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Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

Abstract

Air pollution is a major environmental problem across the world, especially in developing countries, and Vietnam is no exception. A national political and economic hub, Hanoi is facing severe pollution, even topping the global chart of most polluted cities in early 2025. Current levels of air pollution in Hanoi are exceptionally high, with research indicating vehicles are the primary factor. This situation mirrors the past experience of Beijing, a famous success story in addressing air pollution through constant regulatory adjustments. This paper reviews previous academic studies and news articles to produce a comprehensive table that compares policies implemented in each city. It also gathers PM2.5 levels in both cities to show that Hanoi's values exceeded those of Beijing in recent years, suggesting a lack of timely, effective policies. The analyses conclude that some of Beijing's policies may be suitable for Hanoi to apply locally, 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, by contrast, appear impractical for adoption. Ultimately, these findings are intended to guide Vietnamese policymakers in tackling air pollution more effectively.

Keywords: air pollution, PM2.5, transportation, policy, Hanoi, Beijing.

1. Introduction

Despite its current relatively low urban population, Southeast Asia has been experiencing rapid urban growth (Das & Paul, 2021). This trend is reflected by the case of Vietnam: in 1986, Vietnam's urban population was under 13 million, but by 2019, it reached 37 million (World Bank, 2020). Given that Vietnam's national transport structure—characterized by space constraints and inadequate infrastructure—is strongly conducive to personal vehicle use, a growth in population likely increases private vehicle ownerships, specifically cars and motorbikes. In 2011, the numbers of registered cars and motorbikes in Hanoi were estimated at 235,000 and 4 million, respectively.

Thanks to Hanoi's strikingly high 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 air deterioration in Hanoi (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 serious risk.

Colonized by China for over a millenium, Vietnam has been subject to heavy Chinese influences in culture, customs, and religions; politically, both countries are socialist states led by their respective Communist party. Nevertheless, a divergence emerges when it comes to present air quality. On one hand, China has remarkably progressed 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), NO_2 (Nitrogen Dioxide), SO_2 (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 by IQAir, a world leader in air quality apps. Its capital, Hanoi, was named the eighth most polluted city in the world (Unicef, 2024). As a result, an essential question arises: Can air pollution control policies from China be applied to Vietnam, and if so, to what degree? Considering the status of this issue in both countries, it is advisable for Vietnam to look at the key drivers of China’s success so far in combating air pollution and see whether they are applicable in the Vietnamese context.

While many studies dedicated to air pollution have examined China and Vietnam separately, no research on this topic covering both nations has been conducted. Hence, this paper aims to offer an overview of the recent battle against air pollution in both countries, thereby drawing lessons for application to the Vietnamese context. By reviewing the scholarly literature, this paper, with a focus on Beijing (China) and Hanoi (Vietnam), examines the current state of air pollution in both cities. It also compares their transport-related anti-air pollution policies and identifies Hanoi’s areas for improvement based on Beijing’s past experience while accounting for certain limitations in policy transfer between the two cities.

2. Methodological Approach

In order to understand air pollution policies of Hanoi and Beijing, a scoping review was conducted using Google Scholar and Google News to search for previous studies in the field, as well as recent regulatory updates of the government. In this paper, major policy changes were introduced, briefly summarized, and then compared in light of municipal differences in socioeconomic and political contexts.

3. What does recent data show?

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. 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 of pollutants 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 PM2.5 threshold for absolute safety against adverse health effects has been determined (Yu et al., 2023). Moreover, in its updated Air Quality Guidelines (2021), the World Health Organization (WHO) recognised PM2.5 as a classical air pollutant and recommended a threshold of 5 µg/m3 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.

This review compares the quarterly average of PM2.5 from 2016 to 2024 in Beijing and in Hanoi to understand how and to what extent the policies reviewed in each city may have impacted air quality. In order to account for the huge difference between Beijing's and Hanoi's sizes of urban population, the quarterly average PM2.5 concentrations are evaluated per capita (µg/m3/person) for a fairer assessment and comparison (Figure 1).

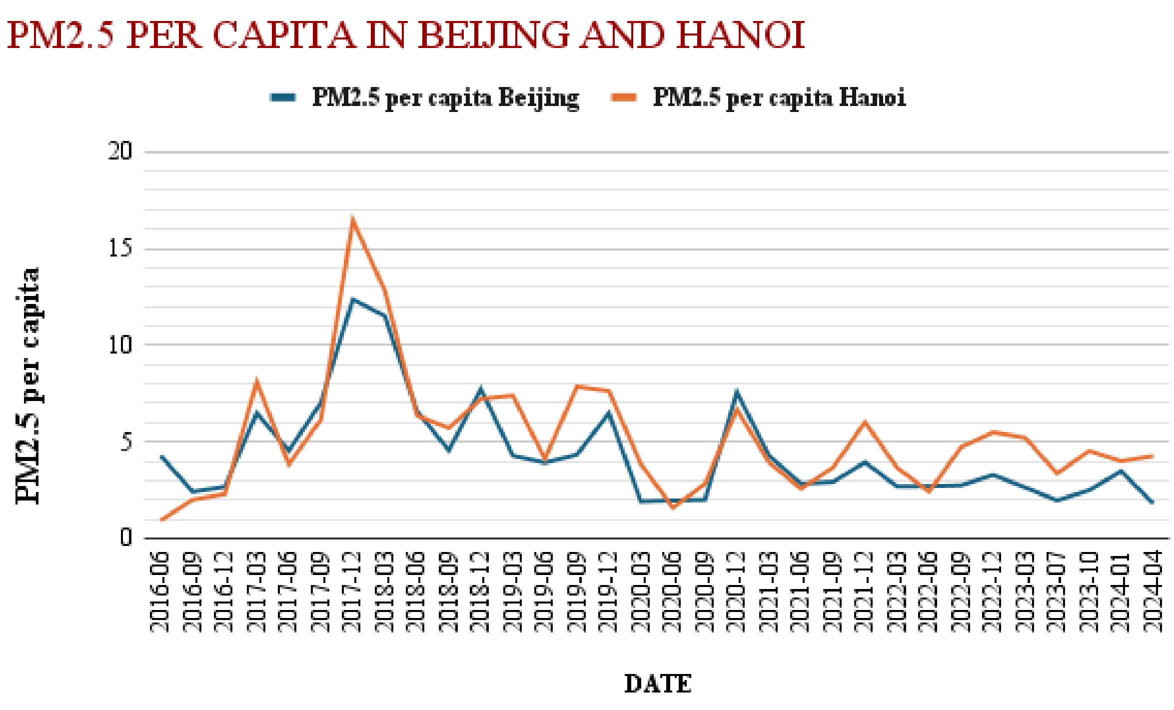

Figure 1 PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to September 2024

Both cities show strong seasonality, but Hanoi's is generally higher and more volatile. The most pronounced spikes occur in late 2017–early 2018, with winter peaks in 2018–2019 and 2020–2021. Dips occurred around mid-2020 and mid-2021, which likely reflected pandemic-era slowdowns, were followed by a rebound in late-2021. From 2022 onwards, most of Beijing's values were between ~2–4 μg/m³ with smaller seasonal swings, whereas those of Hanoi were higher, roughly ~4–6 μg/m³ with occasional winter bumps. Overall, while Beijing's amplitude seems to have dampened over time, Hanoi's remains high with less evidence of a structural step-down. These patterns suggest the effectiveness of Beijing's measures, and imply that Hanoi still has substantial challenges to resolve.

Taken against policy timing, the contrast is consistent with each city's strategy. Beijing's earlier fuel and vehicle controls, scrappage of high emitters, and long-running traffic restrictions align with a lower baseline and smaller seasonal peaks in recent years (Yang et al., 2015). Hanoi's 2019–2021 actions targeted household fuels and open burning, which likely helped curb the most extreme spikes seen in 2017–2018, but its transport levers (motorbike testing, LEZ/cordons) only begin in 2025–2028, so an extensive, durable transport-driven drop is yet to be observed in the series (Vietnam News, 2023; Vietnam News, 2019; Vietnam News, 2024; Vu Tuan, 2025). In short: Beijing resembles a mature, policy-stabilized regime; Hanoi appears mid-transition, with time needed for transport measures to prove their efficacy.

Health-wise, the World Health Organization's annual guideline on PM2.5 is 5 μg/m³. Recent months' PM2.5 levels in Beijing often fall near or below that threshold; meanwhile, Hanoi still records many months above it. That said, month-to-month variation reflects weather and region-wide influences (e.g., stagnation events, biomass burning), so regulatory effects are better analyzed from sustained changes than single spikes.

4. 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 (Environment, 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 centre (Environment, 2019; Yang et al., 2015).

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. 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; Z. 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 (Environment, 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 (Environment, 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% (J. 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 from the metropolitan area since late 2014 (Z. 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; Z. 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 (Z. 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 (Z. 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 (Z. 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.

5. 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, 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, 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 LEZ 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 LEZ 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 (Jan 13, 2012) approved a fixed air-quality monitoring network to 2020, while Decision 02/2005/QĐ-UB and Decision 55/2009/QĐ-UBND require construction sites to control dust and maintain sanitation. These actions were important for PM reductions alongside traffic measures (Vietnam News, 2022).

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

Overall, Beijing and Hanoi are working towards the same objective, cleaner air, but with different approaches. Beijing started early by addressing what enters the tank. It pushed cleaner fuels (down to 10 ppm sulfur and no lead) and required gas stations to capture gasoline vapors, which allows modern emissions equipment to work better. Meanwhile, Hanoi can't set its own fuel rules (those are nationally determined), so its new powers focus on access: starting in 2025, the city uses low-emission zones (LEZs) and road "cordons" to favor cleaner vehicles in key areas.

For new and in-use vehicles, Beijing moved faster in implementing standards and enforced them more rigorously. It introduced strict limits for new cars and trucks; used a color-label system, roadside remote sensing; and ran an inspection/maintenance program to identify and retire the most polluting vehicles. Hanoi follows national standards for new vehicles and is now developing its enforcement tools: periodic emissions testing for motorbikes slated for 2027 (which are piloted in Hanoi and Ho Chi Minh City before expansion).

Traffic management also reflects different strategies. Beijing limits car ownership with a license-plate lottery (since 2011), lays down weekday "last-digit" driving rules, bans motorcycles inside the 4th Ring Road, and keeps high-emitting yellow-label vehicles out entirely. Hanoi, by contrast, doesn't use lotteries or last-digit rules; instead, it's restricting in phases where higher-emitting vehicles can go: a 2017 decision sets up a phase-out of gasoline motorbikes in the urban core by 2030, with a firm cordon inside Ring Road 1 on July 1, 2026, and a wider zone in 2028. LEZs will then scale up thereafter.

Beyond traffic, while Beijing's headline moves were mostly on-road, Hanoi prioritized major non-traffic contributors inside the city: it eliminated honeycomb charcoal stoves by 2021 and banned open burning of crop waste and trash from 2020. Both cities are also pushing cleaner fleets, but in different ways: Beijing built large CNG/LNG and NEV programs whereas Hanoi is linking bus and taxi electrification to its LEZ and cordon timelines toward 2030.

On monitoring and enforcement, Beijing already has a mature system: an extensive air-quality network, roadside testing, and large scrappage programs. Hanoi has a city AQ (air quality) network and district enforcement teams for stove and burning bans, and upcoming testing centers to police motorbike emissions.

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 more limited regulatory authority and later policy start.

Based on these comparisons, a comprehensive table was created (Table 1).

Air Pollution Policy/Strategy	**Beijing**	**Hanoi**
Fuel quality & vapor recovery	Led the nation on cleaner fuels (to 10 ppm sulfur) and gas-station Stage I/II vapor recovery with retrofits before the 2008 Olympics.	No city-specific fuel-quality mandates; fuel is set nationally. LEZ authority (2025) can indirectly tighten via access rules.
New-vehicle emission standards	Applied Euro-pathway early (Beijing 1 in 1999 and China 5 by 2013), often ahead of the national timeline.	Follows national standards; new local authority (Capital Law 2025) to set tighter access by emission tier within LEZs.
In-use vehicle controls (I/M, remote sensing)	Robust I/M and roadside remote sensing; color label system (green/yellow) enabled targeted scrappage.	Periodic emissions testing for motorbikes slated to begin in 2027 (Hanoi/HCMC first), phasing nationwide by 2030.
Traffic control and usage restrictions	Odd-even/last-digit weekday restrictions started during the 2008 Olympics and continued (modified).	Not citywide last-digit rules; instead, phased access limits for high-emitting/fossil-fuel vehicles via LEZs and cordons.
Vehicle population control	License-plate lottery since 2011; annual caps tightened (240k to 150k).	No lottery; strategy is to restrict where/when certain vehicles can circulate (zone-based).
Low-emission zones (LEZ)	Piloted YLV bans and zone-based controls; studied broader LEZ in the mid-2010s.	Legal authority from 2025; pilots in central districts from 2025 with expansion after 2030.

Motorbike restrictions	Motorcycles restricted within 4th Ring Road; focus on YLV ban (2014).	2017 resolution to phase out gasoline motorbikes in urban core by 2030; firm cordon inside Ring Road 1 on 1 Jul 2026, expand in 2028.
Alternative-fuel fleets	CNG/LNG bus rollout; NEV promotion, including separate license caps for NEVs.	EV transition targets for public transport/taxis toward 2030 aligned with LEZ/cordon rollout.
Monitoring & enforcement tools	Expanded AQ network; empowered BEPB for roadside testing; strong scrappage programs for YLVs.	City AQ monitoring network; district-level enforcement for stove/open-burning bans; building out motorbike testing centers.
Household fuels & Open burning	Controls exist but less emphasis citywide; focus remained on transport and industry (coal-to-gas campaign was mostly regional/national).	Directive to eliminate 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; ongoing enforcement.

Table 1. Beijing and Hanoi's transport-related policies targeted at air pollution

7. Discussion:

Ultimately, the review of policies and recent data show that Beijing has experienced a steady decline in PM2.5 per capita. This trend reflects the relative success of Beijing's efforts to tackle air pollution. On the contrary, Hanoi's PM2.5 per capita values fluctuated more dramatically throughout the recorded period, displaying a stable or slightly upward trend over the last 4 years. This suggests that air pollution in the city remains insufficiently addressed or is worsening. Furthermore, among the 100 months illustrated in the chart, Hanoi's PM2.5 per Capita exceeded Beijing's in 70% of the cases. This reality serves as a wake-up call for Hanoi, urging it to take prompt action or risk the city's public health and environment.

