller, rapidly developing, and more economically constrained, relying heavily on a major fleet of motorbikes without fully developed public transport systems (Kieu et al., 2024). This contrasts with Beijing's vast economic capacity and extensive public transport networks (Metro and BRT), which provide robust alternatives when implementing vehicle restrictions. Hanoi, by comparison, only introduced its BRT system in late 2016 and opened its first Metro line in 2021.

Both cities are provincial-level municipalities. However, Beijing has substantial autonomy in policymaking and urban management, whereas Hanoi has only recently gained more decision-making authority following the 2024 Capital Law. These differences in scale, transport infrastructure, and governance structure are crucial to assessing policy transfer feasibility between the two cities.

Table 1: Recommendations for blood shortage solutions.

Feature	Beijing	Hanoi
Population (in 2024)	~21.8 million [(1)]	~8.7 million [(2)]
Land area	16,140 km2 [(3)]	3,360 km2 [(2)]
GRDP (2024)	4.9 trillion CNY (~693 billion USD) [(4)]	1.43 quadrillion VNĐ (~56 billion USD) [(5)]
Public transport infrastructure	Extensive Metro Network (>800 km) and long-established Bus Rapid Transit (BRT) since 2004 [(6) (7)]	Nascent Metro Network (2 operational lines with limited coverage) and young BRT systems (since December 2016) [(8) (9)]
Governance structure	Provincial-level municipality with great autonomy in policymaking and management [(10 (11)]	Special provincial-level administrative unit with autonomy recently enhanced by the 2024 Capital Law [(12) (13)]

Sources: (1): (Beijing Municipal Government, n.d.); (2): (National Statistics Office of Vietnam, 2025); (3): (Beijing Municipal Government, n.d.); (4): (Beijing Municipal Government, 2025); (5): (Vietnam News, 2025); (6): (Beijing Municipal Government, 2025): (7): (BRTData.net, 2021); (8): (Hanoi Metro, n.d.); (9): (Hoang-Tung et al., 2021); (10): (Wong & Karplus, 2017); (11): (Chun et al., 2019); (12): (Lao Động, 2023); (13): (Vietnam News, 2024)

3. Literature Review

A critical review of the existing literature reveals a significant disparity in the quality and depth of research focused on air pollution control in Beijing compared to Hanoi.

3.1. Literature related to Beijing's policies

The policy evolution of Beijing has been documented through detailed, quantitative research, providing a strong basis for policy comparison. Studies focusing on Beijing, such as Wu et al. (2011) and Zhang et al. (2014), offer robust analyses and link policy implementation to measurable air quality improvements. The United Nations Environment Programme (UNEP, 2019) further synthesizes these findings, providing a comprehensive timeline of control measures. Likewise, the work by Yang et al. (2015) provides exhaustive and specific documentation on the motives, mechanisms, and tangible outcomes of Beijing's key policies (e.g. the vehicle registration lottery and last-digit driving restrictions), which is crucial for thorough efficacy assessments. However, the primary limitation of this Beijing-focused literature, for the purpose of this comparative study, is the transferability of findings. They do not explicitly explain how the socioeconomic circumstances of Beijing influenced regulatory decisions and the recorded outcomes, which makes analyses less certain and adaptation to Hanoi's context more challenging.

3.2. Literature related to Hanoi's policies

Literature on Hanoi, while crucial for contextual understanding, is less cohesive and more limited in scope compared to that of Beijing. Foundational research like Bray and Holyoak (2015) provides essential insights into Hanoi's unique transportation structure, especially the dominance and societal role of motorcycles, for designing effective vehicle control measures. Studies such as Sakamoto et al. (2018) confirm the considerable contribution of vehicle emissions to criteria pollutants like VOCs, CO, O3 in Hanoi, underlining transportation's role in the city's worsened air quality. Das and Paul (2021) offer a valuable regional perspective, analyzing the influence of economic growth and urbanization trends across South, East, and Southeast Asian countries. However, these studies suffer from temporal and scope limitations. The Bray and Holyoak (2015) data are now a decade old, failing to account for the recent explosive growth in private vehicle ownership and the emergence of new public transport systems like the metro. Similarly, the Sakamoto et al. (2018) study's time frame is limited to 2015-2016, which does not capture changes in emission sources and policy impacts years later. The regional scope of Das and Paul (2021), while informative for macro trends, lacks the city-specific policy granularity required for direct regulatory recommendations. More broadly, the literature on Hanoi's air policy relies heavily on official government announcements and news reports (e.g., Hanoitimes, Vietnamnews), which may introduce a policy bias and lack the independent, peer-reviewed evaluation of effectiveness available in the Beijing case.

3.3. Research Gap and Justification

Existing studies largely examine these two cities in isolation. While Yang et al. (2015) provide a deep dive into Beijing, there is a notable absence of comparative literature that directly juxtaposes these findings with Hanoi's context. Additionally, previous research often focuses exclusively on absolute concentration levels, which can be misleading given the demographic disparities between the two capitals. This study addresses these gaps by conducting a direct policy comparison and considering PM2.5 per capita besides absolute values to assess the urgency and transferability of transport interventions.

4. Methodology

4.1. Scope and Objectives

The question guiding this research is: "What elements of Beijing's transport-related policy framework are adaptable to Hanoi's local context?". To address this question, the research pursues three objectives. First, it synthesizes existing literature on transport-related policies in both cities. Second, it compares the evolution of their policy trajectories over time. Third, it evaluates the transferability of Beijing's measures to Hanoi.

