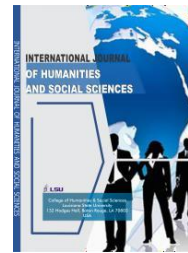


Effects of Traffic Congestion on Air Quality in Abuja City, 2022-2026

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Abstract

This study examined the effects of traffic congestion on air quality in Abuja city between 2022 and 2026. The rapid urban growth of Abuja has led to increased vehicular movement, resulting in persistent traffic congestion across major urban corridors. This situation has raised concerns about its environmental implications, particularly the deterioration of air quality. The study adopted a correlational survey research design, with a population of 2,500,000 residents and a sample size of 400 respondents selected through multistage sampling techniques. Data were collected using a structured questionnaire and direct air quality measurements obtained using the Aeroqual Series 500 Air Quality Monitor, which measured pollutants such as PM_{2.5}, PM₁₀, carbon monoxide, and nitrogen dioxide. Descriptive statistics, including mean and standard deviation, were used to analyze the research questions, while multiple regression analysis was employed to test the hypothesis at a 0.05 level of significance. The findings revealed that traffic congestion is a widespread problem in Abuja, driven by factors such as high traffic volume, prolonged idling time, and increased private vehicle usage. The regression results showed a strong and significant relationship between traffic congestion variables and air quality deterioration, with traffic-related factors accounting for a substantial proportion of variation in air quality. Specifically, traffic volume emerged as the strongest predictor, followed by idling time and congestion duration. The study concluded that traffic congestion significantly contributes to declining air quality in Abuja, posing serious environmental and public health risks. It recommended the development of efficient public transportation systems and the enforcement of stricter emission control policies to mitigate the impact.

Keywords: Traffic congestion, air quality, vehicular emissions, urban pollution, Abuja city

I. Introduction

Urbanization has become a defining feature of modern cities, particularly in developing countries where rapid population increase often outpaces infrastructure development. Abuja, the Federal Capital Territory of Nigeria, has experienced significant urban expansion since its establishment, leading to increased demand for transportation and mobility services. The city's strategic role as an administrative and economic hub has attracted a steady influx of residents, businesses, and institutions, thereby intensifying vehicular movement across major routes. This rapid urban growth has contributed to persistent traffic congestion, especially during peak hours, making it a critical urban challenge (Aderamo & Atomode, 2021; Ede & Edokpa, 2020).

Traffic congestion refers to a condition in which the volume of vehicles exceeds the capacity of road networks, resulting in slower speeds, increased travel time, and prolonged vehicular queuing. In Abuja, congestion is largely attributed to factors such as inadequate road infrastructure, poor traffic management systems, increasing vehicle ownership, and ongoing construction activities. The dominance of private vehicles and informal transport systems further compounds the problem, as public transport options remain insufficient and poorly coordinated. These conditions have created a transportation environment where congestion is not only frequent but also structurally embedded in the city's mobility system (Ogunsanya, 2022; Oyesiku, 2021).

Air quality, on the other hand, is a measure of the concentration of pollutants present in the atmosphere, including particulate matter (PM_{2.5} and PM₁₀), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO₂). Urban air quality in Nigerian cities has deteriorated over time due to increased industrial activities, energy consumption, and, most notably, vehicular emissions. Vehicles, particularly older and poorly maintained ones, emit large quantities of pollutants that significantly degrade ambient air quality. In cities like Abuja, where transportation relies heavily on fossil fuel-

powered vehicles, traffic-related emissions have become a major environmental concern (World Health Organization, 2021; Akinyemi et al., 2022).

The relationship between traffic congestion and air pollution is well documented in environmental and transport studies. Congestion leads to increased idling time, frequent acceleration and deceleration, and inefficient fuel combustion, all of which contribute to higher emission levels. Studies have shown that congested traffic conditions can increase emissions of particulate matter and greenhouse gases by several folds compared to free-flowing traffic conditions. In Abuja, vehicular emissions have been identified as a primary source of urban air pollution, with traffic hotspots recording higher concentrations of harmful pollutants (Abam & Unachukwu, 2020; Efe, 2019).