Hanoi can clean up its air, but it needs to introduce its new measures in a logical sequence and reinforce them with steady enforcement. Beijing's success in tackling vehicular air pollution highlights that progress comes from a set of actions maintained over the years. They include tight vehicle regulations, clear restrictions on where gross-emitting vehicles can operate, and rigorous follow-through. While Hanoi has already addressed several non-traffic sources, such as charcoal “honeycomb” stoves and open burning, its next goal should be to implement low-emission zones (LEZs) and inner-city cordons in a straightforward, equitable, and consistent way.

However, to be more impactful, some policies could be transferred or adapted from Beijing to Hanoi. For instance, zone access with clear rules. Hanoi could start small (inside Ring Road 1), expand on a published schedule, and use cameras so enforcement needn’t depend on spot checks. Additionally, Hanoi could target the worst polluters first and use emissions testing (and quick roadside checks where possible) to find “super-emitters,” then offer trade-in or scrappage bonuses tied to cleaner replacements—ideally electric motorbikes. Hanoi could also make compliance easy by standardizing inspection procedures then linking test results to LEZ access, and storing everything digitally for better organization.

However, it should be emphasized that a difference in cultural contexts between Beijing and Hanoi does exist. Thus, there are some policies that were successful in Beijing, but would likely not be successful in Hanoi. For example, Beijing’s license-plate lottery and weekday last-digit bans worked there, but they’re not a great fit for Hanoi. Hanoi is a motorbike city, and many people use their bikes to earn a living. Limiting how many vehicles exist (lottery) or which plates can drive on a given day (last-digit) could hit lower-income riders the hardest and deliver less air-quality benefit than smarter where-you-can-go rules. Also, Beijing could order cleaner fuel and early vapor recovery systems at gas stations; however, Hanoi can’t set fuel specs on its own. Instead, it should push nationally for those changes while using city purchasing (e-buses, e-taxis, municipal fleets) to promote cleaner technologies into the market.

Local context matters. To keep the transition fair, any LEZ should include subsidies in the form of hardship exemptions, vouchers or micro-loans to help riders switch to cleaner motorbikes, and practical charging or battery-swap options in dense neighborhoods. Hanoi’s budgets and staffing are more limited than Beijing’s, so it is recommended that Hanoi roll out cameras, test centers, scrappage funding in phases and clearly signal what’s coming ahead a sufficient amount of time (e.g., 2026 inner cordon, 2028 expansion). It should keep working on non-traffic sources too: make the open-burning ban doable by funding straw collection and alternative uses (compost, biochar), and continue moving heavy industry out of residential districts.

8. Conclusion

In this paper, I 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 is lagging behind. 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 the municipal government with recommendations for air pollution abatement. 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 that can be resolved in future research. First, air pollution in Hanoi and Beijing is evaluated exclusively through PM2.5 values, which may overlook the significance of other pollutants in degraded air quality and risk oversimplifying their relationships. Second, improvements in Beijing's air quality may have been the collective efforts of multiple sectors, not transport alone. Thus, it is recommended that extensive studies covering policies across various sectors be conducted for a more comprehensive understanding. Still, this paper serves as an introduction to comparative air pollution and related policies in Hanoi and Beijing, laying the foundation for further studies into this topic and aiding Hanoi in its ongoing battle against air pollution.

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This is a promising paper with a timely, relevant topic and well-structured argument. The research question is clear, the paper is well-organized, and the narrative is both clear and strong throughout. The paper features a good synthesis of existing scholarship, with draws from peer-reviewed sources, international reports, and government documents, showing extensive and real research effort. Generally speaking, the trajectories of Beijing and Hanoi's trajectories in terms of air pollution appear to be pretty accurate, fairly nuanced, and well-described in the paper.

However, before we can send it to peer review, we need clarification on (and perhaps expansion to) the methodology (mainly the use of PM2.5 per capita to quantify emissions), a more formal academic tone, and slightly stronger engagement with the literature and limitations. While we believe that these relatively minor fixes could be fixed upon peer review with *Convergence Journal* (and peer reviewers are well-placed to critique and guide the author to fix these things), we believe that the paper will leave a stronger first impression with them and benefit upon further revisions after these initial fixes have been taken:

1. The unconventional yet interesting PM2.5 per capita metric could perplex reviewers, even though it makes sense when trying to connect environmental concerns with sociopolitical ones. The author should clarify or justify this metric before review.
    a. Where else has this been used in the literature? Could you discuss this a bit more. Since PM2.5 alone is a bit more common, it might be good to actually feature both values.
    b. (Optional) maybe you can include at least one additional pollutant, such as NO_2 or O_3, in your analyses/discussion to avoid over-reliance on PM2.5 alone
2. The author should be more careful about how they establish causality between specific policies and PM2.5 trends. After all, many other factors influence air quality, and I am not sure if the data presented account for this. Maybe this should just be mentioned or touched on somewhat!
3. Some of the phrasing seems a bit informal and presents as if you are advocating for policy in a more popular sphere rather than stating more academic, scholarly analysis and synthesis (e.g., "wake-up call," "super-emitters"). This sort of language could be toned down and replaced with more academically precise phrasing. There is nothing wrong with making informed policy recommendations carefully backed up, supported, and tied to evidence, but these should be more formal.
4. The limitations section could be further expanded (influence of meteoreology, industrial relocation, regional transport policy)
    a. This sort of relates to point 2 above. For instance, how do we know that these countries are not just relocating or curbing industries/factories that pollute the inside of cities and moving/expanding production into less populated areas? Or vice-versa?

Overall, this is already a fairly strong submission, but some fairly quick fixes and touch-ups could greatly benefit it if the student is ultimately going to resubmit their paper to *Convergence Journal*.

[Redacted by Managing Editor]

Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

Abstract

Air pollution is a major environmental problem across the world, especially in developing countries, and Vietnam is no exception. A national political and economic hub, Hanoi is facing severe pollution, even ranked among the world's most polluted cities in early 2025. Current levels of air pollution in Hanoi are exceptionally high, with research indicating vehicles are the primary factor. This situation mirrors the past experience of Beijing, a famous success story in addressing air pollution through constant regulatory adjustments. This paper reviews previous academic studies and news articles to produce a comprehensive table that compares policies implemented in each city. It also gathers PM2.5 levels in both cities to show that Hanoi's values exceeded those of Beijing in recent years, suggesting a policy gap and delayed responses. The analyses conclude that some of Beijing's policies may be suitable for Hanoi to apply locally, 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, by contrast, appear impractical for adoption. Ultimately, these findings are intended to provide Vietnamese policymakers with regulatory insights to tackle air pollution more effectively.

Keywords: air pollution, PM2.5, transportation, policy, Hanoi, Beijing.

1. Introduction

Despite its current relatively low urban population, Southeast Asia has been experiencing rapid urban growth (Das & Paul, 2021). This trend is reflected by 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). Given that Vietnam's national transport structure—characterized by space constraints and inadequate infrastructure—is strongly conducive to personal vehicle use, a growth in population likely increases private vehicle ownerships, specifically cars and motorbikes. In 2011, the numbers of registered cars and motorbikes in Hanoi were estimated at 235,000 and 4 million, respectively.

Thanks 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.

Having been under China's rule for over a millennium, Vietnam has been subject to heavy Chinese influences in culture, customs, and religions; politically, both countries are socialist states led by their respective Communist party. Nevertheless, 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), NO_2 (Nitrogen Dioxide), SO_2 (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 by IQAir, a world leader in air quality apps. Its capital, Hanoi, was named the eighth most polluted city in the world (UNICEF, 2024). As a result, an essential question arises: Can air pollution control policies from China be applied to Vietnam, and if so, to what degree? Considering the status of this issue in both countries, Vietnam may benefit from investigating the key drivers of China's success so far in combating air pollution and see whether they are applicable in the Vietnamese context.

While many studies dedicated to air pollution have examined China and Vietnam separately, no research on this topic covering both nations has been conducted. Hence, this paper aims to offer an overview of the recent battle against air pollution in both countries, thereby drawing lessons for application to the Vietnamese context. By reviewing the scholarly literature, this paper, with a focus on Beijing (China) and Hanoi (Vietnam), examines the current state of air pollution in both cities. It also compares their transport-related anti-air pollution policies and identifies Hanoi's areas for improvement based on Beijing's past experience while accounting for certain limitations in policy transfer between the two cities.

2. Methodological Approach

In order to understand air pollution policies of Hanoi and Beijing, a scoping review was conducted using Google Scholar and Google News to search for previous studies in the field, as well as recent regulatory updates of the government. In this paper, major policy changes were introduced, briefly summarized, and then compared in light of municipal differences in socioeconomic and political contexts.

3. What does recent data show?

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. 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 of pollutants 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 PM2.5 threshold for absolute safety against adverse health effects has been determined (Yu et al., 2023). Moreover, in its updated Air Quality Guidelines (2021), the World Health Organization (WHO) recognised PM2.5 as a classical air pollutant and recommended a threshold of 5 μg/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. These statistics serve as background information, providing context for the analysis of air pollution trends in Hanoi and Beijing that form the core focus of this paper.

This review compares the quarterly average of PM2.5 from 2016 to 2024 in Beijing and in Hanoi to understand how and to what extent the policies reviewed in each city may have impacted air quality. In order to account for the huge difference between Beijing's and Hanoi's sizes of urban population, the quarterly average PM2.5 concentrations are evaluated per capita (μg/m^3/person) for a fairer assessment and comparison (Figure 1). PM2.5 per capita refers to the concentration of PM2.5 normalised by population, which offers a measure of individual exposure and allows equitable comparisons across cities with different population sizes. While this approach has not been applied directly to PM2.5, it has been used in other contexts. For example, IPCC's Climate Change 2023: Synthesis Report (Intergovernmental Panel on Climate Change [IPCC], 2023) adopts GHG (greenhouse gas) emissions per capita as a key metric. Likewise, Indicator B-3.1 in the UNECE Guidelines for the Application of Environmental Indicators recommends GHG emissions per capita as a a statistical recommendation with a view to "harmonising the absolute value of GHG emissions for international comparisons" (United Nations Economic Commission for Europe [UNECE], 2025). Extending this precedent to PM2.5, this study employs PM2.5 per capita to provide a more balanced comparison of air quality impacts in Hanoi and Beijing by accounting for their demographic variations (Figure 1).

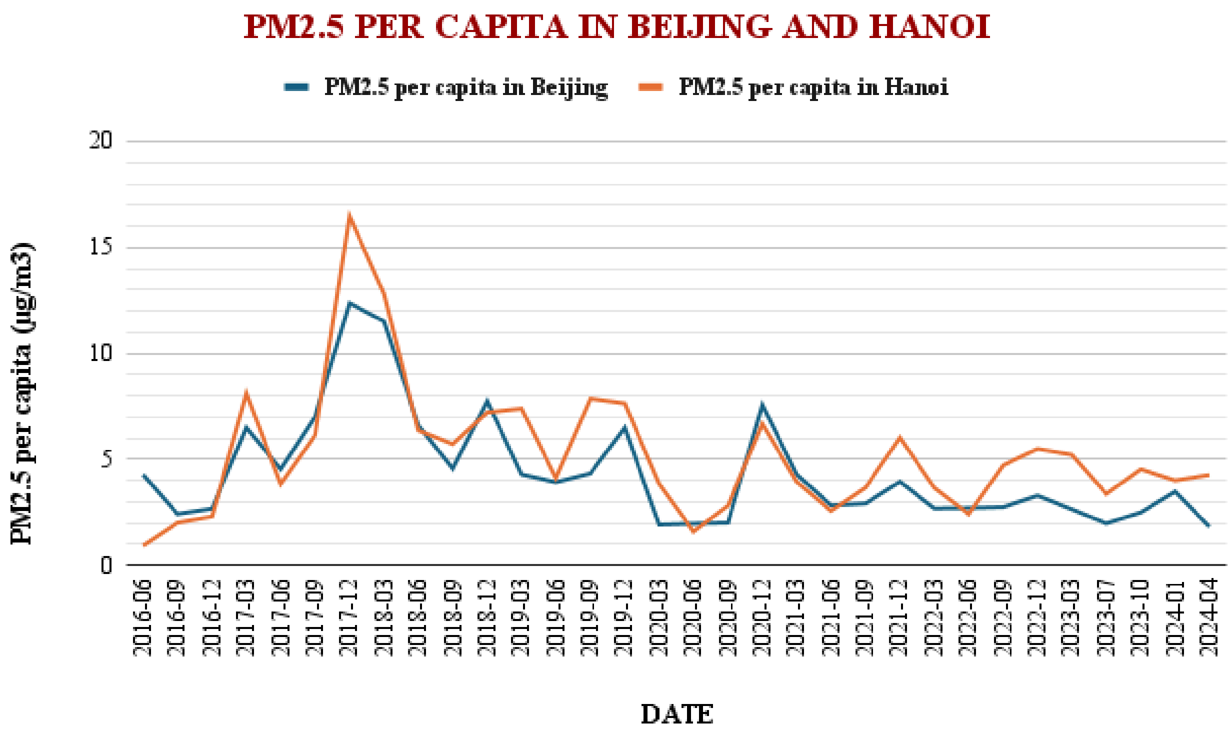

Figure 1 PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to September 2024

Both cities exhibit strong seasonality, but Hanoi's is generally higher and more volatile. The most pronounced spikes occur in late 2017–early 2018, with winter peaks in 2018–2019 and 2020–2021. Dips occurred around mid-2020 and mid-2021, which likely reflected pandemic-era slowdowns, were followed by a rebound in late-2021. From 2022 onwards, most of Beijing's values were between ~2–4 µg/m³ with smaller seasonal swings, whereas those of Hanoi were higher, roughly ~4–6 µg/m³ with occasional winter bumps. Overall, while Beijing's amplitude seems to have dampened over time, Hanoi's remains high with less evidence of a structural step-down. These patterns suggest the effectiveness of Beijing's measures and imply that Hanoi still has substantial challenges to resolve.

Taken against policy timing, the contrast is consistent with each city's strategy. Beijing's earlier fuel and vehicle controls, scrappage of high emitters, and long-running traffic restrictions align with a lower baseline and smaller seasonal peaks in recent years (Yang et al., 2015). Hanoi's 2019–2021 actions targeted household fuels and open burning, which likely helped curb the most extreme spikes seen in 2017–2018; however, its transport levers (motorbike testing, LEZs/cordons) only begin in 2025–2028, thus, an extensive, sustained transport-driven reduction has not yet been observed in the series (Vietnam News, 2023;

Vietnam News, 2019; Vietnam News, 2024; Vu Tuan, 2025). In short, Beijing resembles a mature, policy-stabilized regime, whereas Hanoi remains in transition with time needed for transport measures to prove their efficiency.

Nevertheless, it is difficult to establish a direct causality between PM2.5 fluctuations and specific policy outcomes, as other factors—such as meteorological conditions, regional pollution transport, and biomass burning—may also influence air quality. Therefore, the purpose of this research is to produce a high-level overview of PM2.5 patterns in both cities, framing them within policy contexts to demonstrate how regulatory trajectories may correspond with observed changes while acknowledging that policy-specific efficacy must be concluded from a wider body of literature and not solely from this high-level PM2.5 time series.

