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Analysis of Air Quality Index Based on Traffic Load and Proportion of Green Open Space in Indonesia

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Abstract

The rapid development of urbanization in Indonesia has triggered air quality degradation, mainly caused by an increase in the number of motor vehicles (JKB) and a decrease in green open spaces (RTH) in urban areas. This study aims to analyze the effect of the number of motor vehicles and the proportion of RTH on the Air Quality Index (AQI) in 50 major cities in Indonesia. The main issue addressed is the spatial inequality of air quality, caused by anthropogenic pressures and the low ecological capacity of major cities. The novelty of this study lies in the use of a cross-sectional approach and the integration of the Environmental Kuznets Curve (EKC) theory in the Indonesian spatial context, which is still rarely applied in similar empirical studies. The method used is multiple linear regression with a robust approach, based on secondary data from IQAir Indonesia, BPS, and relevant ministries. The analysis results show that the number of motor vehicles has a significant positive effect on AQI values, reflecting a decline in air quality. Conversely, the proportion of green space shows a significant negative effect on AQI, meaning that the more extensive the green space, the better the air quality. The model explains 87.6% of the variation in AQI between regions. These findings support the relevance of the EKC in the urban context of Indonesia and emphasize the urgency of controlling negative externalities from the transportation sector. This study concludes that sustainable urban planning must synergize vehicle emission reduction strategies with green space expansion to improve air quality, protect public health, and support the achievement of the Sustainable Development Goals (SDGs).

INTRODUCTION

Air pollution has become one of the most significant environmental challenges in the modern era, especially amid increasing rates of urbanization and industrialization (Zhang *et al.*, 2022). Urban population growth is accompanied by an increase in the number of motor vehicles, while urban infrastructure expansion tends to reduce the amount of green open space. The combination of these two factors contributes to the accumulation of air pollutants such as particulate matter (PM2.5), carbon monoxide (CO), and nitrogen dioxide (NO_2), which directly impact air quality and public health (Bikis, 2023).

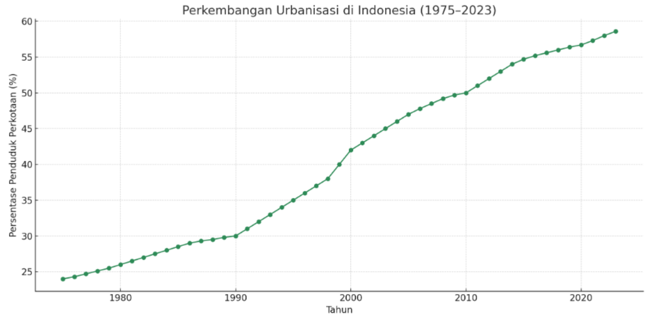
According to a report by the World Health Organization (WHO), poor air quality has contributed to more than seven million premature deaths annually worldwide (Cohen *et al.,* 2017). In the context of developing countries such as Indonesia, the significant increase in the number of motor vehicles and the conversion of land to built-up areas has led to a decline in air quality in many urban areas. Major cities such as Jakarta, Surabaya, and Medan show trends of pollutant concentrations exceeding national and international safety thresholds (Santoso *et al.,* 2020).

Most previous studies have focused on case studies of specific regions or used time-series data approaches, which are less able to capture spatial variations between regions. A cross-sectional approach is needed to describe the systemic relationship between anthropogenic activities and environmental degradation more comprehensively. The availability of secondary data from various government agencies such as the Meteorology, Climatology, and Geophysics Agency (BMKG), the Central Statistics Agency (BPS), the Ministry of Environment and Forestry (KLHK), and the Ministry of Transportation provides a strong foundation for data-based analysis.

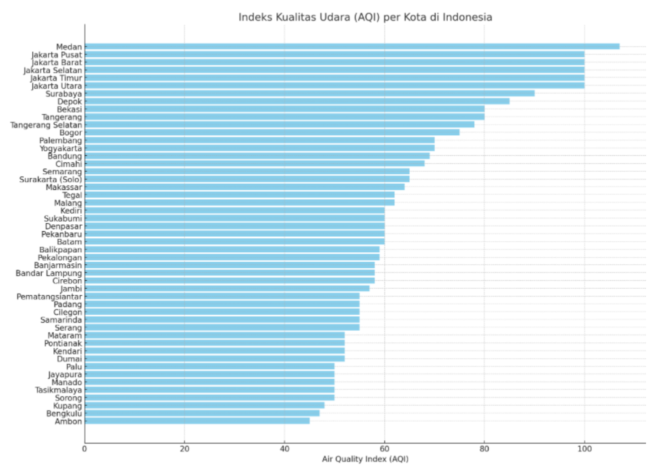
The post-pandemic period of 2024 reflects the stabilization of economic activity and community mobility, making it an opportune time to reassess anthropogenic pressures on air quality. This study utilizes a quantitative approach with cross-regional data to examine the influence of motor vehicle numbers and green open space areas on the Air Quality Index (AQI). Additionally, the Environmental Kuznets Curve (EKC) theory and the sustainable development paradigm are used as a theoretical analytical framework to test the relevance of the relationship between economic development and environmental degradation in the context of urban areas in Indonesia.