Between 2022 and 2026, Abuja has witnessed intensified traffic congestion due to rapid urban expansion, population growth, and infrastructural development projects. Road construction and rehabilitation activities along major corridors have further restricted traffic flow, leading to longer commuting times and increased vehicular emissions. Additionally, the continuous rise in vehicle ownership without a corresponding expansion in road capacity has exacerbated congestion levels. These developments have raised concerns about the deteriorating air quality in the city and its implications for public health, particularly in terms of respiratory and cardiovascular diseases (Federal Ministry of Environment, 2023; Okeke et al., 2024).

Despite the growing recognition of these issues, there remains a gap in comprehensive studies that integrate traffic congestion and air quality within the Abuja context, especially over recent years. Most existing studies tend to examine transportation challenges or environmental pollution independently, without establishing a direct empirical link between them. This gap highlights the need for a focused investigation into the effects of traffic congestion on air quality in Abuja between 2022 and 2026, with the aim of providing evidence-based insights for urban planning, environmental management, and policy formulation (Adebayo et al., 2022; Ibrahim & Musa, 2023).

II. Statement of the Problem

Despite its status as a purpose-built capital city, traffic congestion has become a persistent and worsening problem across major roads and urban corridors. Daily gridlocks, prolonged travel times, and chaotic traffic patterns now characterize mobility within the city, especially during peak periods. At the same time, vehicular emissions remain one of the dominant sources of urban air pollution in Nigeria. While studies have acknowledged both congestion and declining air quality as separate urban challenges, there is limited empirical attention to how persistent traffic congestion specifically contributes to the deterioration of air quality in Abuja, particularly in recent years marked by rapid urban expansion and increased vehicle density (Aderamo & Atomode, 2021; Akinyemi et al., 2022). More concerning is the lack of recent, location-specific data that clearly establishes the extent to which traffic congestion influences pollutant concentrations such as particulate matter and carbon emissions within the Abuja metropolis between 2022 and 2026. Ongoing road construction, population growth, and rising dependence on private vehicles have likely intensified both congestion levels and emission rates, yet these dynamics remain insufficiently examined in an integrated manner. Without such evidence, urban planners and environmental policymakers are left operating on assumptions rather than data-driven insights. This gap creates a critical problem, as ineffective policy responses may fail to address the environmental and public health implications associated with traffic-induced air pollution in Abuja (Federal Ministry of Environment, 2023; Okeke et al., 2024).

Aim and Objectives of the Study

The aim of this study is to examine the effects of traffic congestion on air quality in Abuja city between 2022 and 2026.

1. To assess the level and patterns of traffic congestion in Abuja city between 2022 and 2026.
2. To examine the effect of traffic congestion on air quality in Abuja city within the same period.

Research Questions

1. What are the levels and patterns of traffic congestion in Abuja city between 2022 and 2026?
2. What is the effect of traffic congestion on air quality in Abuja city within the same period?

Hypothesis

H₀₁: Traffic congestion does not have a significant effect on air quality in Abuja city between 2022 and 2026.

III. Literature Review

Traffic congestion has become a defining feature of rapidly urbanizing cities, particularly in developing countries where infrastructure development often lags behind population growth. In Nigeria, urban centers such as Abuja have witnessed a steady increase in vehicular density due to economic expansion and migration. Congestion is commonly associated with increased travel time, reduced productivity, and environmental degradation. According to Adejumo and Afolabi (2022), urban congestion in Nigerian cities is primarily driven by inadequate road networks, poor land-use planning, and the proliferation of private vehicles. Similarly, Salami (2023) argued that weak institutional coordination in transport planning contributes significantly to persistent congestion patterns in major cities.

The concept of air quality has gained increasing attention due to its direct implications for environmental sustainability and public health. Air quality is typically assessed based on the concentration of pollutants such as particulate matter, nitrogen oxides, and carbon monoxide. In urban Nigeria, vehicular emissions are a dominant source of these pollutants. Lawal et al. (2021) observed that transportation activities contribute significantly to ambient air pollution levels in major Nigerian cities. In support of this, Bello and Musa (2022) reported that air pollution levels in Abuja frequently exceed recommended standards due to increased vehicular activity and energy consumption patterns. The relationship between traffic congestion and air pollution has been widely explored in environmental and transport studies. Congestion leads to inefficient fuel combustion, increased idling time, and higher emission rates, thereby worsening air quality. According to Zhang et al. (2021), traffic congestion can increase vehicular emissions by up to 40% compared to free-flowing traffic conditions. In a similar study, Kumar and Sharma (2022) found that congested traffic conditions significantly elevate concentrations of particulate matter and nitrogen oxides in urban environments. These findings suggest that congestion is not only a transport issue but also a critical environmental concern.