Health-wise, the World Health Organization's annual guideline on PM2.5 is 5 $\mu g/m^3$. Recent months' PM2.5 levels in Beijing often fall near or below that threshold; meanwhile, Hanoi still records many months above it. That said, month-to-month variation can result from temporary events or region-wide influences, so regulatory effects are better analyzed from sustained trends than single spikes.

4. 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 centre (UNEP, 2019; Yang et al., 2015).

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. 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; Z. 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% (J. 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 from the metropolitan area since late 2014 (Z. 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; Z. 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 (Z. 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 (Z. 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 CO_2 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 (Z. 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.

5. 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.

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

Overall, Beijing and Hanoi are working towards the same objective, cleaner air, but with different approaches. Beijing started early by addressing what enters the tank. It pushed cleaner fuels (down to 10 ppm sulfur and no lead) and required gas stations to capture gasoline vapors, which allows modern emissions equipment to work better. Meanwhile, Hanoi can't set its own fuel rules (those are nationally determined), so its new powers focus on access: starting in 2025, the city uses low-emission zones (LEZs) and road "cordons" to favor cleaner vehicles in key areas.

For new and in-use vehicles, Beijing moved faster in implementing standards and enforced them more rigorously. It introduced strict limits for new cars and trucks; used a color-label system, roadside remote sensing; and ran an inspection/maintenance program to identify and retire the most polluting vehicles. Hanoi follows national standards for new vehicles and is now developing its enforcement tools: periodic emissions testing for motorbikes slated for 2027 (which are piloted in Hanoi and Ho Chi Minh City before expansion).

Traffic management also reflects different strategies. Beijing limits car ownership with a license-plate lottery (since 2011), lays down weekday "last-digit" driving rules, bans motorcycles inside the 4th Ring Road, and keeps high-emitting yellow-label vehicles out entirely. Hanoi, by contrast, doesn't use lotteries or last-digit rules; instead, it's restricting in phases where higher-emitting vehicles can go: a 2017 decision sets up a phase-out of gasoline motorbikes in the urban core by 2030, with a firm cordon inside Ring Road 1 on July 1, 2026, and a wider zone in 2028. LEZs will then scale up thereafter.

Beyond traffic, while Beijing's headline moves were mostly on-road, Hanoi prioritized major non-traffic contributors inside the city: it eliminated honeycomb charcoal stoves by 2021 and banned open burning of crop waste and trash from 2020. Both cities are also pushing cleaner fleets, but in different ways: Beijing built large CNG/LNG and NEV programs whereas Hanoi is linking bus and taxi electrification to its LEZs and cordon timelines toward 2030.

On monitoring and enforcement, Beijing already has a mature system: an extensive air-quality network, roadside testing, and large scrappage programs. Hanoi has a city AQ (air quality) network and district enforcement teams for stove and burning bans, and upcoming testing centers to police motorbike emissions.

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 more limited regulatory authority and later policy start.

Based on these comparisons, a comprehensive table was created (Table 1).

Air Pollution Policy/Strategy	Beijing	Hanoi
Fuel quality & vapor recovery	Led the nation on cleaner fuels (to 10 ppm sulfur) and gas-station Stage I/II vapor recovery with retrofits before the 2008 Olympics.	No city-specific fuel-quality mandates; fuel is set nationally. LEZs authority (2025) can indirectly tighten via access rules.
New-vehicle emission standards	Applied Euro-pathway early (Beijing 1 in 1999 and China 5 by 2013), often ahead of the national timeline.	Follows national standards; new local authority (Capital Law 2025) to set tighter access by emission tier within LEZs.
In-use vehicle controls (I/M, remote sensing)	Robust I/M and roadside remote sensing; color label system (green/yellow) enabled targeted scrappage.	Periodic emissions testing for motorbikes slated to begin in 2027 (Hanoi/HCMC first), phasing nationwide by 2030.
Traffic control and usage restrictions	Odd-even/last-digit weekday restrictions started during the 2008 Olympics and continued (modified).	Not citywide last-digit rules; instead, phased access limits for high-emitting/fossil-fuel vehicles via LEZs and cordons.
Vehicle population control	License-plate lottery since 2011; annual caps tightened (240k to 150k).	No lottery; strategy is to restrict where/when certain vehicles can circulate (zone-based).
Low-emission zones (LEZs)	Piloted YLV bans and zone-based controls; studied broader LEZs in the mid-2010s.	Legal authority from 2025; pilots in central districts from 2025 with expansion after 2030.

Motorbike restrictions	Motorcycles restricted within 4th Ring Road; focus on YLV ban (2014).	2017 resolution to phase out gasoline motorbikes in urban core by 2030; firm cordon inside Ring Road 1 on 1 Jul 2026, expand in 2028.
Alternative-fuel fleets	CNG/LNG bus rollout; NEV promotion, including separate license caps for NEVs.	EV transition targets for public transport/taxis toward 2030 aligned with LEZs/cordon rollout.
Monitoring & enforcement tools	Expanded AQ network; empowered BEPB for roadside testing; strong scrappage programs for YLVs.	City AQ monitoring network; district-level enforcement for stove/open-burning bans; building out motorbike testing centers.
Household fuels & Open burning	Controls exist but less emphasis citywide; focus remained on transport and industry (coal-to-gas campaign was mostly regional/national).	Directive to eliminate 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; ongoing enforcement.

Table 1. Beijing and Hanoi's transport-related policies targeted at air pollution

7. **Discussion:**

Ultimately, the review of policies and recent data show that Beijing has experienced a steady decline in PM2.5 per capita. This trend reflects the relative success of Beijing's efforts to tackle air pollution. On the contrary, Hanoi's PM2.5 per capita values fluctuated more dramatically throughout the recorded period, displaying a stable or slightly upward trend over the last 4 years. This suggests that air pollution in the city remains insufficiently addressed or is worsening. Furthermore, among the 100 months illustrated in the chart, Hanoi's PM2.5 per Capita exceeded Beijing's in 70% of the cases. This pattern indicates that air pollution remains a major concern for Hanoi, underscoring the importance of timely government regulations to protect public health and the environment.

Hanoi can improve its air quality, but this means introducing its new measures in a logical sequence and reinforcing them with steady enforcement. Beijing's success in tackling vehicular air pollution highlights that progress comes from a set of actions maintained over the years. They include tight vehicle regulations, clear restrictions on where high-emitting vehicles can operate, and rigorous follow-through. While Hanoi has already addressed several non-traffic sources, such as charcoal "honeycomb" stoves and open burning, a recommended next step is to implement low-emission zones (LEZs) and inner-city cordons in a systematic, equitable, and persistent manner. To ensure this transition is socially just, especially for low-income motorbike users, phased implementation must be paired with financial support mechanisms, such as hardship exemptions, vouchers, or micro-loans, to facilitate the switch to cleaner motorbikes.

However, to be more impactful, some policies could be transferred or adapted from Beijing to Hanoi—for instance, zone access with clear rules. Hanoi's phased implementation could start from within Ring Road 1, followed by a scheduled expansion, and employ cameras to reduce the dependence on manual spot checks for enforcement. Additionally, Hanoi could prioritize the highest polluters for targeting and use emissions testing (and quick roadside checks where possible) to find vehicles with disproportionately high emissions, then offer trade-in or scrappage bonuses tied to cleaner replacements—ideally electric motorbikes. Hanoi could also foster compliance by standardizing inspection procedures then linking test results to LEZs access, and storing everything digitally for better organization.

Nonetheless, it is worth noting that a difference in cultural contexts between Beijing and Hanoi does exist. Thus, there are some policies that were successful in Beijing, but would be less feasible in Hanoi's context. For example, Beijing's license-plate lottery and weekday last-digit bans worked there, but they're not as suitable for Hanoi. Hanoi is a motorbike city, and many people use their bikes to earn a living. Limiting vehicle operation through lottery or alternating-day license plate permits could adversely affect lower-income riders, many of whom rely on motorcycles for livelihood, while yielding more limited environmental benefits than spatial restrictions. Also, Beijing could order cleaner fuel and early vapor recovery systems at gas stations; however, Hanoi can't set fuel specs on its own. Instead, it should push nationally for those changes while using city purchasing (e-buses, e-taxis, municipal fleets) to promote cleaner technologies into the market.

It is also crucial that local context be considered. To ensure an equitable transition, LEZs should be accompanied with subsidies like hardship exemptions, vouchers or micro-loans to help riders switch to cleaner motorbikes. In addition, practically sufficient charging or battery-swap options should be offered in dense neighborhoods. Hanoi's budgets and staffing are more limited than Beijing's, so it is advisable for Hanoi to roll out cameras, test centers, scrappage funding in phases and clearly signal what's coming ahead a sufficient amount of time (e.g., 2026 inner cordon, 2028 expansion). It should keep working on non-traffic sources too: facilitate the open-burning ban by funding straw collection and alternative uses (compost, biochar), and continue moving heavy industry out of residential districts.

8. Limitations:

Several limitations should be noted when interpreting these findings. First, PM2.5 per capita 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 analysed 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.

9. 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, laying the foundation for further studies into this topic and supporting Hanoi's efforts in mitigating air pollution.

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Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

Abstract

Air pollution is a major environmental problem across the world, especially in developing countries, and Vietnam is no exception. A national political and economic hub, Hanoi is facing severe pollution, even ranked among the world's most polluted cities in early 2025. Current levels of air pollution in Hanoi are exceptionally high, with research indicating vehicles are the primary factor. This situation mirrors the past experience of Beijing, a famous success story in addressing air pollution through constant regulatory adjustments. This paper reviews previous academic studies and news articles to produce a comprehensive table that compares policies implemented in each city. It also gathers PM2.5 levels in both cities to show that Hanoi's values exceeded those of Beijing in recent years, suggesting a policy gap and delayed responses. The analyses conclude that some of Beijing's policies may be suitable for Hanoi to apply locally, 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, by contrast, appear impractical for adoption. Ultimately, these findings are intended to provide Vietnamese policymakers with regulatory insights to tackle air pollution more effectively.

Keywords: air pollution, PM2.5, transportation, policy, Hanoi, Beijing.

1. Introduction

Despite its current relatively low urban population, Southeast Asia has been experiencing rapid urban growth (Das & Paul, 2021). This trend is reflected by 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). Given that Vietnam's national transport structure—characterized by space constraints and inadequate infrastructure—is strongly conducive to personal vehicle use, a growth in population likely increases private vehicle ownerships, specifically cars and motorbikes. In 2011, the numbers of registered cars and motorbikes in Hanoi were estimated at 235,000 and 4 million, respectively.

Thanks 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.

Having been under China's rule for over a millennium, Vietnam has been subject to heavy Chinese influences in culture, customs, and religions; politically, both countries are socialist states led by their respective Communist party. Nevertheless, 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), NO_2 (Nitrogen Dioxide), SO_2 (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 by IQAir, a world leader in air quality apps. Its capital, Hanoi, was named the eighth most polluted city in the world (UNICEF, 2024). As a result, an essential question arises: Can air pollution control policies from China be applied to Vietnam, and if so, to what degree? Considering the status of this issue in both countries, Vietnam may benefit from investigating the key drivers of China's success so far in combating air pollution and see whether they are applicable in the Vietnamese context.

While many studies dedicated to air pollution have examined China and Vietnam separately, no research on this topic covering both nations has been conducted. Hence, this paper aims to offer an overview of the recent battle against air pollution in both countries, thereby drawing lessons for application to the Vietnamese context. By reviewing the scholarly literature, this paper, with a focus on Beijing (China) and Hanoi (Vietnam), examines the current state of air pollution in both cities. It also compares their transport-related anti-air pollution policies and identifies Hanoi's areas for improvement based on Beijing's past experience while accounting for certain limitations in policy transfer between the two cities.

2. Methodological Approach

In order to understand air pollution policies of Hanoi and Beijing, a scoping review was conducted using Google Scholar and Google News to search for previous studies in the field, as well as recent regulatory updates of the government. In this paper, major policy changes were introduced, briefly summarized, and then compared in light of municipal differences in socioeconomic and political contexts.

3. What does recent data show?

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. 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 of pollutants in the National

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Ambient Air Quality Standards (Suh et al., 2000). These fine particles are also considered a major cause of premature death and illness, and no PM2.5 threshold for absolute safety against adverse health effects has been determined (Yu et al., 2023). Moreover, in its updated Air Quality Guidelines (2021), the World Health Organization (WHO) recognised 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. These statistics serve as background information, providing context for the analysis of air pollution trends in Hanoi and Beijing that form the core focus of this paper.

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(Optional) maybe you can include at least one additional pollutant, such as NO2 or O3, in your analyses/discussion to avoid over-reliance on PM2.5 alone

This review compares the quarterly average of PM2.5 from 2016 to 2024 in Beijing and in Hanoi to understand how and to what extent the policies reviewed in each city may have impacted air quality. In order to account for the huge difference between Beijing's and Hanoi's sizes of urban population, the quarterly average PM2.5 concentrations are evaluated per capita ($\mu g/m^3$/person) for a fairer assessment and comparison (Figure 1). PM2.5 per capita refers to the concentration of PM2.5 normalised by population, which offers a measure of individual exposure and allows equitable comparisons across cities with different population sizes. While this approach has not been applied directly to PM2.5, it has been used in other contexts. For example, IPCC's Climate Change 2023: Synthesis Report (Intergovernmental Panel on Climate Change [IPCC], 2023) adopts GHG (greenhouse gas) emissions per capita as a key metric. Likewise, Indicator B-3.1 in the UNECE Guidelines for the Application of Environmental Indicators recommends GHG emissions per capita as a a statistical recommendation with a view to "harmonising the absolute value of GHG emissions for international comparisons" (United Nations Economic Commission for Europe [UNECE], 2025). Extending this precedent to PM2.5, this study employs PM2.5 per capita to provide a more balanced comparison of air quality impacts in Hanoi and Beijing by accounting for their demographic variations (Figure 1).