The scope of this study is defined along four dimensions. Geographically, the study focuses on Beijing (China) and Hanoi (Vietnam). Temporally, policy developments are reviewed from 1997 to 2025, while PM2.5 trends are analyzed for the period 2016-2024. In terms of sources, the study draws on peer-reviewed studies, government documents, organizational reports, and reputable news outlets that report on air-quality and transport policy updates. The regulatory focus is placed on transport-related air pollution policies regarding fuel quality, emission standards, driving restrictions, LEZs, enforcement tools. Relevant non-transport policies regarding bans on charcoal stove and open burning are also considered in the case of Vietnam.

4.2. Search Strategy

A scoping search was conducted using Google Scholar and Google News between July and September 2025. Boolean keyword combinations were employed, including "air quality" AND ("Beijing" OR "Hanoi"), "Beijing air pollution" AND "transport policy", "Hanoi air pollution" AND "transport policy", "Hanoi air pollution" AND ("honeycomb charcoal stove" OR "open burning"), "air pollutants", and "PM2.5" AND "health".

Filters were applied to publication year and language. Foundational literature on air pollutants was drawn from sources published from 2000 onward, while studies specifically addressing policy implementation were limited to publications from 2010 onward. Only English-language sources were included. Rather than compiling an exhaustive dataset, the search adopted a targeted and iterative approach: sources were progressively added and screened until additional materials no longer offered substantially new insights to the research question.

4.3. Inclusion and Exclusion Criteria

Literature selection was guided by explicit inclusion and exclusion criteria. Included sources comprised studies and reports that detail transport-related policies, including their temporal and spatial scopes, regulatory mechanisms, and observed or expected impacts. News articles reporting regulatory announcements, implementation timelines, and official directives related to air quality management and transport emissions were also included.

Excluded materials consisted of studies focusing solely on indoor air pollution, road dust, or a single type of air pollutant instead of vehicle emissions, as well as research examining short-term or regional air pollution outside Beijing or Hanoi. Studies centered exclusively on modeling, prediction, a single aspect of transport, or mitigation proposals without discussing existing or officially planned policies were also excluded.

Following this screening process, the final analytic sample consists of 17 peer-reviewed academic studies, 13 government documents from central and municipal authorities, 14 verified news articles, and 10 institutional and organizational reports. These figures represent the materials used for this paper's synthesis rather than a comprehensive corpus of available literature.

4.4 Analytical Framework and Data Processing

Variable Selection and Justification

To analyze the most recent trends in air pollution for Hanoi and Beijing, this paper used PM2.5 concentrations, a widely adopted metric for air quality assessments, as the key indicator. The selection of PM2.5 is justified by its strong health relevance and international recognition. In the United States, PM2.5 is classified as one of the criteria air pollutants under the Clean Air Act (1971), which helped establish safe levels in the National Ambient Air Quality Standards (Suh et al., 2000). These fine particles are also considered a major cause of premature death and illness, and no absolute safety threshold against adverse health effects has been determined (Yu et al., 2023). Internationally, the World Health Organization (WHO), in its updated Air Quality Guidelines (2021), recognized PM2.5 as a classical air pollutant and recommended a threshold of 5 $\mu g/m^3$ for annual PM2.5 levels exposure. Additionally, concentrations of PM2.5, alongside PM10, are made Indicator 11.6.2 under Target 11.6 of the Sustainable Development Goals (SDGs), which aims to reduce cities' negative environmental impact.

Data Collection and Spatial Averaging

The analysis utilized the CAMS Near-Real-Time (NRT) ImageCollection (ECMWF/CAMS/NRT) for the period 2016–2024. From each image, the variable particulate_matter_d_less_than_25_um_surface was selected, representing the total surface-level mass concentration of PM2.5, expressed in kilograms per cubic meter (kg/m^3). To align with standard air quality reporting practices, values were converted to micrograms per cubic meter ($\mu g/m^3$) by multiplying by 1×10^9.

Spatial processing focused on bounding boxes encompassing Beijing (115.9°E–116.8°E, 39.4°N–40.3°N) and Hanoi. Each image was clipped to the respective region, and zonal mean PM2.5 values were calculated using a mean reducer, providing a representative daily surface concentration for each city.

Temporal Aggregation and Normalization

Daily mean PM2.5 values were aggregated into monthly averages. This was achieved by grouping the data based on a formatted 'month' field and computing the mean for each group. The final dataset thus consists of monthly averaged PM2.5 values for both cities during 2016–2024, providing a basis for subsequent comparative and trend analyses.

To account for the huge difference between Beijing's and Hanoi's urban population sizes, the quarterly average PM2.5 concentrations are evaluated per capita (μg/m3/person) for a fairer assessment and comparison (Figure 2). Per capita PM2.5, referring to the concentration of PM2.5 normalized by population, does not represent individual exposure but an indicator that allows fairer cross-city comparison by accounting for population size.

While this specific approach has not been applied directly to PM2.5, it has established precedents in climate policy. For example, the IPCC's Climate Change 2023: Synthesis Report (2023) adopts GHG (greenhouse gas) emissions per capita as a key metric. Likewise, the UNECE Guidelines (2025) recommend GHG emissions per capita with a view to "harmonizing the absolute value of GHG emissions for international comparisons." Extending this precedent to PM2.5, this study employs PM2.5 per capita alongside absolute values to provide a more balanced and academically rigorous comparison of air quality impacts.

