

# An overview on the air pollution in Hanoi and suitable solutions proposed to address challenges based on adaptable sustainable development strategies

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**Abstract:** As urbanization accelerates globally, concerns about air pollution have grown, impacting metropolises' quality of life. Hanoi - the Capital of Vietnam - is among these cities, having faced deteriorating air quality due to industrialization, vehicular emissions, and the urban heat island (UHI) effect. While numerous papers address air pollution in Hanoi and strategies adopted globally, a gap exists in deliberating on the alignment of such strategies with Hanoi's context. This paper aims to bridge this gap by investigating Hanoi's air pollution, correlating it with strategies used elsewhere, and proposing tailored solutions. Focusing on urban greening, low-emission zones, and improved waste management practices, this study explores flexible approaches for mitigating air pollution. Considering these strategies within Hanoi's context is essential for evaluating their potential benefits in Vietnam's capital. By linking global strategies to Hanoi's specifics, this research aims to develop localized air pollution solutions, drive sustainable City development, and contribute to existing knowledge. Collaboration among stakeholders is essential for successful and comprehensive implementation, which will result in improved urban air quality for Hanoi residents.

**Key words:** Hanoi; Air pollution; Air quality; The urban heat island effect.

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## 1. INTRODUCTION

Hanoi is the Capital, the political and cultural hub, and has long been of great importance to Vietnam. Hanoi has been growing to achieve the status of an international metropolis, including urban development, sustainable urban planning, luring investment, and opening the nation to globalization (Leducq and Scarwell, 2018). The City strives to manage its urban transition and competing development in its metropolitan area, which spans over 3.300km<sup>2</sup>. Government bodies in Hanoi have passed three Master Plans in 1998, 2003, and 2008, but none have been implemented. Land use, transportation, housing, economic development, environmental protection, and public facilities are typical topics covered. Most significant and flagship projects have been conducted by private companies, and the Vietnamese Government has received assistance internationally. However, the results of these cooperative efforts between the Government and private companies are disputed (Leducq and Scarwell, 2018).

As a result of rapid urbanization and industrialization, Hanoi has been experiencing significant air quality issues (Lasko et al., 2018). The Comprehensive Urban

Development Program in Hanoi (HAID-EP) has identified traffic, industrial activities, and construction as Hanoi's primary sources of air pollution (Lasko et al., 2018). Furthermore, emissions from rice residue biomass burning in suburban areas of the City have also significantly contributed to air pollution in Hanoi (Lasko et al., 2018). The Capital's climate has also adversely impacted its air quality. In a 2017 study, the authors found that temperature inversions had a detrimental effect on the concentration of various air pollutants (Sakamoto et al., 2018). There have been proposed and implemented plans to address the issue of decreasing air quality, ranging from publicity campaigns to raise awareness, stricter regulations to curb the burning of rice straw, and even a proposal to ban motorcycles entirely within the City. The City's master plan for 2030 included policies aimed at various improvements, such as enhancing public transportation and establishing a



Green Corridor. However, most, if not all, of these plans only exist on paper or have not achieved any noticeable results, such as Government agencies and state media have admitted (Leducq and Scarwell, 2018).

Therefore, it is necessary for Hanoi to learn from other nations and cities, to look at what solutions have been implemented, in what way and to what extent they have had impacts, and whether they are suitable for the City. Previous studies have mainly focused on the cause and effect of air pollution and the current state of air pollution in Hanoi. There have also been many strategies implemented in major cities around the world, along with their impact and past, present, and plans for dealing with air quality issues. However, there is a lack of studies focusing on air pollution in Hanoi, examining measures imposed in other metropolises to deal with the same issue, and then suggesting those that can work for Hanoi. This study fills this gap by including the problem within the context of Hanoi, examining what has been done elsewhere to alleviate air pollution, and concluding with probable solutions Hanoi can implement.