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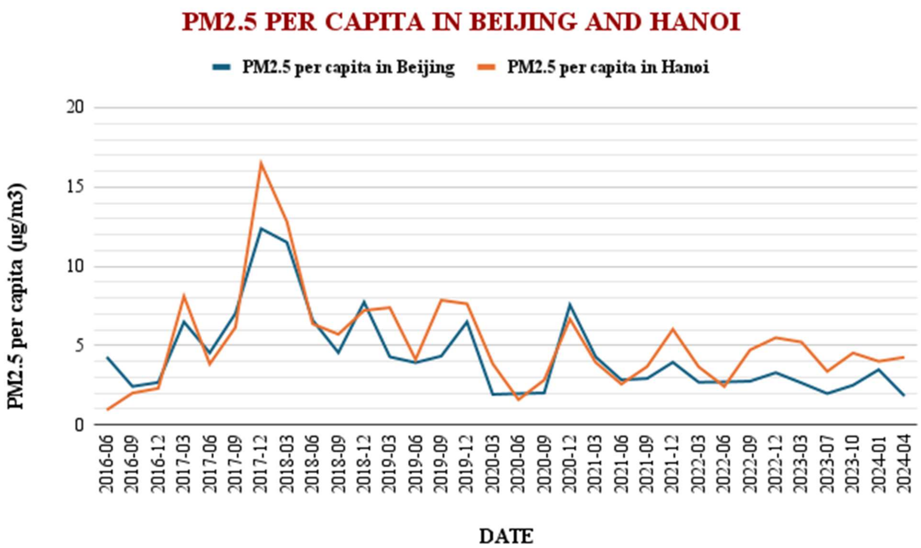

Figure 1 PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to September 2024

Both cities exhibit strong seasonality, but Hanoi's is generally higher and more volatile. The most pronounced spikes occur in late 2017–early 2018, with winter peaks in 2018–2019 and 2020–2021. Dips occurred around mid-2020 and mid-2021, which likely reflected pandemic-era slowdowns, were followed by a rebound in late-2021. From 2022 onwards, most of Beijing's values were between ~2–4 µg/m³ with smaller seasonal swings, whereas those of Hanoi were higher, roughly ~4–6 µg/m³ with occasional winter bumps. Overall, while Beijing's amplitude seems to have dampened over time, Hanoi's remains high with less evidence of a structural step-down. These patterns suggest the effectiveness of Beijing's measures and imply that Hanoi still has substantial challenges to resolve.

Taken against policy timing, the contrast is consistent with each city's strategy. Beijing's earlier fuel and vehicle controls, scrappage of high emitters, and long-running traffic restrictions align with a lower baseline and smaller seasonal peaks in recent years (Yang et al., 2015). Hanoi's 2019–2021 actions targeted household fuels and open burning, which likely helped curb the most extreme spikes seen in 2017–2018; however, its transport levers (motorbike testing, LEZs/cordons) only begin in 2025–2028, thus, an extensive, sustained transport-driven reduction has not yet been observed in the series (Vietnam News, 2023;

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- what is unconventional about this study is that it uses per capita values.

- Beijing's larger population logically emit more pollutants than Hanoi's smaller population do. Therefore, analyses based solely on absolute values may risk underestimating the severity of Hanoi's air pollution (esp relative to Beijing's), as is the case for other small but rapidly urbanizing cities. Even though their aggregate averages are lower than larger counterparts, their dwellers may actually bear a heavier exposure burden.

-> adding per capita values beside absolute ones provide a fairer assessment of air status + health burden inflicted across cities with different sizes.

Other literature: although using per capita values for analyses is unconventional in air quality research, it is practiced in other branches of environmental studies. For instance, greenhouse-gas emissions (in IPCC report) & energy consumption (in World Bank report) are employed to account for equity, highlight the average access/exposure, and imply the sociopolitical consequences of those figures.

I intend to include both absolute PM2.5 and per capita values in this paper. While the former ensures comparability with existing research, the latter provides additional basis for sociopolitical insights.

Vietnam News, 2019; Vietnam News, 2024; Vu Tuan, 2025). In short, Beijing resembles a mature, policy-stabilized regime, whereas Hanoi remains in transition with time needed for transport measures to prove their efficiency.

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Nevertheless, it is difficult to establish a direct causality between PM2.5 fluctuations and specific policy outcomes, as other factors—such as meteorological conditions, regional pollution transport, and biomass burning—may also influence air quality. Therefore, the purpose of this research is to produce a high-level overview of PM2.5 patterns in both cities, framing them within policy contexts to demonstrate how regulatory trajectories may correspond with observed changes while acknowledging that policy-specific efficacy must be concluded from a wider body of literature and not solely from this high-level PM2.5 time series.

Health-wise, the World Health Organization's annual guideline on PM2.5 is 5 $\mu g/m^3$. Recent months' PM2.5 levels in Beijing often fall near or below that threshold; meanwhile, Hanoi still records many months above it. That said, month-to-month variation can result from temporary events or region-wide influences, so regulatory effects are better analyzed from sustained trends than single spikes.

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4. 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 centre (UNEP, 2019; Yang et al., 2015).

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. 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; Z. 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% (J. 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 from the metropolitan area since late 2014 (Z. 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; Z. 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 (Z. 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 (Z. 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 (Z. 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.

5. 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.

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

Overall, Beijing and Hanoi are working towards the same objective, cleaner air, but with different approaches. Beijing started early by addressing what enters the tank. It pushed cleaner fuels (down to 10 ppm sulfur and no lead) and required gas stations to capture gasoline vapors, which allows modern emissions equipment to work better. Meanwhile, Hanoi can't set its own fuel rules (those are nationally determined), so its new powers focus on access: starting in 2025, the city uses low-emission zones (LEZs) and road "cordons" to favor cleaner vehicles in key areas.

For new and in-use vehicles, Beijing moved faster in implementing standards and enforced them more rigorously. It introduced strict limits for new cars and trucks; used a color-label system, roadside remote sensing; and ran an inspection/maintenance program to identify and retire the most polluting vehicles. Hanoi follows national standards for new vehicles and is now developing its enforcement tools: periodic emissions testing for motorbikes slated for 2027 (which are piloted in Hanoi and Ho Chi Minh City before expansion).

Traffic management also reflects different strategies. Beijing limits car ownership with a license-plate lottery (since 2011), lays down weekday "last-digit" driving rules, bans motorcycles inside the 4th Ring Road, and keeps high-emitting yellow-label vehicles out entirely. Hanoi, by contrast, doesn't use lotteries or last-digit rules; instead, it's restricting in phases where higher-emitting vehicles can go: a 2017 decision sets up a phase-out of gasoline motorbikes in the urban core by 2030, with a firm cordon inside Ring Road 1 on July 1, 2026, and a wider zone in 2028. LEZs will then scale up thereafter.

Beyond traffic, while Beijing's headline moves were mostly on-road, Hanoi prioritized major non-traffic contributors inside the city: it eliminated honeycomb charcoal stoves by 2021 and banned open burning of crop waste and trash from 2020. Both cities are also pushing cleaner fleets, but in different ways: Beijing built large CNG/LNG and NEV programs whereas Hanoi is linking bus and taxi electrification to its LEZs and cordon timelines toward 2030.

On monitoring and enforcement, Beijing already has a mature system: an extensive air-quality network, roadside testing, and large scrappage programs. Hanoi has a city AQ (air quality) network and district enforcement teams for stove and burning bans, and upcoming testing centers to police motorbike emissions.

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 more limited regulatory authority and later policy start.

Based on these comparisons, a comprehensive table was created (Table 1).

Air Pollution Policy/Strategy	Beijing	Hanoi
Fuel quality & vapor recovery	Led the nation on cleaner fuels (to 10 ppm sulfur) and gas-station Stage I/II vapor recovery with retrofits before the 2008 Olympics.	No city-specific fuel-quality mandates; fuel is set nationally. LEZs authority (2025) can indirectly tighten via access rules.
New-vehicle emission standards	Applied Euro-pathway early (Beijing 1 in 1999 and China 5 by 2013), often ahead of the national timeline.	Follows national standards; new local authority (Capital Law 2025) to set tighter access by emission tier within LEZs.
In-use vehicle controls (I/M, remote sensing)	Robust I/M and roadside remote sensing; color label system (green/yellow) enabled targeted scrappage.	Periodic emissions testing for motorbikes slated to begin in 2027 (Hanoi/HCMC first), phasing nationwide by 2030.
Traffic control and usage restrictions	Odd-even/last-digit weekday restrictions started during the 2008 Olympics and continued (modified).	Not citywide last-digit rules; instead, phased access limits for high-emitting/fossil-fuel vehicles via LEZs and cordons.
Vehicle population control	License-plate lottery since 2011; annual caps tightened (240k to 150k).	No lottery; strategy is to restrict where/when certain vehicles can circulate (zone-based).
Low-emission zones (LEZs)	Piloted YLV bans and zone-based controls; studied broader LEZs in the mid-2010s.	Legal authority from 2025; pilots in central districts from 2025 with expansion after 2030.
Motorbike restrictions	Motorcycles restricted within 4th Ring Road; focus on YLV ban (2014).	2017 resolution to phase out gasoline motorbikes in urban core by 2030; firm cordon inside Ring

		Road 1 on 1 Jul 2026, expand in 2028.
Alternative-fuel fleets	CNG/LNG bus rollout; NEV promotion, including separate license caps for NEVs.	EV transition targets for public transport/taxis toward 2030 aligned with LEZs/cordon rollout.
Monitoring & enforcement tools	Expanded AQ network; empowered BEPB for roadside testing; strong scrappage programs for YLVs.	City AQ monitoring network; district-level enforcement for stove/open-burning bans; building out motorbike testing centers.
Household fuels & Open burning	Controls exist but less emphasis citywide; focus remained on transport and industry (coal-to-gas campaign was mostly regional/national).	Directive to eliminate 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; ongoing enforcement.

Table 1. Beijing and Hanoi's transport-related policies targeted at air pollution

7. Discussion:

Ultimately, the review of policies and recent data show that Beijing has experienced a steady decline in PM2.5 per capita. This trend reflects the relative success of Beijing's efforts to tackle air pollution. On the contrary, Hanoi's PM2.5 per capita values fluctuated more dramatically throughout the recorded period, displaying a stable or slightly upward trend over the last 4 years. This suggests that air pollution in the city remains insufficiently addressed or is worsening. Furthermore, among the 100 months illustrated in the chart, Hanoi's PM2.5 per Capita exceeded Beijing's in 70% of the cases. This pattern indicates that air pollution remains a major concern for Hanoi, underscoring the importance of timely government regulations to protect public health and the environment.

Hanoi can improve its air quality, but this means introducing its new measures in a logical sequence and reinforcing them with steady enforcement. Beijing's success in tackling vehicular air pollution highlights that progress comes from a set of actions maintained over the years. They include tight vehicle regulations, clear restrictions on where high-emitting vehicles can operate, and rigorous follow-through. While Hanoi has already addressed several non-traffic sources, such as charcoal "honeycomb" stoves and open burning, a recommended next step is to implement low-emission zones (LEZs) and inner-city cordons in a systematic, equitable, and persistent manner. To ensure this transition is socially just, especially for low-income motorbike users, phased implementation must be paired with financial support mechanisms, such as hardship exemptions, vouchers, or micro-loans, to facilitate the switch to cleaner motorbikes.

However, to be more impactful, some policies could be transferred or adapted from Beijing to Hanoi—for instance, zone access with clear rules. Hanoi's phased implementation could start from within Ring Road 1, followed by a scheduled expansion, and employ cameras to reduce the dependence on manual spot checks for enforcement. Additionally, Hanoi could prioritize the highest polluters for targeting and use emissions testing (and quick roadside checks where possible) to find vehicles with disproportionately high emissions, then offer trade-in or scrappage bonuses tied to cleaner replacements—ideally electric motorbikes. Hanoi could also foster compliance by standardizing inspection procedures then linking test results to LEZs access, and storing everything digitally for better organization.

Nonetheless, it is worth noting that a difference in cultural contexts between Beijing and Hanoi does exist. Thus, there are some policies that were successful in Beijing, but would be less feasible in Hanoi's context. For example, Beijing's license-plate lottery and weekday last-digit bans worked there, but they're not as suitable for Hanoi. Hanoi is a motorbike city, and many people use their bikes to earn a living. Limiting vehicle operation through lottery or alternating-day license plate permits could adversely affect lower-income riders, many of whom rely on motorcycles for livelihood, while yielding more limited environmental benefits than spatial restrictions. Also, Beijing could order cleaner fuel and early vapor recovery systems at gas stations; however, Hanoi can't set fuel specs on its own. Instead, it should push nationally for those changes while using city purchasing (e-buses, e-taxis, municipal fleets) to promote cleaner technologies into the market.

It is also crucial that local context be considered. To ensure an equitable transition, LEZs should be accompanied with subsidies like hardship exemptions, vouchers or micro-loans to help riders switch to cleaner motorbikes. In addition, practically sufficient charging or battery-swap options should be offered in dense neighborhoods. Hanoi's budgets and staffing are more limited than Beijing's, so it is advisable for Hanoi to roll out cameras, test centers, scrappage funding in phases and clearly signal what's coming ahead a sufficient amount of time (e.g., 2026 inner cordon, 2028 expansion). It should keep working on non-traffic sources too: facilitate the open-burning ban by funding straw collection and alternative uses (compost, biochar), and continue moving heavy industry out of residential districts.

8. Limitations:

Several limitations should be noted when interpreting these findings. First, PM2.5 per capita 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 analysed 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.

9. 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, laying the foundation for further studies into this topic and supporting Hanoi's efforts in mitigating air pollution.

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The unconventional yet interesting PM2.5 per capita metric could perplex reviewers, even though it makes sense when trying to connect environmental concerns with sociopolitical ones. The author should clarify or justify this metric before review.

a. **Where else has this been used in the literature? Could you discuss this a bit more. Since PM2.5 alone is a bit more common, it might be good to actually feature both values.**

I have included the IPCC report and the UNECE guideline as examples where per capita metrics are used (especially the UNECE case, which aligns with my intended purpose when using PM2.5 per capita in this study). I searched but found no prior study employing this approach for PM2.5, so I believe this application in my paper could be a methodological innovation. I have also elaborated further on what PM2.5 per capita means and why it is advantageous in this context.

Regarding the recommendation to feature both values, this paper deliberately centers on the per-capita normalization of PM2.5 to allow an equitable, population-adjusted comparison between Hanoi and Beijing, ensuring that the analysis remains focused on how policy differences relate to pollutant exposure trends. Including absolute values, in my view, would add little interpretive value while complicating the paper's methodological clarity and focus.

b. **(Optional) maybe you can include at least one additional pollutant, such as NO_2 or O_3, in your analyses/discussion to avoid over-reliance on PM2.5 alone**

Collecting and analysing data for additional pollutants would significantly expand the paper's scope and complexity. Indeed, I believe that the primary aim of this paper is to examine policies and evaluate their adequacy and effectiveness rather than to conduct an extensive analysis of multiple air pollutants. The use of PM2.5 concentration here serves mainly as the contextual background for the hypothesis and regulatory analysis.