5. Results

This section presents a comparative analysis of PM2.5 concentration trends in Beijing and Hanoi from June 2016 to April 2024 using both absolute and population-normalized metrics. Overall, Beijing exhibits higher absolute PM2.5 concentrations and stronger seasonal variability than Hanoi but demonstrates a declining trend in recent years. In contrast, Hanoi's absolute PM2.5 levels remain comparatively lower yet largely stagnant over the same period. When concentrations are normalized by population, the relative burden shifts, with Hanoi displaying higher per capita PM2.5 levels despite its lower absolute concentrations. Figures 1 and 2 illustrate these patterns using absolute and per capita PM2.5 values, respectively, to provide a balanced cross-city comparison.

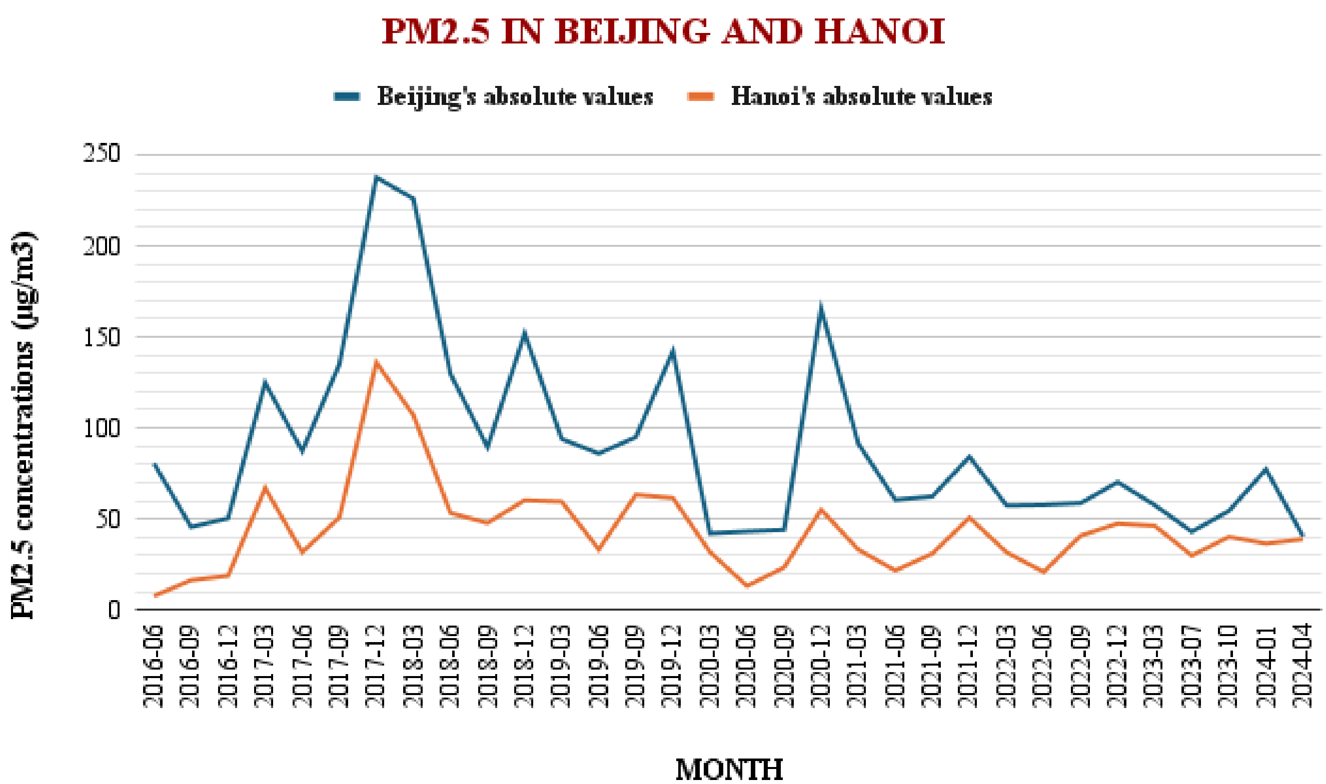

Figure 1: Absolute PM2.5 concentrations in Beijing and Hanoi, June 2016 to April 2024.