## 2. METHODOLOGY

This research is carried out by reviewing previous papers on the state of Hanoi's development, problems Hanoi is facing with, air pollution issues, cause and effect of air pollution in Hanoi and current strategies implementing to mitigate air pollution to find out shortcomings, inadequacies and difficulties that Ha Noi is facing with. Also, lessons and experiences to deal with the same issue of other metropolises will be examined. Based on such reviews and discussions, suitable solutions and recommendations with focus on adaptation of sustainable development strategies from similar major cities will be proposed for Hanoi for further considerations. During the study process, interviews and discussions with experts and policy makers will be held to finalize the findings and solutions proposed for Ha Noi.

## 3. RESULTS AND DISCUSSION

### 3.1. State of Hanoi's urban development

Hanoi's urban planning has transitioned from a rigid Soviet-style Master Plan to a more adaptable Strategic Plan, primarily under the influence of a heightened neoliberal perspective driven by both international and domestic investments (Leducq and Scarwell, 2018). The urban development of the Hanoi Capital Region has been guided by the urban cluster model, which consists of a central core connected to satellite urban areas via road networks and aims to strike a balance between economic growth and environmental preservation (Leducq and Scarwell, 2018). Despite this, the expansion has caused difficulties in managing air pollution, which has been exacerbated by projects such as the Hoa Lac Hi-Tech Park, a science and technology development hub, and the construction of a metro system.

There are some effects that urbanization has caused in Hanoi. In a 2015 paper by Nam et al., it was discovered that the expansion plans in the Hanoi Master Plan 2030 would accelerate the UHI effect and significantly increase energy demand, primarily due to elevated energy consumption. The UHI effect, resulting from urbanization, industrialization, and transportation, causes urban areas to experience higher temperatures compared to their rural surroundings (Nam et al., 2015).

### 3.2. Problems Hanoi is facing, past and present

Hanoi is located in the center of the Red River Delta and covers an area of 3,358.6km<sup>2</sup>, accounting for 1% of the natural area of the whole country. Hanoi's climate is a tropical monsoon, with humid, rainy summers and arid, cold winters (Hoang et al., 2022). Hanoi experiences a higher maximum temperature value than surrounding cities due to population, socio-economic activities, and the UHI effect. Due to the UHI effect, the temperature in the inner City is about 1 - 2°C higher than surrounding areas, while the relative humidity in the inner City area is higher and the wind speed is weaker in the suburban areas (Hoang et al., 2022). As a result of climate change, the frequency and intensity of heatwaves in the City could increase in the future, leading to heat stress and public health concerns (Hoang et al., 2022).

On the other hand, the population rise of Hanoi came an increase in personal transportation, most prominently motorcycles. In Hanoi, motorcycles account for more than 90% of all vehicles (Nguyen Thi Yen et al., 2022). In a paper by Sakamoto et al. (2018), observed results supported the claim that motorbikes were the primary source of air pollution within the City and traffic within Hanoi. The City also has a public bus system that runs on multiple lines with very affordable tickets. However, many buses, either city or privately-run, are often a few years old and have obsolete or inadequate exhaust systems that emit a significant amount of air pollutants (Leducq and Scarwell, 2018).

Hanoi has a highway network that connects it to other cities in Vietnam. However, many of them, including those recently opened, are already congested. This has resulted in significant traffic issues in and around the City (Leducq and Scarwell, 2018).



Regarding waste management, Hanoi's current technologies and strategies for municipal solid waste (MSW) management are obsolete, as the majority of unsorted MSW is incinerated or landfilled (Hoang and Fogarassy, 2020). This has resulted in severe congestion of existing landfills and has had negative effects on the air, soil, and water quality of the City (Hoang and Fogarassy, 2020).

The emissions are generated from the biodegradation of organic matter contained in the waste, the combustion of waste, the release of gases from decomposing waste, and the evaporation of liquids from the waste and the odors from landfills and improper waste sites can further degrade the air quality of surrounding areas. The incineration of MSWs has been found to significantly affect public health, such as evident in the rise of respiratory diseases resulting from airborne particulates generated from this action (Sonibare et al., 2019).

Also, the rapid growth of the City has led to an increase in industrial activities, transportation, and construction, which has contributed to the City's economic growth but also resulted in higher levels of air pollution.