Recommendation: Revise and Resubmit

This is an ambitious and relevant comparative policy review that tackles a significant environmental challenge. The author demonstrates a strong capacity for synthesizing information from diverse sources and has chosen a timely topic with clear practical implications for policymakers in Hanoi. The compilation of policies into Table 1 is particularly useful and represents a solid foundation. However, the manuscript in its current form reads more like a comprehensive literature review and data summary than a cohesive analytical paper. To meet the journal's standards for rigor and clarity, significant revisions are needed to strengthen the methodological justification, deepen the analytical discussion, and refine the core argument. I am happy to review a revised version that addresses these points.

1. Refine the Methodological Approach and Justification:
Critique: The paper identifies its approach as a "scoping review" but does not detail the search strategy, inclusion/exclusion criteria, or the number of sources identified and screened. This lack of transparency makes the methodology difficult to assess or replicate. Furthermore, the use of "PM2.5 per capita" is a highly unusual and problematic metric. While the rationale (normalizing for population) is understandable, it is not a standard measure in air quality science. PM2.5 concentration is a measure of ambient exposure in the air, not a direct output of individual activity. Using it per capita can be misleading, as it implies that a city's air pollution is divided equally among its residents, which distorts the actual environmental conditions.

You need to greatly expand the Methodological Approach section. Specify the exact search terms, databases, and the time frame of the search. Describe how you selected the final sources for analysis. Regarding PM2.5, I strongly recommend re-plotting Figure 1 using standard, absolute PM2.5 concentrations ($\mu g/m^3$). You can still discuss population differences as a contextual factor in the text, but the primary metric must align with established scientific practice. This change will make your analysis more credible and interpretable.

2. Deepen the Analysis from Description to Argument:
The paper excels at describing “what” policies were implemented but spends less time analyzing “why” they were successful in Beijing or “how” their core principles can be abstracted for Hanoi. The discussion of "transferability" is a good start but remains somewhat surface-level. For instance, the conclusion that low-emission zones (LEZs) are suitable while license-plate lotteries are not is sensible, but the underlying reasons (e.g., governance structure, primary vehicle type, social equity) could be explored in much greater depth to build a more powerful argument.

Re-structure the **Discussion** section to be more argument-driven. After presenting the comparative data, create a framework for analysis. For example, you could analyze the policies based on criteria like:1)Technical Efficacy: How much does this policy reduce emissions?2) Institutional Feasibility:Does Hanoi have the legal and bureaucratic capacity to implement it?3)

Social & Political Acceptability: How will this policy be received by the public, especially considering Hanoi's reliance on motorbikes for livelihoods?
Use this framework to systematically evaluate each recommended policy transfer, moving beyond a simple list to a reasoned justification.

3. Strengthen the Link Between Data and Policy Conclusions:
The connection between the PM2.5 trends in Figure 1 and the subsequent policy analysis is currently weak. The text states it's difficult to establish causality, but then the data is used to make broad claims about Beijing's "success" and Hanoi's "delayed responses." A more nuanced interpretation is needed.

When discussing the PM2.5 trends, be more precise. Instead of saying Beijing's policies were successful, specify which clusters of policies (e.g., the pre-2010 fuel and new vehicle standards) appear to correlate with the beginning of its downward trend. For Hanoi, discuss how the observed volatility might reflect its current reliance on banning specific activities (stoves, burning) rather than a continuous, systemic regulatory framework for mobile sources. This will create a more logical and evidence-based flow from your data to your policy recommendations.

4. Enhance Precision in Language and Claims:
There are instances of overly broad or imprecise language. For example, the introduction mentions "Vietnam has been subject to heavy Chinese influences" but doesn't clearly link this historical fact to modern environmental policy capacity. The abstract states the paper "reviews previous academic studies and news articles," which undersells the original work of policy comparison.

Scrutinize the manuscript for sweeping statements and replace them with specific, focused claims. In the abstract and introduction, more accurately describe your contribution—e.g., "This paper provides a systematic comparative analysis of transport-related air pollution policies in Beijing and Hanoi..." This sounds more scholarly and confident.

Reviewer Report

Paper title: Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

Recommendations: **Major changes recommended**

Suggestions for improvement

The manuscript requires a thorough revision to address pervasive issues in sentence structure, grammar, and syntax. Insert a continuous line number or in case of page-based line numbers, please provide the page numbers. Although a better way is a continuous line number so that referencing can be easy.

Title suggestion:

The current title lacks academic strength. Please follow any of the below to be more effective manuscript:

- A Tale of Two Capitals: Policy Transfer for Sustainable Urban Mobility and Air Quality in Beijing and Hanoi.
- Decarbonizing the Urban Fleet: Analysing Beijing's Past as a Policy Blueprint for Hanoi's Vehicle Emissions Challenge.
- A Comparative Analysis of Vehicle Emissions Control Policies in Beijing and Hanoi.
- Mitigation Lessons for Rapid Urbanization: Hanoi's Potential to Learn from Beijing's Air Quality Management Experience.

Abstract

- **Lines 7 to 9**: Please revise this as follows. In an abstract, references cannot be cited, and mentioning specific years without citation is not appropriate. Suggested revision: *"Despite significant economic progress, Vietnam faces a critical environmental sustainability challenge rooted in severe urban air pollution, common to many developing nations. The capital, Hanoi, a vital political and economic hub, is a focal point of this crisis, facing persistent air quality degradation."*
- **Lines 13 to 14**: Kindly provide a clearer methodology. I am sharing some steps in the methodology section that should be followed in detail and then

briefly summarized in the abstract. It is important to specify how the authors conducted the literature search.

- Also, please remove the phrase “comprehensive table.” Any results or findings can be presented in tabular form, but this should not be explicitly mentioned in the abstract.

Main Text

- **Lines 29 and 30**: Please remove the dash (—) for consistency and clarity.
- **Lines 32 to 33**: The data cited from 2011 is outdated. Kindly provide more recent figures and appropriate references. It is important to reflect the current number of registered vehicles in Hanoi in relation to the city’s size and population.
- **Line 35**: Replace the phrase “thanks to” with “due to” to maintain academic tone.
- **Page 2, Line 4**: This statement is incorrect. Vietnam is an independent country and is not under China’s rule. Please revise this to reflect historical context, such as periods of Chinese rule or war-related influence.
- Please also review the manuscript for grammatical errors throughout.
- **Line 12**: A reference is needed to support the claim. If unavailable, please locate relevant research papers that substantiate the statement.
- **Line 13**: The reference mentioned is missing from the reference list. Additionally, the claim that UNICEF is working directly on air pollution appears questionable. Please verify the reliability of this reference and consider replacing it with a more appropriate source.
- **Lines 13 to 27**: This section repeats the same concept multiple times. It would be more effective to consolidate the content into a single paragraph. Suggested structure:
    - Identify the limitations observed in the existing literature.
    - Highlight the novelty of your work.
    - Clearly state the objectives of your study.
- It is also recommended to include statistics on air pollution in Hanoi to illustrate the severity of the issue and its impact on human health.

Study Area: It is recommended to add a dedicated heading titled *“Study Area”* immediately following the introduction. This section should present a comparative overview of both cities, covering trends in demographics, transportation infrastructure, and air pollution levels. Providing this context will help readers better understand the scope and relevance of the analysis. If possible, please include maps of the study areas to visually support the comparison and enhance geographic clarity.

Methodology

Please write this section following these steps:

Define the Scope and Objectives of your work

- Clearly state the research question or problem.
- Set boundaries: time period, geographic focus, type of studies (e.g., empirical, theoretical).

Develop a Search Strategy and write how you search data

- Choose relevant databases: Scopus, Web of Science, Google Scholar, PubMed, JSTOR, etc.
- Use Boolean operators and keyword combinations (e.g., "air pollution AND Hanoi/ Beijing" 'transportation OR air pollution' etc).
- Document your search terms, filters, and inclusion/exclusion criteria.
- Apply inclusion/exclusion criteria (e.g., peer-reviewed only, published after 2015).
- Prioritize high-quality, relevant, and recent studies.

Sample Size and Data Transparency: Please clarify how many studies were included in the literature review that informed the results. Additionally, specify how the empirical PM2.5 data was collected — for example, which monitoring stations were selected, and what criteria were used for their inclusion. It is also important to indicate the time frame your study covers (i.e., which years are included in the analysis) to ensure transparency and reproducibility.

Critically analyse the literature

- Evaluate strengths and weaknesses of each study.
- Discuss methodological limitations, sample sizes, biases, and relevance.

- Compare findings across studies to identify trends or gaps.

Line 37 onwards, the methods described should come under methodology section.

Results

The data presented under the heading ***"What does recent data show?"*** should be relocated to the **Results** section, as it reflects findings rather than introductory context. Additionally, if any methodological details are embedded within that section, they should be moved to the **Methodology** section to maintain structural consistency and ensure proper categorization of content.

Figure 1: The y-axis is labelled with months, yet the figure title refers to dates — please ensure consistency between the axis label and the figure description. Additionally, the data presented focuses on PM2.5 concentrations, which appear relatively similar between the two cities during 2017 and 2018. It would be helpful to explain the underlying reasons for the elevated values in both cities during that period, as well as the subsequent decline. **This trend suggests that it may be more insightful to examine other primary pollutants to better understand the broader dynamics of urban air pollution.**

Page 8 line 22 to 30, recheck for the consistency in font style used here.

It is also suggested to remove Headings 5 and 6, as the content under these sections largely overlaps with the information already presented in the table. Instead, consider integrating the relevant details directly into the table itself. For example, adding a reference column and including further contextual information would enhance the table's value and reduce redundancy. At present, the table and accompanying text are repetitive; consolidating them will improve clarity and streamline the presentation of findings.

Discussion: To strengthen the discussion section, it would be helpful to include examples of global cities that have successfully implemented effective air pollution control measures and urban health mitigation strategies. This comparative perspective can offer valuable insights and practical relevance. Additionally, the current comparison between Hanoi and Beijing appears weak, as the two cities differ significantly in terms of size, economic capacity, and governance structures. A more balanced or contextually aligned comparison would enhance the credibility and depth of the analysis.

Limitations and Conclusion: These sections are well-written and clearly presented. However, the **Methodology** section requires significant improvement. At present, there is no clear explanation of how the work was conducted. The authors should provide a detailed account of the research process, including how data was collected, analyzed, and interpreted. Strengthening this section is essential for ensuring transparency and academic rigor. The remaining suggestions relate to enhancing the presentation and reinforcing the logical flow of the study.

Reference

This section needs to be reconsidered. Several references are inconsistently formatted in the reference list. Also, check that all references cited in text are present in the list and vice versa. Please ensure that all references follow a single, consistent citation style throughout the manuscript. Additionally, the formatting of the reference list should be uniform — currently, some entries are in hanging indent format while others are not. Align all entries to the same style to maintain professional and academic presentation standards.

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Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

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

Abstract

Despite significant economic progress, Vietnam faces a critical environmental challenge rooted in severe urban air pollution, common to many developing nations. The capital, Hanoi, a vital political and economic hub, is a focal point of this crisis, facing persistent air quality degradation. Air pollution is a major environmental problem across the world, especially in developing countries, and Vietnam is no exception. A national political and economic hub, Hanoi is facing severe pollution, even ranked among the world's most polluted cities in early 2025. Current levels of air pollution in Hanoi are exceptionally high, with research indicating vehicles are the primary factor. This situation mirrors the past experience of Beijing, a famous success story case study in addressing air pollution through constant regulatory adjustments. This paper reviews previous academic studies and news articles to produce a comprehensive table that compares policies implemented in each city. It also gathers PM2.5 levels in both cities to show that Hanoi's values exceeded those of Beijing in recent years, suggesting a policy gap and delayed responses. The analyses conclude that some of Beijing's policies may be suitable for Hanoi to apply locally, 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, by contrast, appear impractical for adoption. Ultimately, these findings are intended to provide Vietnamese policymakers with regulatory insights to tackle air pollution more effectively.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. CAMS NRT PM2.5 data during 2016-2024 are collected, then processed through unit conversion, spatial averaging, and monthly aggregation. To present an equitable cross-city comparison, both absolute and per capita concentrations are evaluated. Observed trends show a decline in Beijing's PM2.5 levels recently but stagnation in Hanoi, suggesting relatively delayed policy responses. 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, by contrast, appear impractical. Ultimately, these findings are intended to offer actionable insights for Hanoi's policymakers to tackle air pollution more effectively.

Keywords: air pollution, PM2.5, transportation, policy, Hanoi, Beijing.

1. Introduction

Despite its current relatively low urban population, Southeast Asia has been experiencing rapid urban growth (Das & Paul, 2021). This trend is reflected by 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). Given that Vietnam's national transport structure – characterized by space constraints and inadequate

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infrastructure—is strongly conducive to personal vehicle use, a growth in population likely increases private vehicle ownerships, specifically cars and motorbikes. In 2011, the numbers of registered cars and motorbikes in Hanoi were estimated at 235,000 and 4 million, respectively. Vietnam's national transport structure, which is characterized by space constraints and inadequate infrastructure, is conducive to personal vehicle use (Nicolaisen, 2023). Consequently, a 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).

Thanks 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.

Having been under China's rule for over a millennium, Vietnam has been subject to heavy Chinese influences in culture, customs, and religions; politically, both countries are socialist states led by their respective Communist party. Nevertheless, 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), NO_2 (Nitrogen Dioxide), SO_2 (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 by IQAir, a world leader in air quality apps. Its capital, Hanoi, was named the eighth most polluted city in the world (UNICEF, 2024). As a result, an essential question arises: Can air pollution control policies from China be applied to Vietnam, and if so, to what degree? Considering the status of this issue in both countries, Vietnam may benefit from investigating the key drivers of China's success so far in combating air pollution and see whether they are applicable in the Vietnamese context. 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), NO_2 (Nitrogen Dioxide), SO_2 (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).

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~~While on this topic covering both nations has been conducted. Hence, this paper aims to offer an overview of the recent battle against air pollution in both countries, thereby drawing lessons for application to the Vietnamese context. By reviewing the scholarly literature, this paper, with a focus on Beijing (China) and Hanoi (Vietnam), examines the current state of air pollution in both cities. It also compares their transport-related anti-air pollution policies and identifies Hanoi's areas for improvement based on Beijing's past experience while accounting for certain limitations in policy transfer between the two cities.~~ 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. ~~Methodological Approach~~ Study Area

~~In order to understand air pollution policies of Hanoi and Beijing, a scoping review was conducted using Google Scholar and Google News to search for previous studies in the field, as well as recent regulatory updates of the government. In this paper, major policy changes were introduced, briefly summarized, and then compared in light of municipal differences in socioeconomic and political contexts.~~

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.

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]

Table 1. An overview of Beijing's and Hanoi's socioeconomic circumstances

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,

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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)

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.

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, O_3 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 is now a decade old, failing to account for the recent

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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?".