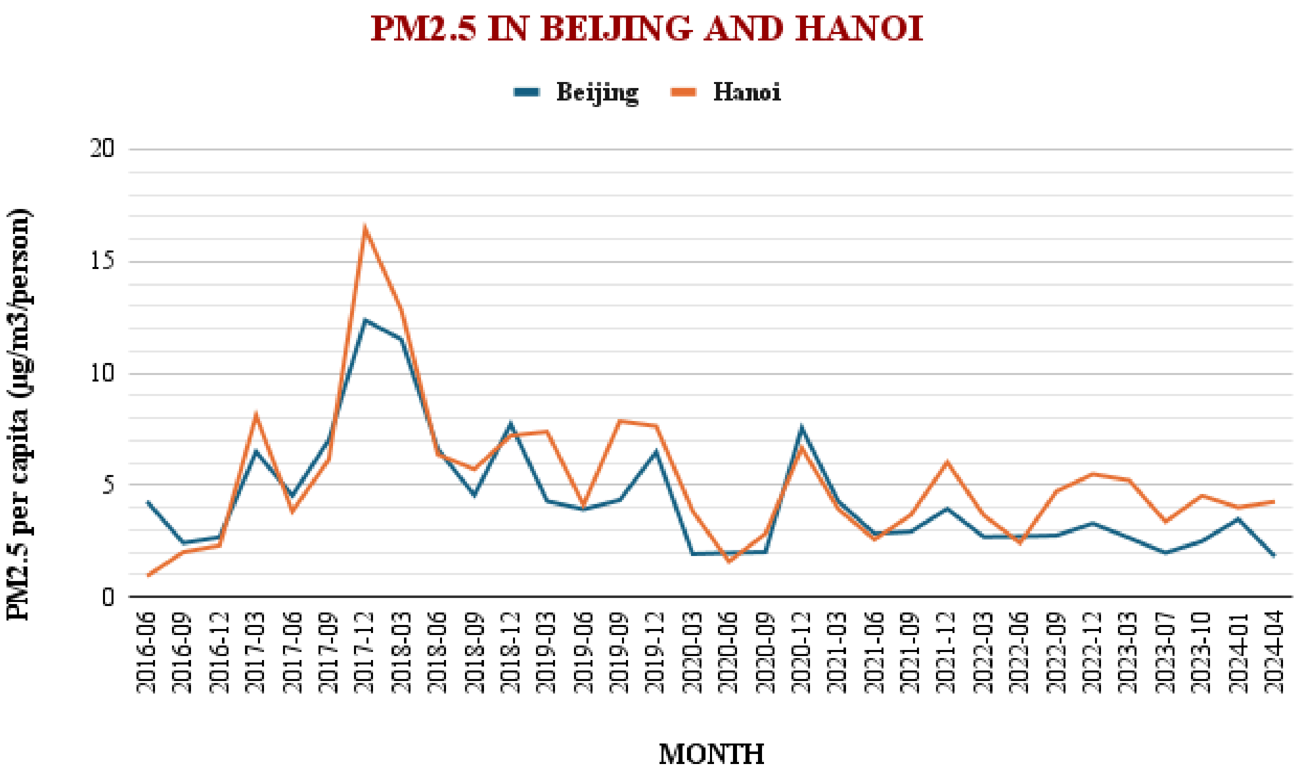

Figure 2: PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to April 2024.

5.1. Absolute PM2.5 concentrations (µg/m³)

Data shown in Figure 1 reveal that Beijing consistently experienced higher PM2.5 levels than Hanoi throughout the 2016-2024 period. Beijing's maximum values exceeded 200 µg/m³ in late 2017-early 2018, whereas Hanoi's stayed considerably lower. Although both cities exhibit strong seasonality, Beijing's amplitude is much greater, which indicates more intense pollution episodes. These differences are understandable given Beijing's larger scale of land area, population, as well as economic and industrial activities. Hanoi, by contrast, has a smaller industrial footprint and lower absolute emissions despite recently recorded expansion in vehicle use and urban activities. However, it is notable that since 2021, Beijing's PM2.5 concentrations have gradually declined, even reaching parity with those of Hanoi in April 2024. Hanoi's levels remained steady over the years since mid 2018 (seasonal peaks and dips not considered). In short, Beijing's absolute PM2.5 levels remain consistently higher than Hanoi's, although the gap has gradually narrowed since 2021

5.2. PM2.5 concentrations per capita (µg/m³/person)

To contextualize the population-level burden and facilitate a more equitable comparison between cities of vastly different population sizes, PM2.5 per capita concentrations are also calculated. This metric does not represent individual exposure but serves as a proxy for the aggregate pollution burden shared by each city's population. Accordingly, Hanoi's residents bear a proportionally higher burden from its ambient pollution than Beijing's residens do. Figure 2 highlights relative exposure: Hanoi's smaller population means that even moderate absolute concentrations translate into a higher exposure burden per resident. Hanoi's per capita values exhibit pronounced spikes in late 2017–early 2018, winter peaks in 2018–2019 and 2020–2021, dips around mid-2020 and mid-2021 (which temporally align with Vietnam's COVID-19 lockdown periods (Prime Minister of the Government, 2020; Hanoi People's Committee, 2021 July 23; Hanoi People's Committee, 2021 August 6). While this overlap does not establish causation, it suggests that mobility restrictions may have played a role), followed by rebounds in late 2021. Beijing's per capita values are generally lower, especially after mid 2021, reflecting both its larger population and long-run regulatory interventions.

5.3. Patterns Analysis

Beijing's early implementation of fuel and vehicle controls, scrappage of high-emitting vehicles, and long-running traffic restrictions since early-mid 2010s appear to be associated with lower baselines and reduced seasonal peaks in recent years as the policies' effects became stabilized and more tangible (Yang et al., 2015). Conversely, Hanoi's rather stagnant PM2.5 trends align with the city's current reliance on activity-specific bans such as restrictions on household solid-fuel use and open burning between 2019 and 2021 (Vietnam News, 2019; 2023). They seem to limit extreme spikes yet do not have continuous dampening effects on emissions, most of which come from vehicles. Direct interventions targeted at transport like periodic motorbike inspection programs, low-emission zones, or traffic-based cordons are planned for 2025–2028, meaning their influence is absent from the time period examined here (Vietnam News, 2019; 2023; 2024; Vu Tuan, 2025). When normalized by population, Hanoi exhibits higher per capita PM2.5 levels despite its lower absolute concentrations, highlighting a relatively greater exposure burden per resident.

Nevertheless, these observations suggest not a definitive causal chain but an empirical correspondence between regulatory trajectories and PM2.5 patterns: Beijing with earlier systematic controls on fuel and vehicle emissions tends to show smoother and more sustained reductions, while Hanoi, which relies on episodic bans, exhibits less visible progress in air quality mitigation. Importantly, causality cannot be established from this dataset alone, as meteorological variability, regional transport, and biomass burning also affect year-to-year fluctuations. Therefore, the purpose of this analysis is to situate PM2.5 patterns within their policy contexts for an overview of both cities' current status rather than a claim of policy-specific effectiveness, which requires a broader body of evidence.