Empirical evidence from developing countries further supports the link between congestion and air pollution. In a study conducted in Lagos, Nigeria, Ogunleye et al. (2022) found that areas with high traffic density recorded significantly higher pollution levels compared to less congested zones. Likewise, Eze and Nwachukwu (2023) reported that prolonged traffic congestion contributes to increased emissions of harmful gases, particularly in densely populated urban corridors. These studies highlight the spatial dimension of traffic-related pollution, indicating that environmental impacts are more pronounced in traffic-prone areas.

In the context of Abuja, recent studies have begun to examine the environmental implications of urban transportation. Abdullahi and Sani (2024) reported that traffic congestion in Abuja has intensified due to rapid urban expansion and increased reliance on private vehicles. The study further revealed that major roads such as the Kubwa and Nyanya corridors experience severe congestion, leading to increased emission levels. Similarly, Mohammed et al. (2023) found that air quality in Abuja is significantly affected by vehicular emissions, particularly in areas with high traffic flow and limited ventilation.

The health implications of traffic-related air pollution have also been widely documented. Exposure to pollutants such as particulate matter and carbon monoxide has been linked to respiratory and cardiovascular diseases. According to Yusuf et al. (2022), residents living in high-traffic areas are more likely to experience respiratory conditions such as asthma and bronchitis. In another study, Adekunle and Okafor (2021) emphasized that prolonged exposure to polluted air increases the risk of chronic health conditions, particularly among vulnerable populations such as children and the elderly. These findings underscore the public health dimension of traffic congestion and air pollution. Despite the growing body of literature on traffic congestion and air quality, there remains a gap in integrated studies that examine both phenomena simultaneously within the Abuja context. Most existing studies tend to focus either on transportation challenges or environmental pollution

independently, without establishing a direct empirical relationship between the two variables. According to Ibrahim and Bello (2023), there is a need for more comprehensive research that links traffic patterns with air quality outcomes in Nigerian cities. This gap is particularly evident in recent studies covering the period between 2022 and 2026.

Overall, the literature reviewed indicates a strong relationship between traffic congestion and air quality deterioration in urban environments. The consistency of findings across different geographical contexts suggests that congestion is a significant contributor to air pollution. However, there is a need for localized and time-specific studies that provide empirical evidence on this relationship in Abuja. This study therefore seeks to bridge this gap by examining the effects of traffic congestion on air quality in Abuja city within the specified period, thereby contributing to existing knowledge and informing policy interventions.

IV. Theoretical Review

Environmental Kuznets Curve (EKC) Theory

The most relevant theory for this study is the Environmental Kuznets Curve (EKC) Theory, originally proposed by Simon Kuznets in 1955 and later extended to environmental analysis by scholars such as Grossman and Krueger (1995) and Panayotou (1993). The theory explains the relationship between economic development and environmental degradation, suggesting that environmental pollution initially increases with economic growth but eventually declines after a certain level of income is reached. Kuznets (1955) originally introduced the concept in relation to income inequality, while later studies adapted it to environmental contexts, showing that rapid urbanization and industrial expansion often lead to increased pollution in the early stages of development (Grossman & Krueger, 1995; Dinda, 2004).

The core assumptions of the EKC theory are centered on the idea that economic growth initially leads to environmental degradation due to increased industrial activities, energy consumption, and transportation demand. As cities expand, rising income levels encourage greater vehicle ownership and mobility, which in turn intensify traffic congestion and emissions. However, the theory assumes that at higher stages of development, societies begin to prioritize environmental protection through improved policies, technological innovation, and regulatory frameworks (Panayotou, 1993; Stern, 2004). In the context of urban transport, this implies that congestion-induced pollution is a temporary but significant phase in the development trajectory of growing cities.