Accordingly, this study aims to:

- Synthesize existing literature on transport-related policies in both cities
- Compare the evolution of their policy trajectories
- Evaluate the transferability of Beijing's measures to Hanoi

The scope of this study is limited to:

- Geographical area: Beijing (China) and Hanoi (Vietnam)
- Time period: 1997-2025 for policy review; 2016-2024 for PM2.5 trend analysis
- Source types: peer-reviewed studies, government documents, organizational reports, and reputable news sources reporting policy updates.
- Regulatory focus: transport-related air pollution policies regarding fuel quality, emission standards, driving restrictions, LEZs, enforcement tools; non-transport policies regarding bans on charcoal stove and open burning.

4.2 Search Strategy

A scoping search was conducted using Google Scholar and Google News between July and September 2025. Boolean keyword combinations included:

- "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"
- "PM2.5" AND "health"

Filters applied:

- Publication year:
- 2000 onward for foundational literature on air pollutants
- 2010 onward for papers about policy implementation.
- Language: English

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

The following criteria guided purposive selection of literature:

Included:

- Studies and reports detailing 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.

Excluded:

- Studies focusing solely on indoor air pollution, road dust, or a single type of air pollutant instead of vehicle emissions
- Studies examining short-term or regional air pollution outside Beijing or Hanoi
- Studies centred solely on modeling, prediction, a single aspect of transport, or providing mitigation suggestions without discussing existing or officially planned policies.

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

4.4.1 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:

- Public health and regulatory relevance: 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).

- International recognition: The World Health Organization (WHO), in its updated Air Quality Guidelines (2021), recognised PM2.5 as a classical air pollutant and recommended a threshold of 5 μg/m³ 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.

4.4.2 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/m³). To align with standard air quality reporting practices, values were converted to micrograms per cubic meter (μg/m³) 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.

4.4.3 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 "harmonising 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.

~~3.~~5. ~~What does recent data show?~~ Results

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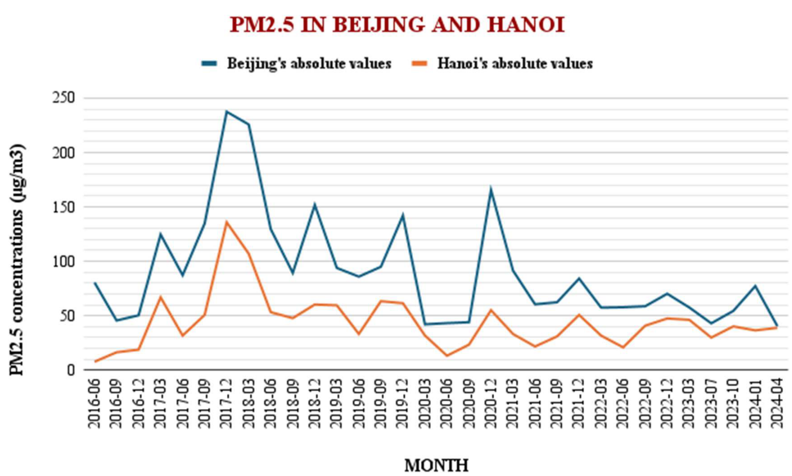

Figure 1

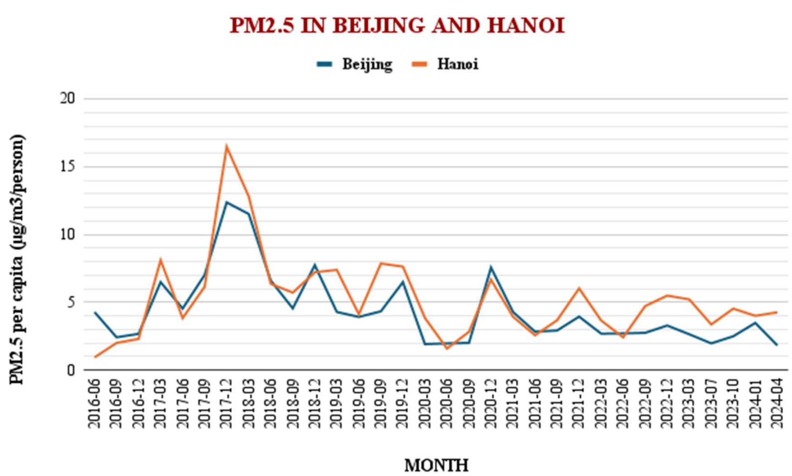

Figure 2 PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to April 2024

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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)

Per capita PM2.5, although not a standard air quality metric, is presented for contextual illustration as absolute PM2.5 values measure ambient concentration rather than individual allocation. 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.

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. 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 of pollutants 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 PM2.5 threshold for absolute safety against adverse health effects has been determined (Yu et al., 2023). Moreover, in its updated Air Quality Guidelines (2021), the World Health Organization (WHO) recognised 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. These statistics serve as background information, providing context for the analysis of air pollution trends in Hanoi and Beijing that form the core focus of this paper.

This review compares the quarterly average of PM2.5 from 2016 to 2024 in Beijing and in Hanoi to understand how and to what extent the policies reviewed in each city may have impacted air quality. In order to account for the huge difference between Beijing's and Hanoi's sizes of urban population, the quarterly average PM2.5 concentrations are evaluated per capita ($\mu g/m^3$/person) for a fairer assessment and comparison (Figure 1). PM2.5 per capita refers to the concentration of PM2.5 normalised by population, which offers a measure of individual exposure and allows equitable comparisons across cities with different population sizes. While this approach has not been applied directly to PM2.5, it has been used in other contexts. For example, IPCC's Climate Change 2023: Synthesis Report (Intergovernmental Panel on Climate Change [IPCC], 2023) adopts GHG (greenhouse gas) emissions per capita as a key metric. Likewise, Indicator B-3.1 in the UNECE Guidelines for the Application of Environmental Indicators recommends GHG emissions per capita as a a statistical recommendation with a view to "harmonising the absolute value of GHG emissions for international comparisons" (United Nations Economic Commission for Europe [UNECE], 2025). Extending this precedent to PM2.5, this study employs PM2.5 per capita to provide a more balanced comparison of air quality impacts in Hanoi and Beijing by accounting for their demographic variations (Figure 1).

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Where else has this been used in the literature? Could you discuss this a bit more. Since PM2.5 alone is a bit more common, it might be good to actually feature both values.

(Optional) maybe you can include at least one additional pollutant, such as NO2 or O3, in your analyses/discussion to avoid over-reliance on PM2.5 alone

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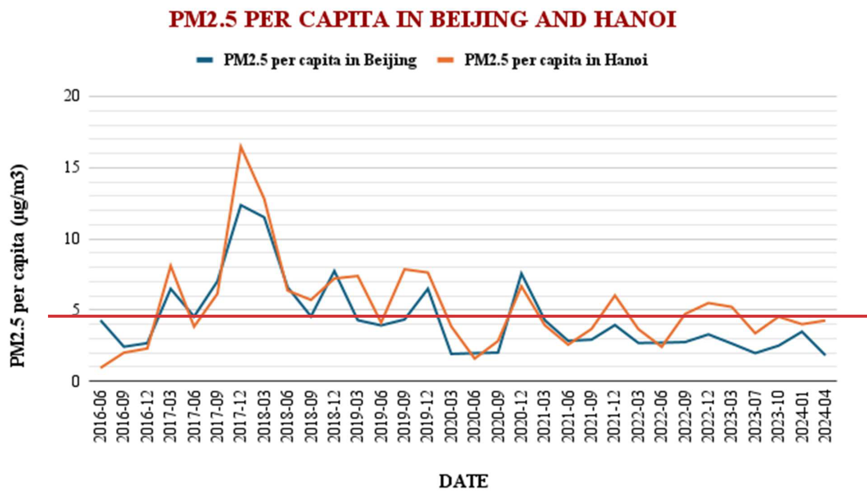

Figure 1 PM2.5 concentrations per capita in Beijing and Hanoi, June 2016 to September 2024

Both cities exhibit strong seasonality, but Hanoi's is generally higher and more volatile. The most pronounced spikes occur in late 2017–early 2018, with winter peaks in 2018–2019 and 2020–2021. Dips occurred around mid-2020 and mid-2021, which likely reflected pandemic-era slowdowns, were followed by a rebound in late-2021. From 2022 onwards, most of Beijing's values were between ~2–4 $\mu g/m^3$ with smaller seasonal swings, whereas those of Hanoi were higher, roughly ~4–6 $\mu g/m^3$ with occasional winter bumps. Overall, while Beijing's amplitude seems to have dampened over time, Hanoi's remains high with less evidence of a structural step-down. These patterns suggest the effectiveness of Beijing's measures and imply that Hanoi still has substantial challenges to resolve.

Taken against policy timing, the contrast is consistent with each city's strategy. Beijing's earlier fuel and vehicle controls, scrappage of high emitters, and long running traffic restrictions align with a lower baseline and smaller seasonal peaks in recent years (Yang et al., 2015). Hanoi's 2019–2021 actions targeted household fuels and open burning, which likely helped curb the most extreme spikes seen in 2017–2018; however, its transport levers (motorbike testing, LEZs/cordons) only begin in 2025–2028, thus, an extensive, sustained transport-driven reduction has not yet been observed in the series (Vietnam News, 2023; Vietnam News, 2019; Vietnam News, 2024; Vu Tuan, 2025). In short, Beijing resembles a mature, policy-stabilized regime, whereas Hanoi remains in transition with time needed for transport measures to prove their efficiency.

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~~Nevertheless, it is difficult to establish a direct causality between PM2.5 fluctuations and specific policy outcomes, as other factors—such as meteorological conditions, regional pollution transport, and biomass burning—may also influence air quality. Therefore, the purpose of this research is to produce a high-level overview of PM2.5 patterns in both cities, framing them within policy contexts to demonstrate how regulatory trajectories may correspond with observed changes while acknowledging that policy-specific efficacy must be concluded from a wider body of literature and not solely from this high-level PM2.5 time series.~~

~~Health wise, the World Health Organization's annual guideline on PM2.5 is 5 µg/m³. Recent months' PM2.5 levels in Beijing often fall near or below that threshold; meanwhile, Hanoi still records many months above it. That said, month to month variation can result from temporary events or region wide influences, so regulatory effects are better analyzed from sustained trends than single spikes.~~

~~4.~~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 centre (UNEP, 2019; Yang et al., 2015).

Existing literature consistently shows that on fuels, Beijing acted earlier and more aggressively than stipulated by national requirements. ~~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; ~~Z.~~ 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,

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retrofits 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% (~~J.~~ 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 ~~from~~ in the metropolitan area since late 2014 (~~Z.~~ 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; ~~Z.~~ 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 (~~Z.~~ 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 (~~Z.~~ 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 (~~Z.~~ 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.

~~5.~~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

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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.

~~6.~~8. Comparison of Beijing and Hanoi's air pollution approaches

~~Overall, Beijing and Hanoi are working towards the same objective, cleaner air, but with different approaches. Beijing started early by addressing what enters the tank. It pushed cleaner fuels (down to 10 ppm sulfur and no lead) and required gas stations to capture gasoline vapors, which allows modern emissions equipment to work better. Meanwhile, Hanoi can't set its own fuel rules (those are nationally determined), so its new powers focus on access: starting in 2025, the city uses low-emission zones (LEZs) and road "cordons" to favor cleaner vehicles in key areas.~~

~~For new and in-use vehicles, Beijing moved faster in implementing standards and enforced them more rigorously. It introduced strict limits for new cars and trucks; used a color-label system, roadside remote sensing; and ran an inspection/maintenance program to identify and retire the most polluting vehicles. Hanoi follows national standards for new vehicles and is now developing its enforcement tools: periodic emissions testing for motorbikes slated for 2027 (which are piloted in Hanoi and Ho Chi Minh City before expansion).~~

~~Traffic management also reflects different strategies. Beijing limits car ownership with a license plate lottery (since 2011), lays down weekday "last digit" driving rules, bans motorcycles inside the 4th Ring Road, and keeps high-emitting yellow-label vehicles out entirely. Hanoi, by contrast, doesn't use lotteries or last-digit rules; instead, it's restricting in phases where higher-emitting vehicles can go: a 2017 decision sets up a phase-out of gasoline motorbikes in the urban core by 2030, with a firm cordon inside Ring Road 1 on July 1, 2026, and a wider zone in 2028. LEZs will then scale up thereafter.~~

~~Beyond traffic, while Beijing's headline moves were mostly on-road, Hanoi prioritized major non-traffic contributors inside the city: it eliminated honeycomb charcoal stoves by 2021 and banned open burning of crop waste and trash from 2020. Both cities are also pushing cleaner fleets, but in different ways: Beijing built large CNG/LNG and NEV programs whereas Hanoi is linking bus and taxi electrification to its LEZs and cordon timelines toward 2030.~~

On monitoring and enforcement, Beijing already has a mature system: an extensive air-quality network, roadside testing, and large scrappage programs. Hanoi has a city AQ (air quality) network and district enforcement teams for stove and burning bans, and upcoming testing centers to police motorbike emissions.

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.

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Based on the policies discussed for each city, a comparative table covering different regulatory aspects was compiled (Table 2).
Based on these comparisons, a comprehensive table was created (Table 1).

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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.Led the nation on cleaner fuels (to 10 ppm sulfur) and gas-station Stage I/II vapor recovery with retrofits 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)No city-specific fuel-quality mandates; fuel is set nationally. LEZs authority (2025) can indirectly tighten via access rules.
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.Applied Euro-pathway early (Beijing 1 in 1999 and China 5 by 2013), often ahead of the national timeline.	Follows national standards for new vehicles. Under the 2024 Capital Law, the local authority can set stricter access rules by emission tier within LEZs. Follows national standards; new local authority (Capital Law 2025) to set tighter access by emission tier within LEZs.

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In-use vehicle controls (I/M, remote sensing)	~~Robust I/M and roadside remote sensing; color label system (green/yellow) enabled targeted scrappage.~~ 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.~~Periodic emissions testing for motorbikes slated to begin in 2027 (Hanoi/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.~~Odd-even/last-digit weekday restrictions started during the 2008 Olympics and continued (modified).~~	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.~~Not citywide last-digit rules; instead, phased access limits for high-emitting/fossil-fuel vehicles via LEZs and cordons.~~
Vehicle population control	License-plate lottery since 2011; annual caps ~~tightened~~ reduced over time (~~240k~~ from 240,000 to 150,000~~to 150k~~).	No population-control strategy. Relies on restricting where and when each vehicle type can enter through zone-based measures.~~No lottery; strategy is to restrict where/when certain vehicles can circulate (zone-based).~~
Low-emission zones (LEZs)	Piloted bans on yellow-label vehicles. Studied broader LEZ models from the mid-2010s onward.~~Piloted YLV bans and zone-based controls; studied broader LEZs in the mid-2010s.~~	Legal LEZ authority from 2025. Pilots in central districts begin from 2025 with expansion after 2030. ~~Legal authority from 2025; pilots in central districts 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.