6. A brief review of Beijing's major transport-related air pollution policies

Beijing's set of actions against vehicular air pollution has developed over more than two decades, characterized by a structured framework across five key fronts: fuel quality and vapor recovery, vehicle emission controls, traffic management, compliance, and alternative-fuel fleets (UNEP, 2019; Wu et al., 2011; Yang et al., 2015). The city's effort marked its beginning with the 1997 Strategies and Implementation Plan for Controlling Motor Vehicle Emissions in Beijing, which served as the cornerstone for applying Euro-equivalent standards to all newly registered vehicles starting in 1999 (Yang et al., 2015). From 1999 to 2015, Beijing took complementary measures targeted at both new and in-use vehicle emissions while controlling how, when, and which vehicles could access the urban center (UNEP, 2019; Yang et al., 2015).

Existing literature consistently shows that on fuels, Beijing acted earlier and more aggressively than stipulated by national requirements. It first banned lead and then limited sulfur content in fuel, enabling modern after-treatment technologies (Yang et al., 2015). Within less than two decades, the city replaced poorly quality-controlled fuel with lead-free gasoline and diesel capped at 10 ppm sulfur, facilitating sizable tailpipe reductions. Beijing also addressed evaporative losses by mandating Stage I and Stage II gasoline vapor recovery at filling stations beginning in 2000, three years ahead of national rules (Yang et al., 2015). In 2007, Beijing funded a large-scale retrofit program that equipped over 1,000 stations and tanker trucks with the required vapor recovery systems for the 2008 Olympics, cutting VOC emissions by an estimated 20,000 metric tons annually (Fung & Maxwell, 2011; Yang et al., 2015).

Emission standards for both light-duty gasoline and heavy-duty diesel vehicles (China I–V and China 1–5, respectively) were adopted by Beijing in an accelerated manner, helping to close its gap with the EU and U.S. as well as reduce new-vehicle emissions (UNEP, 2019). To manage the in-use fleet, the city successfully utilized a color-labeling system that laid the groundwork for subsequent scrappage and retrofitting programs. Scrappage programs were carried out in phases, restricting certain types of vehicle from entering central areas and providing subsidies that encouraged the retirement of high emitters (UNEP, 2019; Wu et al., 2011; Yang et al., 2015). Meanwhile, despite several preliminary pilot programs, retrofits (e.g. three-way catalysts, flexible-fuel engines, diesel particulate filters) met with mixed reception due to their transient benefits but high operation-maintenance costs and limited lifespan (Yang et al., 2015).

Traffic control policies implemented by the Beijing government have significantly decreased demand for and access to new vehicles. In 2011 the city initiated its license-plate lottery to cap new registrations, and the average 26-month queue time to be given an official plate reduced winners' likelihood of actually switching to driving by 16% (Yang et al., 2014). The city also enacted several restrictions: spatially, motorcycles are prohibited within the Fourth Ring Road, and yellow-label vehicles have been fully forbidden in the metropolitan area since late 2014 (Yang et al., 2015; The State Council of the People's Republic of China, 2015); temporally, weekday "last-digit" driving restrictions—which ban vehicles from entering the Fifth Ring Road on designated days according to their license-plate numbers—were first piloted for the 2008 Olympics. Afterwards, they were extended due to their effectiveness, and have continued to help manage peak-hour traffic ever since. For non-local vehicles (excluding already-banned yellow-label vehicles), a provisional City Pass is required to access the Sixth Ring Road; otherwise, they can only travel beyond the Sixth Ring Road from midnight to 6 a.m. (Beijing Municipal Government, 2025; Yang et al., 2015).

Compliance measures were implemented to augment these aforementioned controls. Beijing's inspection-and-maintenance (I/M) program mandates periodic safety and emissions testing. National and local guidelines were introduced to standardize procedures and verification of type-approval criteria; testing intervals vary depending on vehicle type and age (Yang et al., 2015). Concurrently, roadside remote sensing contributes to enhanced enforcement by spotting high-emitting vehicles, tracking fleet trends, and checking I/M program performance despite its inaccuracies in monitoring vehicles individually (Yang et al., 2015). However, loopholes exist: old, unqualified vehicles may slip in ring-road boundaries; some Beijing-registered vehicles may refuel outside the city, where sulfur levels are higher because of inadequate regulation. Both of these scenarios can increase real-world emissions and risk catalyst failure, thus calling for regionally coordinated policies on fuel standards and enforcement to ensure enhanced regulatory efficacy (Zhang et al., 2014).

Finally, Beijing coupled restrictions with cleaner, more sustainable vehicle technologies. The city has strongly promoted new energy vehicles (NEVs) and built one of the world's largest fleets of natural-gas buses, employing both CNG and LNG, technologies that cut life-cycle CO2 emissions by 18-25% compared to gasoline buses (Hao et al., 2016). In an attempt to foster NEV adoption among its citizens, the government released a separate license plate cap for this type of vehicle (Yang et al., 2015). Together, these complementary measures—including cleaner fuels, tighter standards, targeted scrappage, access controls, rigorous compliance tools, and alternative-fuel deployment—create the backbone of Beijing's transport-focused anti-air pollution strategy.

7. A brief review of Hanoi's major air pollution policies

This section reviews Hanoi's city-level efforts to curb transport-related air pollution from mid-2000s to 2025. Due to the recent nature of Hanoi's policies targeted at vehicular air pollution, it also briefly examines related measures, such as the charcoal stoves ban and control on open burning, as key drivers of observed air-quality trends in Hanoi.