The rapid development of urbanization in Indonesia has had a significant impact on environmental quality, particularly in terms of Air Quality Index (AQI) in urban areas. Uncontrolled urbanization is often accompanied by increased transportation activities, industrialization, and land use changes that lead to progressive environmental degradation. One of the most obvious impacts of this process is the increase in air pollution concentrations, particularly fine particles such as PM2.5 and PM10, which are known as microscopic particles that can penetrate human respiration and endanger health (Cholianawati *et al*., 2024).

Graph 1.1 Development of Urbanization Percentage in Indonesia



Graph 1.2 Distribution of Variations (Air Quality Index) AQI in 50 Major Cities in Indonesia

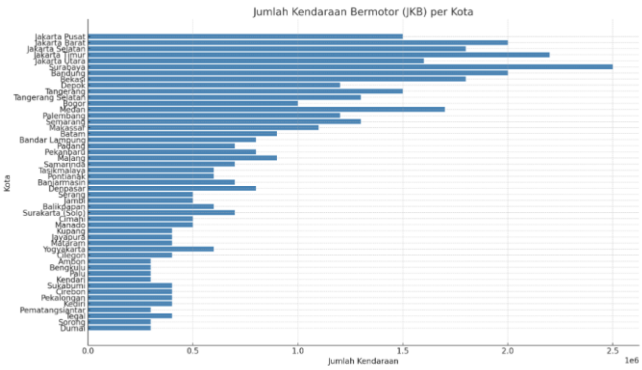


Based on the Air Quality Index (AQI) graph for cities in Indonesia, it can be seen that large and densely populated cities such as Medan and the entire DKI Jakarta administrative area (Central, West, South, East, and North Jakarta) have very high levels of air pollution, with an AQI reaching 100 or more (Medan = 107). These values indicate unhealthy air quality, particularly for sensitive groups such as children, the elderly, and those with respiratory conditions. Other major cities like Surabaya, Depok, and Bekasi also show high AQI levels, indicating that urbanization activities, motor vehicles, and population density significantly contribute to deteriorating air quality. Meanwhile, cities in central to eastern Indonesia, such as Ambon, Kupang, Jayapura, and Bengkulu, showed AQI levels below 50, indicating good and relatively clean air quality. Overall, this graph highlights the disparity in air quality between densely populated metropolitan cities and those with lower levels of urbanization and industrialization. These findings underscore the importance of emission control and sustainable urban planning to improve air quality, especially in areas experiencing high development pressure.

The increase in the number of motor vehicles, particularly in large cities, is the main contributor to air pollutant emissions, along with the decline in the area and function of green open spaces (RTH), which should serve as natural indicators for absorbing pollutants in the air. According to Correia & Roseland (2022), this situation reflects the presence of negative externalities in modern urban development, where economic activities such as transportation and construction generate unintended consequences in the form of air pollution that is not directly borne by the entities engaged in such activities. In other words, the social costs of air pollution are borne by the broader community, not by the primary actors involved in those activities (Kusumaningtyas *et al.*, 2018).

A study by Mustaqiman *et al.* (2025), shows that PM2.5 concentrations can reach 53.6 µg/m³ or 10.6 times the WHO threshold, mainly due to transportation and industrialization as well as meteorological conditions that support pollutant accumulation. Meanwhile, the results of AERMOD simulations in Nairobi by Matara *et al.* (2024), in Nairobi show the significant contribution of motor vehicles to air pollution, although this varies depending on the type of pollutant. For example, CO from traffic accounts for 55% of the total measured CO concentration. In the context of mitigation, the presence of green open spaces is highly strategic. As an important note, Nugroho *et al* (2025) emphasize that Indonesia's air quality monitoring system still faces limitations in spatial coverage and timeliness. They suggest integrating digital technologies such as IoT and artificial intelligence into the monitoring system to make it more effective in supporting pollution control policies and green development in metropolitan areas. The transportation sector is one of the main contributors to air pollutant emissions in major cities in Indonesia. Kusumaningtyas *et al*. (2018), noted that PM2.5 concentrations in Jakarta consistently exceed the air quality thresholds set by the World Health Organization (WHO), with a significant contribution from motor vehicle activities, particularly fossil fuel-powered private vehicles. This situation not only impacts air quality degradation but also poses chronic health risks such as respiratory and cardiovascular diseases. Research by Cholianawati *et al* (2024), further supports these findings by showing that variations in PM2.5 concentrations are influenced by daily traffic density, air humidity, and the height of the atmospheric boundary layer, which affects pollutant dispersion in the air.