### **3.3. Causes and effects of air pollution in Hanoi**

According to Ministry of Natural Resources and Environment (MONRE) (2020), the recent worsening of air quality in Hanoi is a result of weather factors combined with inherent pollution emission sources. In the Northern parts of Vietnam, which include Hanoi, the winter season brings in dust from distant sources, combined with dry, cold weather and high pressure, leading to increased PM<sub>2.5</sub> concentrations (MONRE, 2020). It should be noted that weather is a natural phenomenon that has always existed, and air quality deterioration is due to emissions.

Inversion also plays a role in elevated pollution levels and is particularly pronounced during early mornings, when calm winds are unable to disperse pollutants. When sunlight warms the lower atmosphere, the inversion effect subsides, causing PM<sub>2.5</sub> particles to disperse, resulting in an improvement in air quality (MONRE, 2020).

Air pollution sources in Hanoi include emissions from traffic, household activities like honeycomb charcoal use, construction dust, and straw burning. Industrial production and coal-fired power plants in neighboring provinces also impact the City's air quality (MONRE, 2020). Besides, the main factors contributing to the severe air pollution episodes in 2019 in Hanoi were local emissions from industrial and urban sources, as well as regional sources of pollution such as biomass burning and the formation of secondary inorganic aerosols (Phung Ngoc et al., 2021). Meteorological conditions also had a significant impact, particularly the Northeast monsoon bringing continental cold air from Siberia, which exacerbated the pollution levels (Phung Ngoc et al., 2021).

### **3.4. Review of sustainable development strategies implemented in other major metropolises and their effects on air quality**

#### **3.4.1. Mitigation of the UHI effect in Kuala Lumpur, Malaysia**

Kuala Lumpur (Malaysia) has a similar tropical climate to Hanoi, with distinct wet and dry seasons. The Capital of Malaysia has also undergone significant urbanization in recent years, leading to some environmental concerns that are comparable to those of its Vietnamese counterpart, and similarly, it has taken some measures to combat them (Leducq and Scarwell, 2018; Aflaki et al., 2017), especially urban vegetation. Urban vegetation can significantly mitigate the UHI intensity in Kuala Lumpur, both directly and indirectly, resulting in a decrease in air temperature and mean radiant temperature of up to 4 and 4.5 degrees Celsius, respectively (Aflaki et al., 2017). Green vegetation has also removed pollutants and reduced the concentration of atmospheric nitrogen oxides and sulfur dioxide (Aflaki et al., 2017). However, there are some limitations to the implementation of urban vegetation in the Malaysian Capital, such as limited implementation due to little awareness, lack of suitable spaces for planting, maintenance cost, requirement of highly skilled labor.

#### **3.4.2. Management of MSW in China**

China recently has implemented simultaneously several measures for better management of MSW, such as apply higher control standards for MSW incineration in China, use gasification and pyrolysis instead of incineration... Gasification and pyrolysis are advanced waste disposal technologies that can help reduce the environmental impact of waste management (Tian et al., 2013). In a paper by Tian et al., gasification and pyrolysis were found to reduce the volume of waste by up to 90% and 80%, respectively, and produce less air pollution and greenhouse gas emissions than traditional incineration. It was also highlighted within the same paper that gasification and pyrolysis can recover valuable materials from the waste stream, such as metals and glass from gasification and carbon black and metals from pyrolysis, which can be recycled.

However, both methods require significant investment and may not be suitable for all types of waste. The implementation of gasification and pyrolysis demands high



capital and operational costs, as well as high-quality waste feedstock, while still having the potential to emit toxic pollutants (Tian et al., 2013). Therefore, it is suggested that appropriate regulations be developed to ensure the safe and effective operation of these two methods.

#### 3.4.3. *Low emission zones in European cities*

Low emission zone (LEZ) is a policy implemented in several European cities, including London, England, and Munich, Germany, to reduce air pollution and enhance air quality. The LEZ establishes emission standards for vehicles entering the zone (Ku, Bencekri, Kim, Lee and Lee, 2020). Vehicles that do not meet these standards are required to pay a fee or are prohibited from entering the zone (Ku, Bencekri, Kim, Lee and Lee, 2020).