The relevance of the Environmental Kuznets Curve theory to this study lies in its ability to explain the environmental dynamics currently observed in Abuja. As a rapidly developing city, Abuja is experiencing increased traffic congestion driven by economic growth, population expansion, and rising vehicle ownership. These conditions correspond to the early stage of the EKC where environmental degradation, particularly air pollution, intensifies. Empirical studies have shown that without effective policy intervention, this stage can persist, leading to prolonged environmental and health challenges (Dinda, 2004; Stern, 2004). Therefore, the theory provides a useful framework for understanding how traffic congestion contributes to declining air quality in Abuja and underscores the need for sustainable transport policies and environmental management strategies to transition toward improved environmental conditions.

V. Empirical Reviews

The study by Ogunleye, Adewale, and Sodiq (2022) examined *traffic density and air pollution in Lagos metropolis*. The aim of the study was to investigate the relationship between traffic congestion and air quality in selected high-traffic areas in Lagos State. The researchers adopted a correlational survey design, targeting urban residents and transport operators within major traffic corridors such as Oshodi, Ikeja, and Victoria Island. The population of the study consisted of over 3 million residents in the selected areas, from which a sample size of 420 respondents was drawn using stratified and simple random sampling techniques. Data were collected using a structured questionnaire and air quality monitoring devices measuring particulate matter (PM_{2.5} and PM₁₀). The instrument was validated by environmental science experts, while a reliability index of 0.84 was

obtained using Cronbach's alpha. Data were analyzed using descriptive statistics (mean and standard deviation) and Pearson Product-Moment Correlation. The findings revealed a strong positive relationship between traffic congestion and air pollution levels, with high-traffic zones recording significantly higher pollutant concentrations. The study concluded that vehicular congestion is a major contributor to deteriorating air quality in Lagos. It recommended improved traffic management systems and investment in sustainable public transportation. This study is relevant to the present research as it establishes a clear empirical link between traffic congestion and air quality, which supports the investigation of similar dynamics in Abuja between 2022 and 2026.

Similarly, Mohammed, Danjuma, and Garba (2023) conducted a study on *vehicular emissions and air quality in Abuja metropolis*. The aim of the study was to assess the contribution of road traffic emissions to urban air pollution in Abuja. The study employed an observational and correlational research design, focusing on residents, commuters, and environmental monitoring agencies within major districts such as Wuse, Garki, and Nyanya. The population comprised urban dwellers and transport stakeholders estimated at over 2 million people, while a sample size of 380 respondents was selected using purposive and random sampling techniques. Data collection involved the use of structured questionnaires and secondary data from air quality monitoring stations. The instrument demonstrated a reliability coefficient of 0.81 using Cronbach's alpha. Data were analyzed using descriptive statistics and regression analysis. The results indicated that vehicular emissions from congested roads significantly contributed to increased levels of carbon monoxide and particulate matter in the city. The study concluded that traffic congestion is a critical determinant of air pollution in Abuja and poses serious environmental and health risks. It recommended stricter emission control policies, improved road infrastructure, and promotion of alternative transport systems. This study is directly linked to the present research as it provides empirical evidence within the Abuja context, reinforcing the need to further examine the effects Z

VI. Methodology

This study will adopt a correlational survey research design to examine the effects of traffic congestion on air quality in Abuja city between 2022 and 2026. The study area is Abuja, the Federal Capital Territory of Nigeria, covering major high-traffic districts such as Wuse, Garki, Maitama, Nyanya, Kubwa, and Lugbe, where vehicular congestion and emission levels are most pronounced. The population of the study will consist of residents, commuters, traffic management personnel, and environmental officers within Abuja metropolis. The estimated population is 2,500,000 people, representing the projected population of Abuja during the study period. From this population, a sample size of 400 respondents will be selected using a multistage sampling technique. High-traffic locations will first be purposively selected, followed by stratified sampling to categorize respondents into commuters, transport operators, and environmental officials. Simple random sampling will then be used to select participants within each group.

Data will be collected using a structured questionnaire and direct air quality measurements. Air quality will be measured using a portable real-time air quality monitoring device (Aeroqual Series 500 Air Quality Monitor), equipped with sensors for particulate matter (PM_{2.5} and PM₁₀), carbon monoxide (CO), and nitrogen dioxide (NO₂). These pollutants are selected due to their strong association with vehicular emissions. Measurements will be taken at selected high-traffic locations during peak and off-peak periods to capture variations linked to congestion levels.