Graph 1.3 Distribution of Motor Vehicle Numbers (JKB) in 50 Major Cities in Indonesia



The horizontal bar chart depicting the number of motor vehicles (JKB) by city in Indonesia indicates an imbalance in distribution between regions. Major cities such as Surabaya, East Jakarta, West Jakarta, and Bandung rank at the top with more than two million vehicles. This phenomenon reflects the characteristics of metropolitan areas with high levels of urbanization, dense economic activity, and large populations.

Conversely, cities with smaller economies and populations, such as Dumai, Sorong, Ambon, Bengkulu, and Pematangsiantar, show relatively low numbers of motor vehicles, around 300,000 units. This number is likely correlated with infrastructure limitations, low mobility intensity, and less dense population distribution compared to major urban areas.

Overall, this distribution pattern indicates that motor vehicle ownership is highly concentrated in economically advanced urban areas. This implies that regions with high vehicle density are likely to face issues such as traffic congestion, increased emissions, and greater environmental burdens. Meanwhile, cities with lower vehicle numbers may experience limitations in population mobility, transportation access, and inter-regional integration. These findings are important as a basis for formulating equitable transportation and regional development policies.

A study in Addis Ababa shows that greenery levels are negatively correlated with PM2.5 concentrations and health risks. Conversely, areas with minimal vegetation experience high air pollution and a 57.92% prevalence of respiratory disorders (Bikis, 2023). Research in Baghdad also revealed that the presence of roadside vegetation significantly reduces PM2.5 and PM10 concentrations compared to areas without plant barriers Alobaidi (2024). This effectiveness is confirmed by a study in Japan showing that traffic flow is directly correlated with NOx and CO concentrations, although its effect on PM2.5 is statistically smaller (Nishitateno *et al.*, 2024). A follow-up study in Beijing showed that urban park areas with dominant plant communities (trees, shrubs, grass) had lower PM2.5 levels than open areas without vegetation cover. In other words, an optimal plant community structure can significantly reduce PM2.5 exposure and improve air quality(Pan *et al.*, 2024).

This study also highlights that green spaces with higher levels of biodiversity dominated by flowering plants and complex vegetation tend to exhibit more optimal photosynthetic activity, thereby better maintaining carbon balance in urban areas (Trémeau *et al*., 2024). Through a study of various types of vegetation in Helsinki, it was found that green open spaces have the potential to be effective carbon sinks, although there are differences in performance between long-established grasslands and newly formed ones. A similar finding was observed in a study in Kuala Lumpur, which found that private vehicles are the main contributors to PM10, NOx, and CO emissions. Vehicle pollution increases with urbanization and growth in motor vehicle ownership (Shafie & Mahmud, 2020). Additionally, a study on roadside vegetation in Baghdad found that the presence of plant barriers and median planting can reduce particulate concentrations and provide visual protection and natural shade (Alobaidi, 2024). In a study conducted in Dublin, it was found that PM2.5 and NO_2 concentrations correlate with heavy traffic patterns, particularly at major city intersections. Regression analysis based on traffic and air quality data indicates that motor vehicle volume significantly contributes to daily fluctuations in air pollution (Tafidis *et al.*, 2024).

Regarding mitigation, the presence of green open spaces is crucial in absorbing air pollutants. A global-scale study by Islam *et al.* (2024), showed that cities with vegetation coverage exceeding 27% can significantly reduce PM10 concentrations. This reduction is higher in urban parks than in industrial areas or highways. The presence of green open spaces (RTH) in urban areas has proven effective in reducing air pollutant levels. This occurs because plants can absorb and deposit pollution particles on their surfaces, making RTH crucial in air pollution control efforts (Bermúdez *et al*., 2023).

A study by Kusumaning Asri *et al.*(2021), shows that exposure to green open spaces in Indonesia also has a positive impact on the mental and social health of the community, indirectly reinforcing the argument about the importance of vegetation in urban ecosystems. Green spaces help reduce exposure to air pollution and extreme temperatures, as well as reduce stress caused by urban density and noise. Meanwhile, research by Xuan (2024) shows that population growth and dependence on fossil fuels play a major role in increasing carbon emissions in Indonesia. This study emphasizes that the adoption of renewable energy and energy efficiency is very important in reducing the environmental impact in big cities, although its adoption is still hampered by various challenges.