The backbone of Hanoi's approach has been a 2017 People's Council resolution to rein in private motorbikes (Nguyen Thuy, 2017), followed by legal authority in the revised Capital Law (effective from 2025) that lets the city create low-emission zones and apply more stringent rules on local vehicles (Ngoc Mai & Nguyen Quy, 2025). In parallel, Hanoi banned honeycomb charcoal stoves, curbed open burning, and began relocating polluting factories out of the urban core, while upgrading its monitoring and enforcement toolkit (Vietnam News, 2019; Vietnam News, 2023; VietNamNet News, 2021).

Unlike Beijing's early fuel-quality push, Hanoi's most impactful fuel actions have targeted household sources. In late 2019 the Chairman of the People's Committee ordered the elimination of honeycomb (beehive) charcoal stoves, which the city had identified as a major PM contributor in dense districts (Vietnam News, 2019). In September 2020, a law under Instruction 15/CT-UBND formally banned the open burning of agricultural residues (notably rice straw) and trash; subsequent reporting highlights both the rule and the continuing enforcement challenge in suburban districts (Vietnam News, 2023). To ensure household-fuel compliance, Hanoi's 2019 stove directive shifted from education and support in 2020 to penalties from 2021, with enforcement handled by the city's environmental protection units (Vietnam News, 2019). For open burning, Instruction 15/CT-UBND tasks the Department of Natural Resources and Environment (DONRE) and district authorities with inspections and sanctions, though coverage gaps remain in peri-urban rice areas (Vietnam News, 2023). The city has also run a long-standing program to relocate polluting factories away from central districts; by 2021 it had listed around 90 establishments for removal and reported partial progress, with the program continuing as sites and financing line up (VietNamNet News, 2021).

For new policy architecture, Hanoi's 2017 People's Council resolution laid out a phased restriction on motorbike circulation through 2030, explicitly linking traffic control to air-quality gains and public-transport expansion (Nguyen Thuy, 2017). The 2024 Capital Law then empowered Hanoi to set low-emission zones (LEZs) and adopt stricter local emissions measures; pilots are slated in central districts from January 1, 2025, prioritizing cleaner vehicles and public transport access (Ngoc Mai & Nguyen Quy, 2025). Translating framework into timelines, the city has announced a staged ban on fossil-fuel motorbikes: a first cordon within Ring Road 1 from July 1, 2026, expanding to tighter two-wheel and car restrictions between Rings 1–2 from January 1, 2028 (Vu Tuan, 2025).

In parallel, Hanoi is preparing periodic emissions testing for in-use motorbikes, with a national roadmap pointing to a Hanoi/HCMC start in 2027 and phased coverage by model year thereafter (Vietnam News, 2025). Hanoi's LEZs pilots operationalize zone-based access management, restricting high-emitting fossil-fuel vehicles in core districts, pairing the rule with investment in public transport and charging (Ngoc Mai & Nguyen Quy, 2025). The Capital Law text and city briefings emphasize LEZs authority, phased expansion after 2030, and the use of fees/charges to reinforce behavior change (Ngoc Mai & Nguyen Quy, 2025). These zone-based controls complement the 2017 resolution's longer-run intent to progressively limit motorbike circulation citywide as transit supply improves.

In terms of public transport, to align access rules with cleaner fleets, Hanoi has adopted a green-bus roadmap: targets announced in 2025 aim for a full switch to electric/green-energy buses by 2030, with interim milestones (≈10% in 2025; 20–23% in 2026) and supporting infrastructure/finance measures (Vietnam News, 2024). Several statements and press briefings also reference taxi electrification by 2030 (some sources cite "all taxis," others "at least 50% buses and all taxis"), reflecting evolving targets as plans are finalized (Vietnam News, 2024). Earlier than these transport measures, Hanoi set a foundation for monitoring and dust control. Decision 355/QĐ-UBND (January 13, 2012) approved a fixed air-quality monitoring network to 2020, establishing the city's long-term infrastructure for air-pollution observation (Hanoi People's Committee, 2012). Meanwhile, Decision 02/2005/QĐ-UB and Decision 55/2009/QĐ-UBND required construction sites to control dust and maintain sanitation (Hanoi People's Committee, 2005; 2009). These actions were important for PM reductions alongside later traffic-related measures.

8. Comparison of Beijing and Hanoi's air pollution approaches

Overall, Beijing's model is largely based on technological upgrade and strict enforcement with controls on when and how many cars can drive. Hanoi's model is based on zones and access rules, paired with household-fuel crackdowns and a staged build-out of emissions testing, reflecting its previously more limited regulatory authority and later policy start.

Based on the policies discussed for each city, a comparative table covering different regulatory aspects was compiled (Table 2).

Table 2. Beijing and Hanoi's transport-related policies targeted at air pollution.

Air Pollution Policy/Strategy	Beijing	Hanoi
Fuel quality & vapor recovery	Began early by controlling what goes in the tank: pushed cleaner fuels (down to 10 ppm sulfur, no lead), which enabled modern after-treatment technologies to work effectively. Required Stage I/II vapor recovery at gas stations with major retrofit programs completed before the 2008 Olympics.	No city-specific fuel-quality mandates because fuel standards are set nationally. However, the new LEZs authority (from 2025) allows Hanoi to indirectly tighten fuel-quality control by regulating zone access based on vehicles' pollution levels (particularly favoring cleaner ones).