In London, vehicles must either meet emission standards or pay a daily fee, which can reach up to 110 Euros (Ku, Bencekri, Kim, Lee and Lee, 2020). The analysis of air quality concentrations indicates that the Ultra Low Emission Zone (ULEZ) has significantly reduced NO<sub>2</sub> levels, with central London concentrations decreasing by 46% and inner London concentrations decreasing by 21% compared to a scenario without the ULEZ (Mayor of London, 2023). However, the ULEZ in London still has some limitations.

In Munich, Germany, the LEZ requires vehicles to meet certain emissions standards to enter (Fensterer et al., 2014). The Munich LEZ was implemented in multiple phases, with each phase enforcing increasingly stringent emission standards (Fensterer et al., 2014). The study by Fensterer et al. shows significant reductions in PM10 levels, notably near busy roads and to a lesser extent, in urban background areas. Similar to London, LEZ in Munich still has some limitations which must be overcome.

### 3.5. *Discussion*

The findings of this paper, which shows that Hanoi can borrow effective ideas from other cities, can be highly beneficial and serve as suggestions or proposals for policymakers to consider. The effects of these strategies on the air quality of their respective cities have been noteworthy, and with the necessary modifications, they can be implemented in Hanoi. These strategies can work in Hanoi, but modifications are required to accommodate the Capital's distinct personality. There is no solution that is universally applicable. When comparing the findings of this paper to existing research, there are numerous similarities. In other cities, strategies such as planting more vegetation to cool the urban environment and restricting the use of polluting vehicles have been effective. However, this study has limitations. It did not investigate the costs of these strategies or request opinions from residents. In future work, it is essential to examine the costs and public opinions. Also, investigating how different strategies can be combined can be beneficial to better address the research question. The key to making these

changes a reality is cooperation between the Government, businesses, and citizens. While this research helps to determine future steps, additional research and collaboration among concerned parties are needed to implement these changes.

## 4. RECOMMENDATIONS FOR HANOI

As Hanoi goes through its own urbanization process, the incorporation of successful strategies employed in other global cities becomes a potential avenue for sustainable development and effective urban planning. To successfully implement these strategies, Hanoi must adapt them to its unique sociocultural, geographical, and infrastructural characteristics.

### 4.1. *Urban vegetation*

Adapting the urban vegetation strategy from Kuala Lumpur to Hanoi requires adjustments that consider each City's unique characteristics. Even though both cities have a tropical climate with wet and dry seasons, Hanoi's layout, weather patterns, and particular challenges affect the efficacy of the strategy. Introducing elements such as green roofs, vertical gardens, and green pavements could assist in mitigating the UHI effect, improving air quality, and creating more comfortable outdoor spaces (Leducq and Scarwell, 2018; Aflaki et al., 2017). However, the selection of plant species should be tailored to Hanoi's climate, which includes both high temperatures and heavy precipitation (Leducq and Scarwell, 2018).

Also, adapting the strategy for Hanoi requires consideration of space constraints and the population density of the City. Hanoi, in contrast to Kuala Lumpur, has narrower streets and a distinct urban layout, requiring innovative means of incorporating green spaces (Leducq and Scarwell, 2018; Aflaki et al., 2017). It will be essential to collaborate with City planners, environmental experts, and local communities to find good locations and designs that complement Hanoi's urban landscape. Lessons from Kuala Lumpur demonstrate the importance of involving and educating local residents (Aflaki et al., 2017). By describing the numerous advantages of urban greenery, Hanoi can foster a sense of community involvement in its evolving urban landscape. Collaboration with those who have a stake in the City will be crucial to long-term success.



To keep Hanoi's urban vegetation flourishing, its people and policymakers must prioritize and develop regular maintenance and management strategies. Creating clear guidelines for maintenance and closely monitoring the condition of the green installations will ensure their longevity. In addition, keeping track of ongoing research will assist in making well-informed decisions, enhancing the strategy's effectiveness and adaptability. In short, adapting Kuala Lumpur's urban vegetation strategy for Hanoi necessitates combining global concepts with local factors.