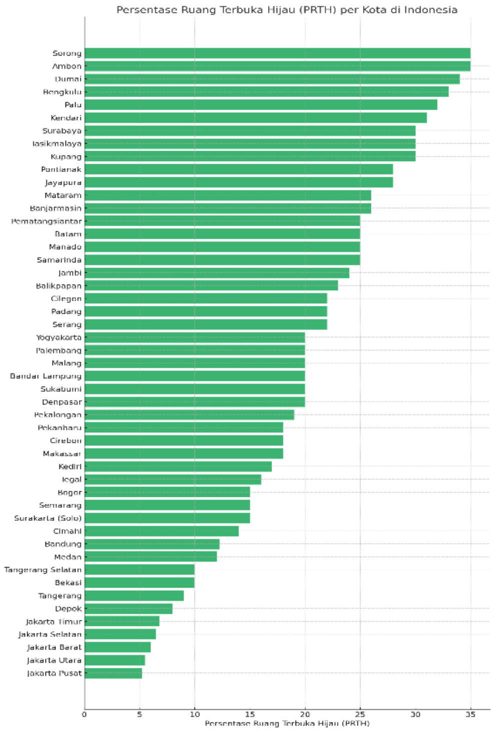
In the context of air pollution mitigation, green open spaces (RTH) play a very strategic role as natural absorbers of air pollutants. Surya Maulana *et al.* (2023), show that areas with high Normalized Difference Vegetation Index (NDVI) values, an indicator of vegetation density and health, have PM2.5 and PM10 concentrations up to 50% lower than industrial areas and high-traffic zones. This finding indicates that adequate vegetation can significantly reduce the risk of exposure to pollutants in urban environments. A similar phenomenon is also reflected in the urban context in Indonesia. Research by Juwito & Poerwoningsih. (2017), shows that the limited availability of green open spaces (GOS) is one of the main factors contributing to the decline in environmental health quality in urban areas. The scarcity of GOS not only exacerbates air pollution but also increases a city's vulnerability to hydrometeorological disasters such as floods and extreme heat. Thus, GOS not only serves aesthetic and recreational functions but also plays a crucial ecological role in maintaining air quality and climate resilience in urban areas.

The impacts of air pollution are not only ecological but also have direct implications for public health. Poor air quality has been linked to increased incidence of respiratory diseases, heart conditions, and reduced work productivity. Interestingly, research by Limayani & Tanur. (2024), shows that a high air quality index (AQI) has a positive correlation with the happiness index of communities in Indonesia. In other words, when air quality improves, not only does physical health improve, but so does subjective well-being. This indicates that clean air is a basic need that influences overall quality of life.

One structural solution frequently proposed in various scientific studies is the improvement of the quality and quantity of green open spaces in urban areas. A case study at Taman Indonesia Kaya in Semarang, conducted by Harjanti (2020), illustrates that well-designed and managed urban parks not only serve as recreational spaces but also fulfill ecological functions in reducing air pollution and environmental temperatures. The presence of urban parks has also been proven to increase social interaction among residents, strengthen social cohesion, and create inclusive spaces that support the overall well-being of the community. In Indonesia, policies to improve air quality in the transportation sector have been implemented in Bandung, using a local policy approach to reduce vehicle emissions and evaluate the role of green open spaces as a factor influencing differences in air quality index (AQI) values. In addition, a study based on Sentinel-2 imagery and the NDVI index in five major cities Jakarta, Bandung, Yogyakarta, Surabaya, and Semarang also shows differences in the spatial distribution of urban green spaces and their potential benefits in reducing air pollution levels (Agustiyara *et al*., 2025).

However, the implementation of green open space development policies in Indonesia still faces considerable challenges. Many large cities in Indonesia have not been able to meet the minimum requirement of 30% green open space of the total area, as explained by Saputra *et al.* (2013), on Spatial Planning. Unsustainable development, such as the conversion of land into commercial and intensive residential areas, has led to a decline in green areas in urban areas. Additionally, weak oversight, lack of public participation, and limited local budgets pose further obstacles in achieving the ideal proportion of green open space provision.

Graph 1.4 Availability of Green Open Spaces in 50 Major Cities in Indonesia



Based on the results of data visualization, it can be seen that the distribution of green open spaces (RTH) in urban areas in Indonesia shows quite striking disparities between regions. Cities such as Ambon, Sorong, Dumai, Bengkulu, and Palu occupy the top positions with RTH percentages reaching more than 30%. This achievement can be attributed to relatively lower development intensity compared to metropolitan cities, allowing green spaces to be maintained on a fairly large scale. The high presence of RTH in these cities has the potential to support cleaner air quality, maintain ecosystem balance, and provide social and ecological benefits for the local community.

Conversely, major cities such as Central Jakarta, North Jakarta, West Jakarta, and South Jakarta show very low PRTH figures, ranging from 5% to 7%. This low proportion reflects high urbanization and land conversion pressures as a consequence of massive population growth and economic activity. The lack of RTH in metropolitan areas can increase the risk of environmental degradation, worsen air quality, and exacerbate the urban heat island effect. Overall, these findings indicate the need for urban spatial planning that is more oriented toward environmental sustainability. Local governments need to formulate integrated conservation and rehabilitation policies for green open spaces to ensure a balance between development needs and environmental preservation in urban areas.

Given the complexity of the issue and its interconnection with traffic and green open space factors, it is important to conduct a comprehensive empirical study. This research aims to analyze the determinants of air quality based on traffic load and the proportion of green open space in 50 major cities in Indonesia. Using a quantitative approach and secondary data, this study is expected to provide tangible contributions to the formulation of more sustainable environmental policies.