New-vehicle emission standards	Adopted Euro-pathway standards early (Beijing 1 in 1999 and China 5 by 2013), often ahead of the national timeline, pushing cleaner new vehicles sooner.	Follows national standards for new vehicles. Under the 2024 Capital Law, the local authority can set stricter access rules by emission tier within LEZs.
In-use vehicle controls (I/M, remote sensing)	Operates a robust I/M system and widespread roadside remote sensing. A green/yellow label system enabled targeted retirement of high-emitting vehicles through scrappage programs.	Developing enforcement tools: periodic emissions testing for motorbikes slated to begin in 2027 (piloted in Hanoi and HCMC first), phasing nationwide by 2030.
Traffic control and usage restrictions	Uses usage controls: odd-even/last-digit weekday driving restrictions (started during the 2008 Olympics and continued with modifications); a ban on motorcycles inside the 4th Ring Road; and complete bans on yellow-label vehicles.	Does not adopt last-digit rules. Instead phased geographic restrictions: the 2017 plan mandates phasing out gasoline motorbikes in the urban core by 2030, with a strict cordon inside Ring Road 1 on 1 July 2026 and expansion in 2028.
Vehicle population control	License-plate lottery since 2011; annual caps reduced over time (from 240,000 to 150,000).	No population-control strategy. Relies on restricting where and when each vehicle type can enter through zone-based measures.
Low-emission zones (LEZs)	Piloted bans on yellow-label vehicles. Studied broader LEZ models from the mid-2010s onward.	Legal LEZ authority from 2025. Pilots in central districts begin from 2025 with expansion after 2030.
Motorbike restrictions	Motorcycles restricted inside the 4th Ring Road. Placed priority on eliminating yellow-label vehicles (2014).	2017 resolution targets full phase-out of gasoline motorbikes in the urban core by 2030, firm cordon inside Ring Road 1 from 1 July 2026, and expansion in 2028.
Alternative-fuel fleets	Extensive use of CNG/LNG buses and strong promotion of NEVs, including separate license quotas for NEVs.	Ties bus and taxi electrification to LEZ and cordon timelines, targeting major transitions by 2030.

Monitoring & enforcement tools	Mature systems including: an expanded AQ network, empowered BEPB for roadside testing, and strong scrappage programs for YLVs.	Operates a citywide AQ monitoring network, district-level enforcement for bans on honeycomb stoves and open-burning. Building motorbike emissions-testing centers.
Household fuels & Open burning	Has controls but historically emphasized transport and industry more than household fuels. Major coal-to-gas campaigns were mostly regional/national.	Eliminated honeycomb charcoal stoves by 2021 (support in 2020; fines from 2021). Instruction 15/CT-UBND (Sep 2020) bans open burning of agricultural waste and trash, with ongoing enforcement.

9. Discussion

The comparative PM2.5 analysis reveals two distinct trajectories. Although Beijing continues to record higher absolute PM2.5 concentrations, it has experienced a consistent downward trend in recent years. Hanoi, despite a lower starting point, shows prolonged stagnation and a higher per capita pollution burden. These patterns indicate that Hanoi's past targeted bans have been insufficient to shift its air quality trend, thereby underscoring the urgent need for more systemic, transport-focused interventions.

The data and literature generally confirm that Beijing's aggressive policy interventions have effectively reduced air pollution to some extent. However, it is essential to acknowledge that Beijing and Hanoi are not directly comparable: they differ significantly in terms of urban population size, economic capacity, and governance structure. This study does not propose direct replication, but rather uses Beijing's policies as a reference to isolate mechanisms that successfully targeted vehicle emissions. The goal is to identify potentially transferable, not identical, policies. Therefore, to move beyond a theoretical list of measures and provide a contextually relevant evaluation, this section analyzes the adaptability of Beijing's measures to Hanoi through three criteria: technical efficacy (the potential for significant emission reductions), institutional feasibility (the legal and bureaucratic capacity of Hanoi to implement the measure), and social & political acceptability (the likelihood of public approval and compliance, particularly given Hanoi's heavy reliance on motorbikes).

9.1. Transferable policies with adaptation

Among reviewed Beijing's measures, low-emission zones (LEZs) emerge as a highly transferable policy instrument for Hanoi. Technically, this approach represents one of the most straightforward emission reduction measure. Given Hanoi's 6.7 million motorbikes, restricting the oldest, most polluting vehicles from entering the urban core (e.g., Ring Road 1) yields immediate, concentrated benefits to air quality, especially in central areas where air pollution is typically the most severe due to intense traffic activities. Institutionally, Hanoi's revised Capital Law (effective from 2025) grants Hanoi the legal authority to establish LEZs, ensuring regulatory feasibility. This, in turn, forms a strong foundation for the planned gas-powered motorbike ban starting in 2026. However, social and political acceptability remains a key constraint. Unlike

Beijing, Hanoi lacks an extensive subway system, so LEZs risk being inequitable because motorbikes are crucial to the working class' livelihoods. Hence, implementation should be gradual and closely linked to the accelerated development of public transportation modes, especially bus and metro.

Vehicle scrappage programs are another policy area in which Hanoi can draw relevant lessons from Beijing's experience. Technically, scrappage directly remove the highest-emitting vehicles from the fleet. By focusing on the largest contributors to pollutants like PM, NOx, and VOCs, this strategy allows for rapid reductions in tailpipe emissions. Institutionally, while such programs are legally feasible in Hanoi, managing, verifying millions of motorbikes and securing substantial funding required for subsidies present a significant bureaucratic and fiscal challenge to Hanoi, in contrast to greater resources available in Beijing. In terms of social acceptability, scrappage schemes are likely to face less resistance than outright bans, as they offer financial incentives and a more equitable transition mechanism. If subsidies are fair, particularly sufficient to cover the cost difference for more technologically modern vehicles, then the programs are likely to gain public support.