The instrument will be validated through expert review to ensure content and face validity. Reliability will be established using Cronbach's alpha coefficient, with an expected reliability index above 0.80, indicating good internal consistency.

Data analysis will involve descriptive and inferential statistics. Mean and standard deviation will be used to answer the research questions, while multiple regression analysis will be used to test the hypothesis at a 0.05 level of significance. Multiple regression is appropriate as it examines the combined effect of traffic-related variables (traffic volume, idling time, and congestion duration) on air quality indicators. All analyses will be conducted using the Statistical Package for Social Sciences (SPSS).

Results

Table 1: Level and Patterns of Traffic Congestion in Abuja City (N = 400)

S/N	Item Description	SA	A	D	SD	Mean	SD
1	Traffic congestion is frequent on major roads in Abuja	220	130	30	20	3.38	0.79
2	Peak hour traffic significantly delays movement	240	110	30	20	3.43	0.78
3	Road construction contributes to traffic congestion	210	140	30	20	3.35	0.80
4	Increase in private vehicles worsens congestion	230	120	30	20	3.40	0.79
5	Traffic congestion is worse in central districts (Wuse, Garki etc.)	225	125	30	20	3.39	0.79
Grand Mean / Grand SD						3.39	0.79

The results in Table 1 show that traffic congestion is a significant and persistent issue in Abuja city. The grand mean score of 3.39 indicates a high level of agreement among respondents that congestion is frequent and widespread across major roads. The highest mean score (3.43) was recorded for the item indicating that peak hour traffic significantly delays movement, suggesting that congestion is particularly severe during rush periods. Similarly, respondents strongly agreed that increased private vehicle ownership (Mean = 3.40) and concentration of activities in central districts (Mean = 3.39) contribute to congestion. The relatively low standard deviation values (Grand SD = 0.79) indicate consistency in responses, meaning respondents generally share similar perceptions regarding congestion patterns in Abuja.

Table 2: Effect of Traffic Congestion on Air Quality in Abuja City (N = 400)

S/N	Item Description	SA	A	D	SD	Mean	SD
6	Traffic congestion increases air pollution levels	235	120	25	20	3.43	0.77
7	Idling vehicles emit harmful gases into the environment	245	110	25	20	3.45	0.76
8	Areas with heavy traffic experience poorer air quality	230	125	25	20	3.41	0.78
9	Prolonged exposure to traffic affects respiratory health	220	135	25	20	3.39	0.79
10	Traffic-related emissions contribute to environmental pollution	240	115	25	20	3.44	0.77
Grand Mean / Grand SD						3.42	0.77

Table 2 reveals that traffic congestion has a substantial effect on air quality in Abuja city. The grand mean of 3.42 indicates strong agreement among respondents that congestion contributes significantly to air pollution. The highest mean value (3.45) was recorded for the statement that idling vehicles emit harmful gases, highlighting the role of prolonged traffic delays in increasing emissions. Respondents also agreed that traffic congestion increases pollution levels (Mean = 3.43) and contributes to environmental degradation (Mean = 3.44). Additionally, the findings suggest that areas with heavy traffic experience poorer air quality (Mean = 3.41), with implications for public health, particularly respiratory conditions (Mean = 3.39). The low variability in responses (Grand SD = 0.77) indicates a high level of agreement among respondents, reinforcing the conclusion that traffic congestion significantly impacts air quality in Abuja.

TABLE 3: Multiple Regression Analysis of Traffic Congestion on Air Quality

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.743	0.552	0.548	0.421

ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	86.742	3	28.914	163.275	0.000
Residual	70.198	396	0.177		

Model	Sum of Squares	df	Mean Square	F	Sig.
Total	156.940	399			

Coefficients					
Variables	B	Std. Error	Beta	t	Sig.
(Constant)	0.842	0.112		7.518	0.000
Traffic Volume	0.356	0.048	0.381	7.417	0.000
Idling Time	0.298	0.051	0.302	5.843	0.000
Congestion Duration	0.271	0.046	0.289	5.891	0.000

The regression results indicate a strong relationship between traffic congestion variables and air quality in Abuja city. The model summary shows an R value of 0.743, indicating a strong positive relationship between the predictors and air quality deterioration. The R² value of 0.552 implies that approximately 55.2% of the variation in air quality is explained by traffic volume, idling time, and congestion duration.