In line with the increasing dynamics of urbanization, various major cities in Indonesia are experiencing high environmental pressure due to the imbalance between development activities and their ecological carrying capacity. One of the most evident impacts of this condition is the high level of air pollution caused by a combination of transportation emissions, industrial expansion, and reduced vegetation cover. This phenomenon not only affects the physical environment but also poses risks to public health, quality of life, and economic burdens due to increased healthcare costs and reduced productivity as a result of externalities generated.

This context, in line with the study conducted by oleh Kurniawan *et al.* (2025), makes an important contribution through an analytical approach that examines the social and economic factors that influence carbon emissions in West Java Province. The study uses the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model and integrates it with the Environmental Kuznets Curve (EKC) approach to observe the relationship between economic growth and environmental degradation over the period 2015–2021. The results show that population growth, industrial investment, and an increase in the number of motor vehicles have a positive and significant relationship with increased CO_2 emissions. On the other hand, vegetation density measured by the NDVI index was found to significantly reduce carbon emissions. This indicates that green open spaces are not merely aesthetic complements to the city but vital elements in maintaining urban ecosystem balance and mitigating air pollution.

The findings of Kurniawan *et al.* (2025), also confirm the validity of the Environmental Kuznets Curve (EKC) hypothesis, which shows that in the early stages of economic growth, environmental pressure tends to increase alongside industrialization and infrastructure expansion. However, after passing a certain turning point, increases in per capita income actually contribute to a decrease in emissions, as society and governments become more aware and able to invest in environmentally friendly technologies and ecological protection. This reflects the importance of balancing economic growth with sustainable development strategies that integrate social, economic, and environmental aspects holistically.

Furthermore, the research results show that development models that place too much emphasis on the industrial sector without considering land use and vegetation availability can trigger the phenomenon of pollution havens, where areas with weak environmental regulations become places for highly polluting industries to operate. This further underscores the need for policies that not only target economic growth but also consider energy efficiency, controlling the number of private vehicles, and restoring urban ecosystems through the optimization of green open spaces.

The context highlighted in Kurniawan, Hasabi, et al.'s (2025) study at the provincial level, such as West Java, represents many of the challenges also faced by other major cities in Indonesia. Although regional characteristics, topography, and population density vary, the patterns of relationships between vehicle traffic, industrialization, and the limitations of green open spaces on air quality tend to be similar. Therefore, national-scale research is needed to comprehensively and systematically capture the complexity of the relationship between traffic load and the extent of green open spaces with air quality in various major cities in Indonesia.

By analyzing secondary data from 50 major cities in Indonesia, this study aims to identify the main determinants that influence air quality, particularly in the context of traffic load and the proportion of green open space. The quantitative approach used is expected to yield findings that can serve as a reference in formulating policies for air pollution control based on ecological spatial planning and sustainable transportation. Furthermore, the results of this study are expected to strengthen the empirical basis for inclusive, environmentally conscious urban planning that is aligned with the Sustainable Development Goals (SDGs), particularly Goal 11 (sustainable cities and communities) and Goal 13 (climate action).

PROBLEM STATEMENT

To what extent do the number of motor vehicles (JKB) and the proportion of green open space (PRTH) affect air quality (AQI) in urban areas of Indonesia? And, is there a significant influence between development variables (urbanization, transportation, and green open space) on air pollution within the framework of sustainable development theory and the Environmental Kuznets Curve?

OBJECTIVES

The study aims to analyze the extent to which the number of motor vehicles (JKB) and the proportion of green open space (PRTH) affect air quality (Air Quality Index/AQI) in urban areas of Indonesia and to test for a significant causal relationship between development variables such as urbanization, transportation, and green open space on air pollution levels, as well as to evaluate their interrelationships within the framework of sustainable development theory and the Environmental Kuznets Curve (EKC) concept.

LITERATURE REVIEW

1. Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC) illustrates that environmental damage, including air quality degradation, initially tends to increase in line with the rate of economic growth and industrialization in a region. Over time, once per capita income reaches a certain level, awareness of environmental issues and the implementation of environmentally friendly regulations and technologies begin to develop, which ultimately reduces the level of pollution. Empirical findings in Indonesia by Prasetyanto & Sari (2021) show that the EKC pattern applies both in the short and long term to environmental degradation, where economic growth and energy use have a positive impact on pollution levels. However, long-term education emerges as a factor capable of mitigating these adverse effects. Meanwhile, research by Rahayuningrum (2024) examines the relationship between CO_2 emissions, energy consumption, and economic growth in Indonesia from 1990 to 2019. The results reveal that while CO_2 emissions and energy consumption have a significant impact on environmental pollution, economic growth only has a direct impact in the short term, indicating that Indonesia has not yet fully reached the EKC turning point.