#### **4.2. Management of MSW**

Adapting effective waste management strategies to Hanoi demands a strategic, adaptive approach. Effective implementation requires consideration of the City's distinct waste generation patterns, existing infrastructure, and socioeconomic factors. The patterns of waste generation in Hanoi must be thoroughly examined so strategies can be adapted accordingly. Appropriate waste management solutions can be determined by analyzing the types and amounts of waste produced as well as their seasonal variations. Equally important is evaluating the compatibility of Hanoi's current waste infrastructure with the proposed strategies.

Socioeconomic variables also play an important role. Adaptations will only be equitable if income disparities, local industries, and resident needs are considered. Garnering engagement from residents, businesses, and waste management authorities will be essential for gaining support and achieving success.

Increasing public awareness is essential. Informative campaigns can educate the citizens of Hanoi on the benefits of new strategies, encouraging their participation and compliance. Developing regulations that address Hanoi's unique waste management challenges will provide a solid foundation for transformation.

Partnerships with industries, academic institutions, and relevant stakeholders will facilitate the transfer of technology and the development of applicable solutions. These partnerships ensure that adaptations are compatible with Hanoi's context and contribute to an improvement in air quality and a greener urban environment.

#### **4.3. Implementation of LEZ**

For Hanoi to adapt LEZ strategies effectively, careful planning is necessary. It is essential to identify the unique characteristics of Hanoi's air pollution sources, traffic patterns, and urban layout. Hanoi's street and road system is different from that in European cities, with different types and amounts of vehicles and varying levels of emissions. By adapting emission standards and zone boundaries to Hanoi's unique challenges, the City can ensure the most influential impact. Campaigns and initiatives promoting public participation and awareness are equally important. Collaboration with local industries, transport providers, and regulatory bodies will facilitate the integration of LEZ policies into Hanoi's infrastructure.

Furthermore, Hanoi can learn from the limitations of existing LEZs. Although such zones have been effective, they are not a stand-alone solution (Fensterer et al., 2014; Mayor of London, 2023). Consequently, Hanoi must supplement a LEZ with broader strategies addressing industrial emissions, construction activities, and residential heating. By taking a comprehensive approach and fostering inclusivity, Hanoi can pave the way for cleaner air, improved public health, and a more sustainable urban future.

#### **5. CONCLUSION**

As Hanoi is facing ongoing air quality issues because of rapid urbanization, population growth, and industrialization, learning from sustainable development strategies implemented in major cities around the world can provide valuable insights for the City's own sustainable development. The complex interactions of factors contributing to Hanoi's air pollution emphasize the need for individualized, multifaceted solutions that consider the City's distinct features.

The urban vegetation initiatives of Kuala Lumpur provide Hanoi with a model for mitigating the UHI effect and improving air quality. By adapting this strategy to Hanoi's climate and urban layout, the City can strategically introduce green spaces to combat the UHI effect and subsequently improve the City's air quality.

China's advancements in regulating waste management and the development of advanced waste disposal techniques such as gasification and pyrolysis provide Hanoi with models for effective municipal waste management. Adapting these strategies to Hanoi's waste generation patterns and infrastructure can reduce waste volume and, as a result, air pollution.

Lessons learned from the implementation of LEZs in cities such as London and Munich highlight the need for targeted policies to reduce vehicle emissions and improve air quality. These cities' experiences can be used to design policies that encourage the use of public transportation, promote cleaner modes of transportation, and set up effective compliance mechanisms considering Hanoi's growing vehicle congestion and number, combined with rising air pollution.



To implement these measures, Government bodies, private sector stakeholders, and local communities must cooperate. Effective governance mechanisms, transparent regulations, and clear implementation strategies are essential for closing the gap between policy development and measurable outcomes.

Furthermore, by utilizing technology for real-time monitoring and data-driven decision-making, Hanoi could be able to track progress and make informed adjustments as needed. Furthermore, aligning economic incentives with sustainable practices can encourage citizens and businesses to adopt more environmentally friendly behaviors.

Overall, Hanoi's goal of enhanced air quality through the adaptation of successful strategies from other cities requires a systematic approach. The city can address air quality challenges with precision and informed choices by tailoring these strategies to Hanoi's unique urban landscape, legal framework, and social and economic context ■

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