	~~Ring Road; focus on YLV ban (2014).~~	~~2017 resolution to phase out gasoline motorbikes in urban core by 2030; firm cordon inside Ring Road 1 on 1 Jul 2026, expand in 2028.~~
Alternative-fuel fleets	Extensive use of CNG/LNG buses and strong promotion of NEVs, including separate license quotas for NEVs. ~~CNG/LNG bus rollout; NEV promotion, including separate license caps for NEVs.~~	Ties bus and taxi electrification to LEZ and cordon timelines, targeting major transitions by 2030. ~~EV transition targets for public transport/taxis toward 2030 aligned with LEZs/cordon rollout.~~
Monitoring & enforcement tools	Mature systems including: an expanded AQ network, empowered BEPB for roadside testing, and strong scrappage programs for YLVs. ~~Expanded AQ network; empowered BEPB for roadside testing; 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. ~~City AQ monitoring network; district-level enforcement for stove/open-burning bans; building out motorbike 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. ~~Controls exist but less emphasis citywide; focus remained on transport and industry (coal-to-gas campaign was 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. ~~Directive to eliminate 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; ongoing enforcement.~~

Table 2~~1~~. Beijing and Hanoi's transport-related policies targeted at air pollution

~~7.~~9. Discussion:

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 using a tripartite framework:

1. Technical Efficacy: The potential for significant emission reductions.
2. Institutional Feasibility: The legal and bureaucratic capacity of Hanoi to implement the measure.
3. Social & Political Acceptability: The likelihood of public approval and compliance, particularly given Hanoi's heavy reliance on motorbikes.

9.1 Transferable policies with adaptation

The analysis concludes that three policies utilized by Beijing, including low-emission zones (LEZs), scrappage programs, and camera-based enforcement, have high potential for transfer, provided they are strategically adapted.

9.1.1 Low-emission zones (LEZs)

- Technical Efficiency: High

This is the most direct 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.

- Institutional Feasibility: High

This criterion is now met due to the revised Capital Law (effective from 2025), which grants Hanoi the legal authority to establish LEZs and enforce stricter vehicle emission standards. This forms a strong institutional backbone for the planned gas-powered motorbike ban starting in 2026.

- Social & Political Acceptability: Low to Medium

This is the main source of friction. Hanoi lacks Beijing's 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.

9.1.2 Scrappage programs

- Technical Efficiency: High

Scrappage targets the worst-polluting vehicles in the fleet. This strategy specifically addresses the largest contributors to pollutants like PM, NOx, and VOCs, thereby leading to a rapid reduction in tailpipe emissions.

- Institutional Feasibility: Medium

While legally feasible, 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.

- Social & Political Acceptability: Medium to High

This is socially and politically more easily acceptable than outright bans as it offers financial incentives and a fairer 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.

9.1.3 Camera-based enforcement

- Technical Efficiency: High

This tool provides consistent and systematic compliance with LEZ and emission regulations, thereby boosting their effectiveness. It enables reliable enforcement over large areas without dependence on manual policing.

- Institutional Feasibility: High

Hanoi is already 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)

- Social & Political Acceptability: High

Automated enforcement is generally perceived as more transparent, stringent and less prone to corruption than human police interaction. This shift towards system integrity is likely to promote higher compliance rates among the citizens.

9.2 Impractical policies

In contrast, two key policies employed by Beijing are assessed as likely impractical for Hanoi's current context, which consist of license-plate lotteries (vehicle quotas) and weekday last-digit rotation bans.

9.2.1 License-plate lotteries

- Technical Efficiency: Low to Medium

This only curtails new vehicles, while Hanoi's air pollution mainly stems from existing, 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.

- Institutional Feasibility: Medium

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.

- Social & Political Acceptability: Low

Motorbikes serve not only as the primary means of transportation but also a source of income for many (Pojani et al., 2024). Implementing a quota system to limit the number of motorbike registrations could be perceived as restricting a basic right to mobility, and could negatively impact the city's economy. This would likely result in massive public backlash.

9.2.2 Weekday last-digit rotation bans

- Technical Efficiency: Medium

Although this ban could indirectly reduce emissions by limiting days 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.

- Institutional Feasibility: Medium

This policy requires only the deployment of automated camera systems (as discussed in 9.1.3) and clear signage, making it highly feasible from the administrative standpoint.

- Social & Political Acceptability: Low

This policy relies on users having an alternative on their banned days, which Hanoi has not provided yet. 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.

Ultimately, the review of policies and recent data show that Beijing has experienced a steady decline in PM2.5 per capita. This trend reflects the relative success of Beijing's efforts to tackle air pollution. On the contrary, Hanoi's PM2.5 per capita values fluctuated more dramatically throughout the recorded period, displaying a stable or slightly upward trend over the last 4 years. This suggests that air pollution in the city remains insufficiently addressed or is worsening. Furthermore, among the 100 months illustrated in the chart, Hanoi's PM2.5 per Capita exceeded Beijing's in 70% of the cases. This pattern indicates that air pollution remains a major concern for Hanoi, underscoring the importance of timely government regulations to protect public health and the environment.

Hanoi can improve its air quality, but this means introducing its new measures in a logical sequence and reinforcing them with steady enforcement. Beijing's success in tackling vehicular air pollution highlights that progress comes from a set of actions maintained over the years. They include tight vehicle regulations, clear restrictions on where high-emitting vehicles can operate, and rigorous follow-through. While Hanoi has already addressed several non-traffic sources, such as charcoal "honeycomb" stoves and open burning, a recommended next step is to implement low-emission zones (LEZs) and inner-city cordons in a systematic, equitable, and persistent manner. To ensure this transition is socially just, especially for low-income motorbike users, phased implementation must be paired with financial support mechanisms, such as hardship exemptions, vouchers, or micro-loans, to facilitate the switch to cleaner motorbikes.

However, to be more impactful, some policies could be transferred or adapted from Beijing to Hanoi—for instance, zone access with clear rules. Hanoi's phased implementation could start from within Ring Road 1, followed by a scheduled expansion, and employ cameras to reduce the dependence on manual spot checks for enforcement. Additionally, Hanoi could prioritize the highest polluters for targeting and use emissions testing (and quick roadside checks where possible) to find vehicles with disproportionately high emissions, then offer trade-in or scrappage bonuses tied to cleaner replacements—ideally electric motorbikes. Hanoi could also foster compliance by standardizing inspection procedures then linking test results to LEZs access, and storing everything digitally for better organization.

Nonetheless, it is worth noting that a difference in cultural contexts between Beijing and Hanoi does exist. Thus, there are some policies that were successful in Beijing, but would be less feasible in Hanoi's context. For example, Beijing's license-plate lottery and weekday last-digit bans worked there, but they're not as suitable for Hanoi. Hanoi is a motorbike city, and many people use their bikes to earn a living. Limiting vehicle operation through lottery or alternating-day license plate permits could adversely affect lower-income riders, many of whom rely on motorcycles for livelihood, while yielding more limited

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~~environmental benefits than spatial restrictions. Also, Beijing could order cleaner fuel and early vapor recovery systems at gas stations; however, Hanoi can't set fuel specs on its own. Instead, it should push nationally for those changes while using city purchasing (e-buses, e-taxis, municipal fleets) to promote cleaner technologies into the market.~~

~~It is also crucial that local context be considered. To ensure an equitable transition, LEZs should be accompanied with subsidies like hardship exemptions, vouchers or micro-loans to help riders switch to cleaner motorbikes. In addition, practically sufficient charging or battery-swap options should be offered in dense neighborhoods. Hanoi's budgets and staffing are more limited than Beijing's, so it is advisable for Hanoi to roll out cameras, test centers, scrappage funding in phases and clearly signal what's coming ahead a sufficient amount of time (e.g., 2026 inner cordon, 2028 expansion). It should keep working on non-traffic sources too: facilitate the open-burning ban by funding straw collection and alternative uses (compost, biochar), and continue moving heavy industry out of residential districts.~~

~~8.~~10. Limitations:

Several limitations should be noted when interpreting these findings. First, PM2.5 ~~per capita~~ 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 analysed 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.

~~9.~~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, ~~laying the foundation for further studies into this topic and supporting Hanoi's efforts in mitigating air pollution~~ supporting Hanoi's efforts in mitigating air pollution, and informing future comparative research on urban transport policies.

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Recommendation: Revise and Resubmit

This is an ambitious and relevant comparative policy review that tackles a significant environmental challenge. The author demonstrates a strong capacity for synthesizing information from diverse sources and has chosen a timely topic with clear practical implications for policymakers in Hanoi. The compilation of policies into Table 1 is particularly useful and represents a solid foundation. However, the manuscript in its current form reads more like a comprehensive literature review and data summary than a cohesive analytical paper. To meet the journal's standards for rigor and clarity, significant revisions are needed to strengthen the methodological justification, deepen the analytical discussion, and refine the core argument. I am happy to review a revised version that addresses these points.

1. **Refine the Methodological Approach and Justification:**

Critique: The paper identifies its approach as a "scoping review" but does not detail the search strategy, inclusion/exclusion criteria, or the number of sources identified and screened. This lack of transparency makes the methodology difficult to assess or replicate. Furthermore, the use of "PM2.5 per capita" is a highly unusual and problematic metric. While the rationale (normalizing for population) is understandable, it is not a standard measure in air quality science. PM2.5 concentration is a measure of ambient exposure in the air, not a direct output of individual activity. Using it per capita can be misleading, as it implies that a city's air pollution is divided equally among its residents, which distorts the actual environmental conditions.

You need to greatly expand the Methodological Approach section. Specify the exact search terms, databases, and the time frame of the search. Describe how you selected the final sources for analysis. Regarding PM2.5, I strongly recommend re-plotting Figure 1 using standard, absolute PM2.5 concentrations (μg/m³). You can still discuss population differences as a contextual factor in the text, but the primary metric must align with established scientific practice. This change will make your analysis more credible and interpretable.

> <u>I have significantly expanded the Methodology section to address concerns about transparency and replicability. This now includes specific details regarding the search terms, databases utilized, the time frame, and the inclusion/exclusion criteria for selecting the final sources.</u>
> <u>Regarding the PM2.5 metric, I acknowledge that absolute PM2.5 concentration is the established scientific measure of ambient air quality. Therefore, I have revised Figure 1 and added a paragraph of analysis dedicated to it. Nevertheless, I have decided to keep the original table that features the PM2.5 per capita metric, but explicitly presented it in the paper for contextualization only. This figure allows readers to grasp the PM2.5 levels relative to the population of each city, but is not used to draw conclusions on policy efficacy or individual exposure.</u>

2. **Deepen the Analysis from Description to Argument:**

The paper excels at describing “what” policies were implemented but spends less time analyzing “why” they were successful in Beijing or “how” their core principles can be abstracted for Hanoi. The discussion of "transferability" is a good start but remains somewhat surface-level. For instance, the conclusion that low-emission zones (LEZs) are suitable while license-plate lotteries are not is sensible, but the underlying reasons (e.g., governance structure, primary vehicle type, social equity) could be explored in much greater depth to build a more powerful argument.

Re-structure the **Discussion** section to be more argument-driven. After presenting the comparative data, create a framework for analysis. For example, you could analyze the policies based on criteria like:1)Technical Efficacy: How much does this policy reduce emissions?2) Institutional Feasibility:Does Hanoi have the legal and bureaucratic capacity to implement it?3) Social & Political Acceptability: How will this policy be received by the public, especially considering Hanoi's reliance on motorbikes for livelihoods?
Use this framework to systematically evaluate each recommended policy transfer, moving beyond a simple list to a reasoned justification.

> The Discussion section has been restructured to be more argument-driven rather than descriptive. I grouped Beijing's policies into five clusters and developed the suggested analytical framework based on three key criteria:
> 1. Technical Efficacy: The potential for significant emission reductions.
> 2. Institutional Feasibility: The legal and bureaucratic capacity of Hanoi to implement the measure.
> 3. Social & Political Acceptability: The likelihood of public approval and compliance, particularly given Hanoi’s heavy reliance on motorbikes.
>
> I systematically evaluated each of the five policy groups against these three criteria, assigning a qualitative assessment (Low, Medium, or High) and providing detailed justification for each rating.

3. Strengthen the Link Between Data and Policy Conclusions:
The connection between the PM2.5 trends in Figure 1 and the subsequent policy analysis is currently weak. The text states it's difficult to establish causality, but then the data is used to make broad claims about Beijing's "success" and Hanoi's "delayed responses." A more nuanced interpretation is needed.

> I have adjusted portions of the language that appeared inappropriate for this context; however, some phrasing may still be misleading or unintentionally suggest causal relationships. I would therefore appreciate further feedback on my language to help me improve it.

When discussing the PM2.5 trends, be more precise. Instead of saying Beijing's policies were successful, specify which clusters of policies (e.g., the pre-2010 fuel and new vehicle standards) appear to correlate with the beginning of its downward trend. For Hanoi, discuss how the observed volatility might reflect its current reliance on banning specific activities (stoves, burning) rather than a continuous, systemic regulatory framework for mobile sources. This will create a more logical and evidence-based flow from your data to your policy recommendations.

> I have attempted to link certain policy groups to the periods shown in the charts. However, because the policies' timeframes do not exactly align with those of the charts, I am uncertain whether these linkages are entirely accurate or satisfactory enough.

4. Enhance Precision in Language and Claims:
There are instances of overly broad or imprecise language. For example, the introduction mentions "Vietnam has been subject to heavy Chinese influences" but doesn't clearly link this historical fact to modern environmental policy capacity. The abstract states the paper "reviews previous academic studies and news articles," which undersells the original work of policy comparison.

Scrutinize the manuscript for sweeping statements and replace them with specific, focused claims. In the abstract and introduction, more accurately describe your contribution—e.g., "This paper provides a systematic comparative analysis of transport-related air pollution policies in Beijing and Hanoi..." This sounds more scholarly and confident.

> I have addressed the points you highlighted and reviewed the text for other potentially sweeping statements. However, I recognize that I may be biased toward my own work, making it difficult to identify all instances that might read as overly general to readers. I would therefore greatly appreciate any further feedback on this aspect for improvements.

Reviewer Report

Paper title: Hanoi's potential to learn from Beijing's past experience in addressing air pollution caused by vehicle emissions.

Recommendations: **Major changes recommended**

Suggestions for improvement

The manuscript requires a thorough revision to address pervasive issues in sentence structure, grammar, and syntax. Insert a continuous line number or in case of page-based line numbers, please provide the page numbers. Although a better way is a continuous line number so that referencing can be easy.