On the other hand, Green Open Spaces (GOS) play an important ecological role in absorbing air pollutants such as $PM_{2.5}$, NO_2, SO_2, and CO through photosynthesis and other physical mechanisms, thereby helping to improve air quality in urban areas. From an EKC perspective, increasing the area of GOS is one form of environmental intervention typically implemented after a region has passed the turning point of the curve. Thus, in this study, the traffic load variable can be interpreted as an indicator of pollution pressure reflecting the early phase of the EKC, while the RTH proportion variable describes the form of environmental investment in the stage after passing the turning point.

2. Air Quality Index

The Air Quality Index (AQI) measures pollutant levels such as PM2.5, PM10, NO_2, SO_2, CO, and O_3 to assess air quality and its impact on health, helping the public and government take preventive measures (Abulude *et al*., 2024). A study conducted by Orellano *et al*. (2020), revealed a significant correlation between increased concentrations of these pollutants and rising overall mortality rates. Stieb *et al*. (2008), explained that Canada developed the Air Quality Health Index (AQHI) as a tool to help vulnerable groups such as children, the elderly, and those with chronic illnesses in choosing daily activities appropriate to air conditions. Rapid urbanization in large cities, coupled with increased industrial and motor vehicle activities, has led to a decline in air quality (Abulude *et al*., 2024). A study conducted by Orellano *et al*. (2020), in 338 cities in China revealed that the urbanization process significantly drives the increase in PM2.5 concentrations. In this context, the Ecological Urbanization Theory explains that the urbanization process alters the relationship between humans and the physical environment, leading to ecological stress due to concentrated activities, increased energy consumption, traffic growth, and large-scale infrastructure development, which collectively have a negative impact on air quality (Park & Burgess., 1925).

Air pollution from various sources needs to be analyzed comprehensively, considering transportation, industry, and the environment, to ensure accurate Air Quality Index (AQI) mapping and more targeted policy decisions (Marcotullio & Lee., 2003). A study by Choi *et al*. (2015), developed the Aggregate Air Quality Index (AAQI) using PCA to assess the overall impact of transportation pollution in the US, covering pollutants such as CO, NO_2, PM, SO_2, and VOCs, and supporting urban and transportation planning. Additionally, research conducted by Gangwar *et al*. (2023), emphasizes the importance of technologies such as the Internet of Things (IoT), Big Data, and Machine Learning in real-time air quality monitoring for swift and accurate responses. A study by Kinnon *et al*. (2019), states that without proper policies, urban growth and transportation worsen air quality. Therefore, air quality analysis is crucial in sustainable urban planning. Research by Santoso *et al*. (2020), states that air in major cities such as Jakarta, Surabaya, and Bandung is often unhealthy due to high levels of PM2.5 and PM10 from vehicles, industry, and biomass burning. A study by Lestari *et al*. (2020), noted that in 2015 in Jakarta, the transportation sector was the main contributor to NOx emissions at 57% and CO at 93%, while the industrial sector was responsible for 67% of SO_2 emissions.

3. Traffic Load

Motor vehicle emissions are the main cause of air pollution in cities, including Indonesia, with increased traffic raising levels of NOx, CO, SO_2, and particulates PM2.5 and PM10 (Kumar *et al*., 2015). Poor fuel quality and old vehicle age exacerbate pollutant emissions, with a small proportion of vehicles known as "gross polluters" responsible for the majority of emissions (Ketzel *et al*., 2021). Research by Nishitateno *et al*. (2024), shows that an increase in traffic volume significantly raises concentrations of NOx, CO, and NMHC pollutants. The elasticity ranges from 0.04–0.05 in the short term and 0.09–0.17 in the long term. Research by Minmin *et al*. (2021), shows that an increase in traffic volume significantly raises concentrations of NOx, CO, and NMHC pollutants. The elasticity ranges from 0.04–0.05 in the short term and 0.09–0.17 in the long term. Ziying (2018), also highlights the higher health risks for vulnerable groups such as children, the elderly, and those with respiratory problems due to pollution. Glover (1999), states that as cities develop, pollution shifts from local to global.

In the early stages of urbanization, vehicle emissions were the main contributor to the decline in air quality before environmental management improved. Rapid urbanization in Indonesia has exacerbated this condition, as people have become increasingly dependent on private vehicles due to the lack of effective public transportation (Pavão *et al*., 2021). Pepi *et al*. (2016), show that the Air Quality Index (AQI) in cities varies by time and location. During peak hours, vehicle volume increases sharply, leading to higher pollutant emissions and AQI levels. Areas such as intersections and densely trafficked zones have significantly higher pollution levels compared to quieter areas. In a study conducted in Krueng Geukuh, Jaya (2017), found that an increase in the number of vehicles led to higher levels of CO and NO_2, although these values remained below national air quality standards.