With regard to enforcement mechanisms, camera-based enforcement appears highly applicable to Hanoi. Technically, automated monitoring systems enable consistent and systematic compliance with LEZ and emission regulations, thereby enhancing their effectiveness. They allow reliable enforcement over large areas without dependence on manual policing. Institutionally, Hanoi has already begun investing in 'smart city' infrastructure, including cameras on select roads (VNA, 2025). The technology for plate recognition technology is widely available and scalable as it is already used to detect traffic violations (Nguyen & Pojani, 2018). Socially, automated enforcement is often perceived as more transparent, stringent and less prone to corruption than human policing. This shift towards system integrity is likely to promote higher compliance rates among the citizens.

9.2. Less feasible policies under current conditions

In contrast, two key policies employed by Beijing face substantial constraints in Hanoi. Vehicle population control through license-plate lotteries, while effective in limiting new car ownership in Beijing, offers limited technical benefits for Hanoi, where air pollution mainly stems from existing and aging motorbikes. Therefore, the policy would only provide a delayed, marginal benefit to current emissions levels. However, once air pollution is generally mitigated, it could help sustain long-term control over pollution. Institutionally, implementing an equitable and secure lottery system for millions of motorbikes would be an administrative burden for the government disproportionate to immediate gains in terms of air quality. Socially and politically, motorbikes serve not only as the primary means of transportation but also a source of income for many (Pojani et al., 2024). Thus, limiting motorbike registrations may be perceived as restricting a basic right to mobility and income generation, potentially provoking significant public backlash and broader negative economic impacts across the city.

Similarly, weekday last-digit rotation bans appear impractical in Hanoi's present context. Although this measure could indirectly reduce emissions by limiting days that a vehicle could be on the road, its main benefit lies in alleviating traffic congestion, which can easily be outweighed by the significant institutional and social costs. Instead of specifically retiring high-emitting vehicles, it merely rotates them. Institutionally, this approach requires only the deployment of automated camera systems and clear signage, making it highly feasible from the administrative standpoint. However, social acceptability is low in Hanoi, where public transport systems remain underdeveloped like Hanoi, leaving citizens with inadequate mobility alternatives. Consequently, forcing a motorbike rider off the road without a thorough, functional network of Metro or bus will lead to economic disruption or incentivize purchasing a second vehicle, which counteracts the policy's intent. This strategy is only viable once major public transit infrastructure is complete.

Taken together, the comparison suggests that the effectiveness of transport-related air pollution policies depends not only on individual measures but also on their integration into a coherent regulatory framework. Beijing's experience highlights the importance of early intervention, progressive tightening, and strong enforcement. Hanoi's recent initiatives, particularly its plans for low-emission zones, emissions testing, and vehicle electrification, signal a move toward a more systematic approach to air pollution. The extent to which these efforts deliver sustained air-quality improvements will depend on how well they are sequenced, enforced, and supported by broader investment in public transport and urban accessibility.

10. Limitations

Several limitations should be noted when interpreting these findings. First, PM2.5 was used as the sole indicator of air quality in this paper, potentially overlooking other air pollutants that also affect public health, such as NO_2, SO_2, and VOCs. Second, the study only focuses on Beijing and Hanoi, making the results less appropriate for generalization and transferral to urban contexts with different population densities, infrastructures, or governance systems. Third, while PM2.5 trends are analyzed alongside policy timelines, proving a direct causality is impossible given other external influences on air quality, including industrial relocation, regional pollution transport, weather, and temporary events. Finally, not all policies are transferable across cities due to socioeconomic, cultural, and regulatory variations. Hence, future research could expand to multiple pollutants, additional cities, and cross-sector policy influences for a more comprehensive assessment of urban air quality management.

11. Conclusion

This paper examined the current status of air pollution in Hanoi and Beijing from mid-2016 to mid-2024, using PM2.5 as the core metric. The findings suggested that: while Beijing has successfully mitigated the impacts of air pollution through rigorous regulatory measures, Hanoi has shown modest progress. Policies aimed at improving air quality were then reviewed for both cities, focusing on transport-related measures for Beijing and a broader range of fields for Hanoi. A thorough table was compiled, categorizing and contrasting policies in both cities. Main differences in each category were then identified and briefly discussed. Subsequently, Beijing's policies were assessed if they are suitable for Hanoi's local application, proposing recommendations for air pollution abatement to the municipal government. The review also took into account cultural and socioeconomic factors to outline potential adjustments for effective policy adoption.

This comparative survey aims to help Vietnam and other countries streamline existing policies to accelerate progress towards better air quality through transport measures. Nevertheless, there are certain shortcomings in this study, which can be resolved in future research. As the analysis is limited to two cities and only focuses on PM2.5, future studies should expand to cover multiple pollutants (such as NO2, SO2, and VOCs) and include additional urban contexts with varying population densities or governance systems to improve generalizability. Furthermore, research should also explore cross-sector policy influences, as improvements in Beijing's air quality resulted from multiple factors, not transport alone, while accounting for the non-transferability of some policies due to socioeconomic and cultural differences. Still, this paper serves as an introduction to comparative air pollution and related policies in Hanoi and Beijing, supporting Hanoi's efforts in mitigating air pollution, and informing future comparative research on urban transport policies.

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Mentor Contribution Statement

Dr. Samantha Farquhar supported this project from its inception through the desk review process. She assisted in refining key arguments and provided valuable guidance on the paper's structure, analytical reasoning, data collection, and processing methods. She also suggested the appropriate scope and depth of each paragraph presented in the study. Additionally, her strategic advice on addressing reviewer feedback helped integrate external comments while maintaining the study's original focus. Her mentorship was instrumental in improving the scholarly quality and coherence of the manuscript.

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