# The impact of driving restrictions on air pollution and public health in Beijing

Tianxin Lu *

Duke Kunshan University, Suzhou, China

* Corresponding Author Email: tl319@duke.edu

**Abstract.** This paper investigates the impact of road traffic-related air pollution on public health in Beijing and evaluates the effectiveness of driving restriction policies in mitigating both traffic congestion and environmental pollution. With Beijing facing severe air quality challenges due to rapid urbanization and increased vehicle use, various measures have been implemented over the years to improve air quality. The 2008 Beijing Olympics served as a catalyst for stricter emissions controls and vehicle restrictions, leading to a reduction in pollutants such as nitrogen dioxide (NO2) and particulate matter (PM). This study traces the evolution of these policies, assesses their effectiveness in reducing air pollution and carbon emissions, and examines the broader public health implications. The paper concludes that while significant progress has been made, further innovations such as low-emission zones and congestion pricing could help address the remaining challenges of air pollution and traffic congestion in the city.

**Keywords:** Beijing, air pollution, public health, driving restrictions, vehicle emissions.

## 1. Introduction

Ambient air pollution is one of the most pressing environmental challenges with far-reaching impacts on human health globally. According to the World Health Organization (WHO), air pollution is responsible for approximately 7 million premature deaths each year, and makes it the largest health risk factor of non-communicable diseases worldwide, including heart disease, stroke, lung cancer, and respiratory infections [1]. In both developing and developed countries, urbanization and industrialization have exacerbated such problems, which have become more severe in metropolitan areas primarily due to the significant vehicular emissions.

Beijing, the capital city of China, serves as a prime example of a rapidly developing city facing significant air pollution challenges. With its rapid economic growth and increasing demand for transportation, vehicle emissions have become a primary source of air pollution in Beijing. As of 2018, the city had more than 5.9 million registered vehicles, contributing significantly to the emission of pollutants such as nitrogen dioxide ($NO_2$), particulate matter (PM), and volatile organic compounds (VOCs) [2]. These pollutants have been linked to a range of adverse health outcomes, including respiratory and cardiovascular diseases, as well as premature death.

The 2014 United Nations Environment Programme (UNEP) Yearbook reported that road transport accounted for 50% of air pollution-related health costs in OECD countries in 2010 [3]. In China, the impacts of vehicle emissions on health are even more pronounced due to higher population densities and the prevalence of high-emission vehicles. In this context, there is also a growing awareness of the health risks posed by air pollution, which has prompted both government and public health agencies to take action. However, the effectiveness of these interventions, particularly those targeting vehicular emissions, remains a subject of ongoing debate.

While numerous research has been conducted on the health impacts of air pollution in China, most studies have focused on PM or total suspended particulate matter (TSP). Research on these topics has been instrumental in establishing links between air pollution and health outcomes, particularly concerning respiratory and cardiovascular diseases. However, relatively few studies have specifically examined the impact of traffic-related pollution on public health, such as $NO_2$. $NO_2$ is a major pollutant associated with vehicular emissions and has been shown to have serious health implications, including reduced lung function and increased susceptibility to respiratory infections [4].

In addition to the gaps in research on specific pollutants, there is also a need for a better understanding of the broader social and health implications of traffic management policies, such as driving restrictions. Current studies have primarily focused on the environmental benefits of these policies, such as reductions in PM and $NO_2$ levels. However, there has been less emphasis on assessing the effectiveness of improving public health outcomes and its impact on social factors such as equity, accessibility, and economic activity. In the context of Beijing's rapid transportation growth and its complex socio-economic background, a comprehensive evaluation of these policies is necessary.

This paper aims to explore the overall impact of road traffic-related air pollution on public health in Beijing and assess the effectiveness of driving restriction policies in mitigating traffic congestion and air pollution. This study will complement the existing literature by providing a more nuanced understanding of how traffic-related pollution specifically affects public health, as well as evaluating the broader social implications of driving restrictions. The paper will first analyze the historical causes of air pollution in Beijing, followed by analyzing changes in air quality over time and their associated health impacts. It will then examine the current traffic situation in Beijing, highlighting the relationship between traffic and air pollution. Finally, the study will assess the evolution and effectiveness of Beijing's driving restriction policies, while considering both their environmental and public health impacts. By doing so, this research aims to inform future policymaking and contribute to ongoing efforts to improve air quality and public health in rapidly urbanizing cities like Beijing.

## 2. Air Pollution and Public Health

### 2.1. Historical Causes of Air Pollution in Beijing

Beijing's air pollution problems have deep historical roots, influenced by a combination of geographic, economic, and political factors. Its location in the North China Plain contributes to poor air dispersion, trapping pollutants within the city, especially during the winter heating season when coal consumption is high. Historically, coal has been the dominant source of energy in northern China, including Beijing, due to its affordability and accessibility. The extensive use of coal for heating, especially during the cold winter months, was a primary contributor to sulfur dioxide ($SO_2$) and PM emissions in the past decades. Furthermore, rapid industrialization in the late 20th century, alongside population growth, exacerbated these pollution problems. Factories located around Beijing released substantial amounts of sulfur oxides, nitrogen oxides, and particulates into the atmosphere [5].