Munir *et al*. (2022), noted that traffic management measures such as access restrictions can improve air quality and environmental awareness. Appropriate transportation policies are crucial for reducing urban pollution. Bandung, a major industrial and high-mobility city, exhibits similar patterns. Pontoh *et al*. (2023), found a direct correlation between the number of motor vehicles and increases in the Air Quality Index (AQI), particularly during morning and evening rush hours. Industrial activities also contribute to air pollution, posing health risks to city residents. Various traffic management strategies effectively reduce emissions and improve air quality. Elliott & Miniat (2021), emphasize that vehicle restrictions, public transportation development, and environmentally friendly technologies are important for reducing transportation pollution. These policies are crucial in sustainable urban planning to address urban air pollution.

4. Urban Green Open Spaces (UGOS)

Urban Green Open Spaces (UGOS), such as parks, gardens, and green corridors, function as natural filters for pollution through deposition and absorption processes. Various international studies indicate that expanding UGOS correlates with reduced pollutants and improved overall air quality (Annavarapu & Kathi, 2016). Research by Islam et *al*. (2024), shows that cities with at least 27% green space have lower PM10 levels, emphasizing the important role of RTHK in reducing air particle pollution. Bi *et al*. (2024), developed a practical approach integrating Urban Green Open Spaces (RTHK) into spatial planning in Wuhan to effectively improve air quality and reduce pollution. Lorot (2024), evaluated the impact of RTHK on air quality in metropolitan areas. The study found that vegetation in green spaces acts as a natural filter that absorbs pollutants such as CO_2, NO_2, and ozone, and helps reduce pollution through deposition and absorption processes. Salman *et al*. (2023) noted a 16% decrease in green spaces and a 34.7% increase in built-up areas in Dhaka since 1991. The Air Quality Index (AQI) rose, then decreased slightly in 2021 due to pollution mitigation efforts. This study emphasizes the role of green spaces in maintaining air quality and supporting the Sustainable Development Goals (SDGs).

Fu *et al*. (2024a), analyzed data from 31 provinces in China and found that green open space provides environmental benefits while improving public health, especially in areas with lower levels of air pollution. Research conducted by Bikis (2023), shows that the uneven distribution of RTHK in Ethiopia causes differences in pollution exposure and health risks between regions. Research by Jaung *et al*. (2020), in Singapore found that the community most values the benefits of RTHK in reducing temperature and pollution; this highlights the important role of RTHK in improving quality of life in tropical climates. Alberti (2005), argues that cities are complex ecosystems involving reciprocal relationships between humans and the environment. In this framework, green open spaces play a crucial role in maintaining ecosystem stability, particularly through the role of vegetation in filtering the air and reducing the urban heat island effect.

Research by Auwalin *et al*. (2024), applied a difference-in-differences approach to assess the impact of green open spaces on urban environmental conditions in Indonesia, and the results showed that an increase in the area of green open spaces significantly reduced air pollution levels. In Semarang, the availability of green open spaces is linked to air quality, where the addition of green open spaces also helps improve air conditions (Nawangsari & Maulidia, 2018). According to Haq (2023), Bandung City, green open spaces only absorb approximately 99,026.70 tons of CO_2 per year, while vehicle emissions reach 5.6 million tons, indicating a significant disparity between absorption and emissions.

RESEARCH METHOD

This study was conducted using a quantitative approach to examine the influence of the number of motor vehicles (JKB) and the proportion of green open space (PRTH) on the air quality index (AQI) in 50 major cities in Indonesia. The focus of this study is to understand the extent to which transportation pressure and the ecological capacity of cities to provide green space can influence air pollution levels. In this context, the AQI serves as the primary indicator of air quality, while the number of motor vehicles (JKB) and the ratio of green open space (PRTH) are positioned as independent variables. Secondary data was collected from various sources such as IQAIR, BPS, Dishub, and the Ministry of ATR/BPN.
The theoretical foundation of this study refers to previous studies that have shown a strong correlation between traffic density and deteriorating air quality in urban areas (Yuwono & Sari, 2020). Additionally, green open spaces play a crucial role in reducing air pollutants through natural mechanisms, such as the absorption of pollutants by leaves and the deposition of particles on vegetation surfaces. The presence of plants in urban green spaces can effectively reduce concentrations of pollutants like PM10 and PM2.5, particularly in areas with high environmental stress (Sun, 2024). In a broader context, green open spaces have even been identified as having a significant contribution to improving the quality of life of the community, especially in terms of respiratory and mental health (Fu *et al*., 2024).