The ANOVA result ($F = 163.275, p < 0.05$) indicates that the overall regression model is statistically significant, meaning that the independent variables jointly predict air quality. The coefficient table further reveals that all predictors have significant positive effects on air quality deterioration. Traffic volume ($\beta = 0.381, p < 0.05$) has the strongest effect, followed by idling time ($\beta = 0.302$) and congestion duration ($\beta = 0.289$). This implies that increases in these factors lead to worsening air quality. Based on these findings, the null hypothesis (H_{01}) is rejected, and it is concluded that traffic congestion has a significant effect on air quality in Abuja city.

VII. Discussion of Findings

The findings of this study revealed that traffic congestion variables significantly predict air quality deterioration in Abuja, with traffic volume emerging as the strongest predictor. This result aligns with the study of Zhang et al. (2021), who found that increased vehicle density leads to higher emission concentrations due to intensified fuel combustion. Similarly, Kumar and Sharma (2022) reported that traffic volume is a major determinant of urban air pollution, particularly in rapidly growing cities where vehicle numbers increase faster than infrastructure development. The agreement between these studies and the present findings suggests that vehicle density plays a central role in shaping urban air quality.

The study also found that idling time significantly contributes to air pollution. This supports the findings of Eze and Nwachukwu (2023), who observed that prolonged idling in congested traffic increases emissions of carbon monoxide and particulate matter. In the same vein, Lawal et al. (2021) emphasized that stop-and-go traffic conditions lead to inefficient fuel combustion, thereby increasing pollutant release into the atmosphere. The implication is that not just the number of vehicles, but how long they remain stationary in traffic, significantly affects air quality.

Furthermore, congestion duration was found to have a significant effect on air quality, indicating that longer exposure to traffic conditions results in higher pollution levels. This finding is consistent with Ogunleye et al. (2022), who reported that areas experiencing prolonged traffic congestion recorded higher pollutant concentrations than areas with shorter congestion periods. Similarly, Abdullahi and Sani (2024) noted that extended traffic delays in Abuja corridors contribute to cumulative emission buildup, worsening environmental conditions over time.

The overall result showing that traffic congestion explains a substantial proportion (55.2%) of air quality variation reinforces the argument that transportation is a major driver of urban environmental degradation. This finding agrees with Mohammed et al. (2023), who identified vehicular emissions as a primary contributor to air pollution in Abuja. It also supports the Environmental Kuznets Curve perspective, which suggests that early-stage urban development is often associated with increased environmental degradation due to rising economic activities and mobility demand (Stern, 2004; Dinda, 2004).

The implication of these findings is that traffic congestion is not merely a mobility issue but a critical environmental and public health concern. The strong predictive relationship observed suggests that reducing congestion through improved traffic management, expansion of public transport, and stricter emission controls could significantly improve air quality. The consistency of these findings with existing literature strengthens their validity and highlights the urgent need for integrated urban transport and environmental policies in Abuja.

VIII. Conclusion

This study examined the effects of traffic congestion on air quality in Abuja city between 2022 and 2026 and found that traffic congestion is both widespread and structurally embedded within the urban transport system. The findings revealed that factors such as high traffic volume, prolonged idling time, and extended congestion duration significantly contribute to the deterioration of air quality. The regression analysis further confirmed that these variables collectively explain a substantial proportion of variations in air quality, indicating that traffic congestion is a major environmental stressor in the city.

The study therefore concludes that traffic congestion is not merely a transportation inconvenience but a critical environmental and public health issue in Abuja. The significant relationship established between congestion and air quality deterioration implies that without targeted interventions, increasing urbanization and vehicle dependency will continue to worsen pollution levels and associated health risks. Addressing traffic congestion is therefore essential for improving environmental quality and achieving sustainable urban development in Abuja.

IX. Recommendations

1. The government and relevant urban planning authorities should invest in efficient and reliable public transportation systems, such as Bus Rapid Transit (BRT) and rail networks, to reduce dependence on private vehicles and alleviate traffic congestion.
2. Regulatory agencies should enforce stricter vehicular emission standards and promote the adoption of cleaner fuels and technologies, while also implementing traffic management strategies that minimize idling time and improve traffic flow across major urban corridors.

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