The post-reform economic boom of the 1980s and 1990s intensified the problem. With increasing economic prosperity came a sharp rise in vehicle ownership and construction activities, both of which contributed to heightened pollution levels. Unregulated emissions from automobiles, particularly from trucks and heavy-duty vehicles, became a significant contributor to $NO_2$ pollution. This mixture of industrial emissions, vehicle exhaust, and coal combustion created a toxic blend that has impacted the public's health for decades.

### 2.2. Changes in Beijing's Air Quality

Beijing has experienced significant changes in its air quality over the past two decades, moving from critically hazardous levels to gradual improvements. Several major milestones mark this journey, with the 2008 Beijing Olympics serving as a pivotal moment in China's environmental management strategies.

In preparation for the Olympics, the Chinese government implemented a series of aggressive measures to reduce air pollution. These included the relocation of polluting industries, stricter emission controls for vehicles, and temporary shutdowns of factories. Additionally, driving restrictions, which limited vehicle use on specific days based on license plate numbers, were introduced to curb traffic emissions [6]. These measures led to an immediate and noticeable improvement in air quality. During the Olympics, levels of $PM_{10}$ and $NO_2$ were significantly reduced, demonstrating the potential effectiveness of coordinated governmental actions to reduce pollution [7].

However, the improvements following the Olympics were short-lived. Once temporary restrictions were lifted, pollution levels began to climb again, although the government's introduction of permanent measures, such as stricter vehicle emission standards and a broader ban on high-emission vehicles, helped mitigate some of the post-Olympic spikes. Over the years, Beijing has also focused on reducing coal usage by switching to cleaner energy sources, such as natural gas and renewable energy, resulting in further reductions in $SO_2$ levels [8].

By the mid-2010s, $PM_{2.5}$ levels, a particularly harmful pollutant due to its small size, began to decline as a result of comprehensive measures taken under the Air Pollution Prevention and Control Action Plan, implemented in 2013. The average annual concentration of $PM_{2.5}$ in Beijing dropped by over 30% between 2013 and 2017 [9], reflecting both governmental commitment and public pressure to address the issue. Despite these improvements, air quality in Beijing remains a concern, and seasonal spikes, particularly in the winter, continue to affect public health.

### 2.3. Public Health Impacts Under Different Air Quality Conditions

Beijing's fluctuating air quality has had distinct health impacts over the years, with different pollutants posing unique risks. During the era of frequent sandstorms, particularly in the 1990s and early 2000s, respiratory illnesses were a major public health issue. Sandstorms originating from northern deserts carried coarse particulate matter ($PM_{10}$), which led to high rates of asthma exacerbations, bronchitis, and other respiratory conditions [10]. During this period, hospital admissions for respiratory diseases surged on days when sandstorms hit the city.

In more recent years, the primary concern has shifted from sandstorms to smog, driven largely by high concentrations of $PM_{2.5}$ and $NO_2$. Smog episodes, often caused by stagnant weather patterns trapping pollution, have been linked to increases in cardiovascular and respiratory diseases. Research shows that prolonged exposure to $PM_{2.5}$ increases the risk of lung cancer and premature death from heart disease [11]. During periods of heavy smog, such as the winter months when coal heating is at its peak, emergency room visits for respiratory issues, heart attacks, and strokes tend to spike [12].

WHO has classified air pollution, particularly $PM_{2.5}$, as a carcinogen, underscoring the severe public health risks posed by long-term exposure to pollutants. Studies have also indicated that children and the elderly are particularly vulnerable, with higher rates of respiratory infections and chronic conditions observed in these populations [13]. Overall, while improvements in air quality have reduced the intensity and frequency of some health issues, the long-term impacts of historical pollution, particularly on vulnerable groups, remain a significant concern.

## 3. Transportation and Air Pollution in Beijing

### 3.1. Overview of Beijing's Transportation System

Beijing's transportation infrastructure has expanded rapidly in response to the city's growing population and economic demands. The city boasts one of the most extensive road networks in China, with over 22,000 kilometers of roads by 2018. The public transportation system, particularly the subway network, has also seen substantial growth, with the total operational length exceeding 700 kilometers as of 2020, making it one of the largest metro systems in the world [14]. Despite this, Beijing continues to face severe traffic congestion, especially during peak hours, as a result of the high volume of private vehicles.

The city's population, exceeding 21 million, puts immense pressure on both public and private transportation systems. In 2018, the daily passenger volume for public transportation, including buses and subways, reached over 10 million trips, indicating a heavy reliance on public transit [15]. Despite the extensive public transportation system, private car ownership has soared, exacerbating traffic congestion. As of 2020, Beijing had over 6 million registered vehicles, with an annual growth rate of around 3% [16]. This increase in vehicle numbers has significantly contributed to the city's air pollution challenges.

### 3.2. The Relationship Between Transportation and Air Quality

Transportation is one of the primary sources of air pollution in Beijing, particularly in terms of $NO_2$ and PM emissions. The combustion of fossil fuels by vehicles releases $NO_2$, which contributes to the formation of ground-level ozone and secondary particulate matter. Research has shown that over 30% of Beijing's $PM_{2.5}$ is directly linked to vehicular emissions [17]. In addition to $PM_{2.5}$ and $NO_2$, vehicles also emit carbon monoxide (CO) and hydrocarbons, which further deteriorate air quality.