<u>I have adjusted the line numbering to a continuous format.</u>

Title suggestion:

The current title lacks academic strength. Please follow any of the below to be more effective manuscript:

- A Tale of Two Capitals: Policy Transfer for Sustainable Urban Mobility and Air Quality in Beijing and Hanoi.
- Decarbonizing the Urban Fleet: Analysing Beijing's Past as a Policy Blueprint for Hanoi's Vehicle Emissions Challenge.
- A Comparative Analysis of Vehicle Emissions Control Policies in Beijing and Hanoi.
- Mitigation Lessons for Rapid Urbanization: Hanoi's Potential to Learn from Beijing's Air Quality Management Experience.

<u>I have decided to adopt the title *Decarbonizing the Urban Fleet: Analysing Beijing's Past as a Policy Blueprint for Hanoi's Vehicle Emissions Challenge.*</u>

Abstract

- **Lines 7 to 9**: Please revise this as follows. In an abstract, references cannot be cited, and mentioning specific years without citation is not appropriate. Suggested revision: *"Despite significant economic progress, Vietnam faces a critical environmental sustainability challenge rooted in severe urban air pollution, common to many developing nations. The capital, Hanoi, a vital* *political and economic hub, is a focal point of this crisis, facing persistent air quality degradation."*

- **Lines 13 to 14**: Kindly provide a clearer methodology. I am sharing some steps in the methodology section that should be followed in detail and then briefly summarized in the abstract. It is important to specify how the authors conducted the literature search.
- Also, please remove the phrase "comprehensive table." Any results or findings can be presented in tabular form, but this should not be explicitly mentioned in the abstract.

<u>I have significantly revised the abstract according to all your feedback regarding this section.</u>

Main Text

- **Lines 29 and 30**: Please remove the dash (—) for consistency and clarity.

<u>I have removed the emdash.</u>

- **Lines 32 to 33**: The data cited from 2011 is outdated. Kindly provide more recent figures and appropriate references. It is important to reflect the current number of registered vehicles in Hanoi in relation to the city's size and population.

<u>I have replaced the 2011 reference with more recent ones and also provided some data about Hanoi's size and population.</u>

- **Line 35**: Replace the phrase "thanks to" with "due to" to maintain academic tone.

<u>I have replaced it as suggested.</u>

- **Page 2, Line 4**: This statement is incorrect. Vietnam is an independent country and is not under China's rule. Please revise this to reflect historical context, such as periods of Chinese rule or war-related influence.

<u>I have rephrased the statement for accuracy and clarity.</u>

- Please also review the manuscript for grammatical errors throughout.

- **Line 12**: A reference is needed to support the claim. If unavailable, please locate relevant research papers that substantiate the statement.

I have deleted the claim about IQAir's credibility, just keeping the data that It reported.

- **Line 13**: The reference mentioned is missing from the reference list. Additionally, the claim that UNICEF is working directly on air pollution appears questionable. Please verify the reliability of this reference and consider replacing it with a more appropriate source.

I have rechecked and found that the UNICEF article cites the results of an IQAir report rather than producing them itself. Therefore, I have replaced the UNICEF reference with the original IQAir report.

- **Lines 13 to 27**: This section repeats the same concept multiple times. It would be more effective to consolidate the content into a single paragraph. Suggested structure:
    - Identify the limitations observed in the existing literature.
    - Highlight the novelty of your work.
    - Clearly state the objectives of your study.

I have rewritten this part according to your recommendations.

- It is also recommended to include statistics on air pollution in Hanoi to illustrate the severity of the issue and its impact on human health.

While detailed air pollution statistics could provide further context, Hanoi's ranking in international reports has already been mentioned earlier in the manuscript. Including additional statistics would require substantial work and is unlikely to add significant new insight.

Study Area: It is recommended to add a dedicated heading titled *"Study Area"* immediately following the introduction. This section should present a comparative overview of both cities, covering trends in demographics, transportation infrastructure, and air pollution levels. Providing this context will help readers better understand the scope and relevance of the analysis. If possible, please include maps of the study areas to visually support the comparison and enhance geographic clarity.

I have added a section to the paper that includes a table comparing Beijing and Hanoi on selected socioeconomic aspects, providing readers with an overview before discussing each city's policies in subsequent sections Regarding air pollution levels, it is difficult to draw direct comparisons between the two cities without referencing the dataset presented later in the paper. Additionally, the existing literature on air pollution in each city employs varied methodologies, criteria, and scales, which further complicates direct comparison.

I did not include maps of the study areas due to uncertainty about the specific type of maps being requested as well as time constraints.

Methodology

Please write this section following these steps:

Define the Scope and Objectives of your work

- Clearly state the research question or problem.
- Set boundaries: time period, geographic focus, type of studies (e.g., empirical, theoretical).

Develop a Search Strategy and write how you search data

- Choose relevant databases: Scopus, Web of Science, Google Scholar, PubMed, JSTOR, etc.
- Use Boolean operators and keyword combinations (e.g., "air pollution AND Hanoi/ Beijing" 'transportation OR air pollution' etc).
- Document your search terms, filters, and inclusion/exclusion criteria.
- Apply inclusion/exclusion criteria (e.g., peer-reviewed only, published after 2015).
- Prioritize high-quality, relevant, and recent studies.

I have revised the Methodology section based on your suggestions, with some minor adjustments to accurately reflect the research process I followed.

Sample Size and Data Transparency: Please clarify how many studies were included in the literature review that informed the results. Additionally, specify how the empirical PM2.5 data was collected — for example, which monitoring stations were selected, and what criteria were used for their inclusion. It is also important to indicate the time frame your study covers (i.e., which years are included in the analysis) to ensure transparency and reproducibility.

Critically analyse the literature

- Evaluate strengths and weaknesses of each study.
- Discuss methodological limitations, sample sizes, biases, and relevance.
- Compare findings across studies to identify trends or gaps.

Line 37 onwards, the methods described should come under methodology section.

I have clarified how many studies were included in the literature review and elaborated on how PM2.5 data was collected. Regarding the critical analysis of literature, I have added a *Literature Review* section to go through the literature as a whole.

Additionally, I have relocated the methods starting from line 37 onwards as suggested.

Results

The data presented under the heading ***"What does recent data show?"*** should be relocated to the **Results** section, as it reflects findings rather than introductory context. Additionally, if any methodological details are embedded within that section, they should be moved to the **Methodology** section to maintain structural consistency and ensure proper categorization of content.

Figure 1: The y-axis is labelled with months, yet the figure title refers to dates — please ensure consistency between the axis label and the figure description. Additionally, the data presented focuses on PM2.5 concentrations, which appear relatively similar between the two cities during 2017 and 2018. It would be helpful to explain the underlying reasons for the elevated values in both cities during that period, as well as the subsequent decline. **This trend suggests that it may be more insightful to examine other primary pollutants to better understand the broader dynamics of urban air pollution.**

I have refined the table based on your feedback. Regarding the suggestion to include additional primary pollutants, I considered two options: either further revise the existing data and analyses, or omit the data and charts entirely, as including other pollutants would require substantial additional work although not the study's main focus.

Page 8 line 22 to 30, recheck for the consistency in font style used here.

I have double-checked and made sure that there is no font inconsistency.

It is also suggested to remove Headings 5 and 6, as the content under these sections largely overlaps with the information already presented in the table. Instead, consider integrating the relevant details directly into the table itself. For example, adding a reference column and including further contextual information would enhance the table's value and reduce redundancy. At present, the table and accompanying text are repetitive; consolidating them will improve clarity and streamline the presentation of findings.

I was not entirely sure what was meant by removing Headings 5 and 6, which in my original manuscript correspond to 'A Brief Review of Hanoi's Major Air Pollution Policies' and 'Comparison of Beijing and Hanoi's Air Pollution Approaches.' Still, I have incorporated the accompanying text in the original 'Comparison of Beijing and Hanoi's Air Pollution Approaches' section into Table 2 for enhanced clarity and conciseness.

Discussion: To strengthen the discussion section, it would be helpful to include examples of global cities that have successfully implemented effective air pollution control measures and urban health mitigation strategies. This comparative perspective can offer valuable insights and practical relevance. Additionally, the current comparison between Hanoi and Beijing appears weak, as the two cities differ significantly in terms of size, economic capacity, and governance structures. A more balanced or contextually aligned comparison would enhance the credibility and depth of the analysis.

I did not have an opportunity to include examples of global cities in this section. Furthermore, since other cities have implemented different policies in different socioeconomic contexts, including them would require substantial additional work to ensure fair and thorough analysis, while potentially shifting the focus away from Beijing and Hanoi. Nevertheless, I have restructured the Discussion section based on the other referee's feedback to make it more argument-driven and less like a theoretical listing of policies.

Limitations and Conclusion: These sections are well-written and clearly presented. However, the **Methodology** section requires significant improvement. At present, there is no clear explanation of how the work was conducted. The authors should provide a detailed account of the research process, including how data was collected, analyzed, and interpreted. Strengthening this section is essential for ensuring transparency and academic rigor. The remaining suggestions relate to enhancing the presentation and reinforcing the logical flow of the study.

Reference

This section needs to be reconsidered. Several references are inconsistently formatted in the reference list. Also, check that all references cited in text are present in the list and vice versa. Please ensure that all references follow a single, consistent citation style throughout the manuscript. Additionally, the formatting of the reference list should be uniform — currently, some entries are in hanging indent format while others are not. Align all entries to the same style to maintain professional and academic presentation standards.

I have double-checked the References section and ensured that all of your feedback has been addressed.

Accept with Minor Revisions

This is a good revision. The author has engaged thoughtfully with the previous critiques, resulting in a manuscript that is vastly improved in structure, rigor, and tone. The new title is excellent, and the addition of a structured Methodology, a dedicated Study Area/Literature Review, and a sophisticated analytical framework for the Discussion elevates this from a descriptive report to a genuine comparative policy analysis. My remaining feedback is focused on final polishing, clarity, and ensuring the data narrative is perfectly aligned with the paper's core argument.

Critical and Actionable Feedback for Final Polishing:

1. Resolve the Tension Between the Two PM2.5 Narratives:
Comment: There is a critical inconsistency between the data presented in Section 5 and the narrative in the paper's introduction and abstract. Section 5.1 clearly states that Beijing's absolute PM2.5 levels are and have consistently been higher than Hanoi's (see lines 281-293: "Beijing consistently experienced higher PM2.5 levels than Hanoi..."). However, the abstract and introduction frame the problem as Hanoi facing "severe" pollution while Beijing is a "success story," which is slightly misleading based on your own absolute data.

Suggestion: This is a crucial point to clarify. You must reconcile these statements in the Abstract, Introduction, and Discussion. The accurate story your data tells is more nuanced and powerful: Beijing started with catastrophically higher pollution, implemented aggressive policies, and has seen a dramatic decline, nearly catching up to (or in per capita terms, falling below) Hanoi's levels. Meanwhile, Hanoi started at a lower baseline but has shown stagnation, with less pronounced improvement. Revise the framing to emphasize rate of improvement and trajectory, not just a snapshot of "severity." For example: "While Beijing's absolute PM2.5 concentrations remain higher, its aggressive policy framework has driven a steep, sustained decline. In contrast, Hanoi's lower baseline levels have shown stagnation, indicating its more recent and less comprehensive policy approach has yet to alter its pollution trajectory significantly." This turns a potential contradiction into a sophisticated analytical point.

2. Clarify and Justify the "PM2.5 per Capita" Metric in the Narrative:
Comment: You've done a good job in the Methodology explaining the rationale for PM2.5 per capita (Section 4.4.3). However, in the Results (Section 5.2), the explanation is still a bit muddled. The sentence "Per capita PM2.5... is presented for contextual illustration as absolute PM2.5 values measure ambient concentration rather than individual allocation" could confuse readers about what the metric actually represents.
Suggestion: Strengthen the language in Section 5.2. Be explicit: "To contextualize the population-level burden and enable a more equitable comparison between cities of vastly different sizes, we also calculate PM2.5 per capita. This metric does not represent individual exposure but serves as a proxy for the aggregate pollution burden shared by each city's population, revealing that Hanoi's residents bear a proportionally higher burden from its

ambient pollution than Beijing's residents do." This precise language will prevent reviewer confusion and strengthen your argument about the urgency for Hanoi.

3. Final Synthesis: Tighten the Link Between Data and Policy Recommendations:
Comment: The Discussion is excellent but could more directly use the data trends from Section 5 to justify the urgency of your recommended policies (LEZs, scrappage).
Suggestion: In the opening paragraph of the Discussion (Section 9), add a sentence that bridges your findings. For example: "The observed stagnation in Hanoi's PM2.5 trends, coupled with a higher per capita burden, underscores the insufficiency of its past, targeted bans and highlights the urgent need for the systemic, transport-focused interventions now being planned." This creates a seamless "Results -> Therefore -> Discussion" logic flow.

4. Minor Formatting and Proofreading:
Action Required: The document still contains formatting artifacts (e.g., "Formatted" tags, comments like `[Commented [3]]`). These must be removed for final submission. Conduct a meticulous line-by-line proofread to:
-Delete all tracked changes and review comments.
-Ensure consistent font (Lora) and spacing (1.15) throughout.
-Verify that all in-text citations have corresponding references and vice-versa.
-Confirm that Figure 1 (and any other figures) are correctly numbered, referenced in the text, and have clear captions that can stand alone.

Conclusion:

You have executed a impressive revision. The core analytical work is now complete and of high quality. The final steps are about precision in communication—ensuring your data narrative is crystal clear, consistent, and powerfully connected to your conclusions. Addressing these points will perfect an already good manuscript.

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

General Comments:
The manuscript has improved significantly compared to the previous version. While some major changes suggested earlier could not be fully implemented due to the author's workload, I am satisfied with the article in its current form. The study is relevant and well-structured, but a few presentation and formatting issues need attention before publication.

Specific Comments

1. **Abstract (Line 26):**
   Avoid abbreviations such as *CAMS NRT PM2.5 data* without prior explanation. Always provide the full term first, followed by the abbreviation in parentheses.
2. **Tables:**
   Place table captions **above the tables**, as per publication standards.
3. **Study Area Description (Lines 115–124):**
   This section should appear before the table as a descriptive introduction before providing table.
4. **Results Section:**
   The results should not begin with figures directly. Include a descriptive paragraph summarizing key findings before presenting figures.
5. **Section 4 (Lines 170–220):**
   Rewrite this section in **proper paragraphs**, not bullet points. The headings are logical, but the content should follow a journal-style presentation.
6. **Discussion Section:**
   - Remove excessive headings and subheadings.
   - Replace minor subheadings with transitional sentences to ensure smooth flow.
   - Retain only essential headings for clarity.
   - Present the discussion in a narrative style rather than fragmented sections.