Traffic congestion exacerbates this problem. During rush hours, when vehicle speeds are low and idling time is high, emissions of $NO_2$ and PM from cars and trucks increase dramatically. Studies conducted in Beijing have found that areas with high traffic density consistently experience poorer air quality than less congested regions. The high concentration of pollutants in traffic-dense areas also correlates with an increased incidence of respiratory and cardiovascular diseases among residents living near major roads [18].

In addition to tailpipe emissions, transportation also contributes to non-exhaust sources of PM, such as road dust resuspension and tire wear. These sources, while often overlooked, are significant contributors to the overall $PM_{10}$ and $PM_{2.5}$ levels in the city, particularly during dry and windy conditions [19]. This complex interplay between transportation and air pollution highlights the challenges Beijing faces in improving air quality while managing its growing population and transportation needs.

## 4. Driving Restriction Policies in Beijing

### 4.1. Evolution of Beijing's Driving Restriction Policies

Beijing's journey toward controlling vehicle emissions began in response to the rising levels of air pollution driven largely by rapid urbanization and increasing car ownership. In 2008, Beijing implemented its first temporary driving restrictions ahead of the Summer Olympics to reduce air pollution during the event. This measure, known as odd-even vehicle restrictions, limited cars with license plates ending in odd or even numbers to alternate days of operation. This initial restriction was temporary but achieved notable reductions in nitrogen oxides (NOx) and PM, leading to an improvement in air quality during the Olympic Games.

The success of these temporary measures led to the introduction of more permanent restrictions. In 2009, the government launched a policy that restricted car use based on the last digit of license plates, rotating the days that certain vehicles could operate. This policy aimed to reduce traffic congestion and emissions while encouraging public transportation. Over the years, these restrictions have been periodically adjusted, with the city government expanding the scope to include higher emission standards and incentivizing the purchase of electric vehicles (EVs).

### 4.2. Current Policies and Their Impact on Air Pollution and Carbon Emissions

The current driving restriction policies in Beijing remain centered around the license plate rotation system. However, the restrictions have been combined with other stringent measures to tackle air pollution, such as the implementation of "China VI" vehicle emission standards, which are stricter than their European counterparts. These standards mandate the reduction of NOx and particulate matter emissions from both diesel and gasoline vehicles [20].

Additionally, the government has been promoting the transition to electric and hybrid vehicles by offering subsidies and expanding the network of charging stations throughout the city. The number of EVs in Beijing has steadily increased, which has had a positive effect on lowering vehicular emissions. According to recent reports, Beijing's $PM_{2.5}$ levels have seen a significant decline, falling by nearly 30% between 2013 and 2017. NOx levels have also decreased, although at a slower rate compared to particulate matter [21].

Moreover, driving restrictions and emission standards have contributed to reducing the city’s carbon footprint. The shift towards electric vehicles, combined with the restrictions on gasoline-powered cars, has led to a reduction in $CO_2$ emissions. In the transportation sector, Beijing has achieved a decline in $CO_2$ emissions of over 10% since 2015, largely due to these policies [22]. However, the long-term impact of these measures on greenhouse gas emissions remains an area that requires further analysis.

### 4.3. Future Directions and Potential of Driving Restriction Policies

While the current policies have shown measurable success, there is still room for improvement in the future. The rapid increase in car ownership and the associated rise in traffic volume continue to pose challenges to Beijing's air quality. As the population grows, the demand for private vehicles is expected to rise, necessitating further policy innovations.

One potential direction for policy development is the expansion of low-emission zones (LEZs) in key areas of the city. LEZs restrict high-emission vehicles from entering specific zones and have been successful in European cities like London and Paris. Implementing more LEZs in Beijing could target pollution hotspots and further reduce emissions [23].

Another potential direction for future policy development is the promotion of shared and autonomous electric vehicles. These technologies can help reduce the number of vehicles on the road, thereby cutting emissions and easing congestion. Furthermore, integrating smart city technologies that optimize traffic flow could reduce the amount of time vehicles spend idling in traffic, contributing to cleaner air.

In the longer term, Beijing may need to consider more radical measures, such as congestion pricing, which has been effective in other global cities like Singapore. Charging vehicles to enter congested urban areas can deter unnecessary trips, reduce traffic volume, and lower emissions. Such policies, combined with continued investment in public transportation and the promotion of green technology, offer significant potential for further reducing air pollution and carbon emissions in the city.

## 5. Conclusion

In summary, Beijing's driving restriction policies have evolved over the past two decades in response to rising levels of air pollution and congestion. From the initial odd-even restrictions during the 2008 Olympics to the current license plate rotation and stringent emission standards, these measures have contributed significantly to improving the city's air quality and reducing vehicle emissions. While progress has been made, the future development of more comprehensive policies, such as expanding low-emission zones and implementing congestion pricing, will be essential for Beijing to continue addressing the dual challenges of air pollution and carbon emissions.

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