The analysis in this study was conducted using a multiple linear regression model to explain the relationship between two independent variables and one dependent variable simultaneously. The model is as follows:

$$\boldsymbol{AQI_i = \alpha + \beta_1 . JKB_i + \beta_2 . PRTH_i + \varepsilon_i}$$

$\boldsymbol{AQI_i}$ = Air Quality Index for unit *i*

$JKB1_i$ = Number of Motor Vehicles for unit *i*
$PRTH_i$= Proportion of Green Open Space for unit *i*
α = Intercept or constant
β_i = Regression coefficient for each variable PRTH and JKB
ε_i= Error for unit i

Model validity was analyzed through a series of statistical tests to ensure that classical assumptions were met, such as the absence of multicollinearity, heteroscedasticity, normal residual distribution, and homogeneous residual variance. The study by Matthaios *et al*. (2024), serves as an important reference in assessing the spatial influence between road proximity, green space, and air quality. Tafidis *et al*. (2024), also reinforce these findings by emphasizing that dense traffic patterns not only result in high emissions but are also significantly influenced by complex spatial and temporal configurations. On the other hand, Rahman & Utomo (2020), emphasize the need for a holistic approach that integrates environmental and public health aspects, particularly in the management of green open spaces and air pollution control in large cities.

The approach in this study is expected to contribute significantly to the development of more adaptive and sustainable urban policies, considering the synergy between transportation system management and green open space planning to maintain air quality in urban areas.

HYPOTHESIS

H_0 : The number of motor vehicles and the proportion of green open spaces have no effect on the air quality index in major cities in Indonesia.

H_1 : The number of motor vehicles and the proportion of green open spaces have a significant effect on the air quality index in major cities in Indonesia.

RESULTS AND DISCUSSION

Data analysis using STATA software shows significant differences in air quality between regions in Indonesia. The lowest Air Quality Index (AQI) value was recorded in Ambon City, at 45, while the highest value was recorded in Medan City, at 107. Based on the international AQI classification, a value of 45 indicates that the air quality in Ambon is still in the “good” to ‘moderate’ category, posing no significant health risks to the general population. Conversely, an AQI value of 107 in Medan indicates that the air quality is at a level that is “unhealthy for sensitive groups,” particularly children, the elderly, and those with chronic respiratory diseases.

This difference reflects the diversity of geographical, ecological, and human activity levels in each region. Ambon City is geographically located on the eastern coast of Indonesia, surrounded by the waters of the Banda Sea. This location provides ecological advantages such as strong and consistent sea air circulation, which accelerates the dispersion of air pollutants. Additionally, low population density and minimal industrial and motorized transportation activities help keep pollutant emissions at low levels. The well-preserved green areas around the city also act as natural carbon dioxide (CO_2) absorbers and filters for fine particles (PM2.5 and PM10), supporting relatively stable and clean air quality.

In contrast, the city of Medan is the main center of economic and industrial activity on the island of Sumatra. As a metropolitan city with high population growth and urbanization, Medan has experienced a significant increase in the volume of motor vehicles, most of which still use fossil-based fuels. Motor vehicles, especially older or poorly maintained ones, are the main contributors to fine particulate emissions. In addition to the transportation sector, industrial areas on the outskirts of the city also contribute significantly to air pollution through combustion activities and environmentally unfriendly production processes. Furthermore, the Medan region is periodically affected by transboundary haze originating from land burning activities in central and eastern Sumatra. This haze is carried by seasonal winds and contributes to increased concentrations of air pollutants.

The contrasting conditions between Ambon and Medan demonstrate that air quality is greatly influenced by a combination of local and regional factors, both natural and anthropogenic. From a statistical perspective, these findings support the hypothesis that geographical and socio-economic variables have a significant correlation with AQI variability between regions. Thus, the results of this analysis have important implications for the formulation of air pollution control policies. A place-specific approach to policy is crucial to ensure the effectiveness of environmental interventions, as the characteristics of pollution sources, environmental carrying capacity, and meteorological dynamics vary significantly between cities. Therefore, air pollution mitigation efforts must be designed contextually and based on empirical evidence to ensure the protection of public health and the sustainability of urban environmental quality.

The results of the data analysis also show that there are striking disparities in the distribution of motor vehicles (JKB) in urban areas in Indonesia. Testing results show that Pematangsiantar City has the lowest number of motor vehicles, at 300,000 units, while Surabaya City ranks highest with 2,500,000 units. This significant variation not only reflects differences in population size and urbanization levels but also highlights disparities in transportation infrastructure development and economic activities between regions. Geographically and demographically, Pematangsiantar is a medium-sized city in North Sumatra Province with relatively low population density and a limited geographical area. Economic activities in the city primarily rely on local trade and community-based services, making the need for private vehicle ownership less urgent. In addition, the use of public transportation and informal modes of transportation such as motorized rickshaws is still quite dominant in the daily lives of the local community, which also suppresses the growth rate of private motor vehicles. This is in line with empirical observations showing that cities with low levels of industrialization tend to have more controlled and non-exponential growth in vehicle ownership.

In contrast, Surabaya, as the largest economic and administrative center in eastern Indonesia, has a very high number of motor vehicles. With a total of 2.5 million units, the dominance of private vehicles in this city is a direct indicator of the high level of urbanization, population mobility, and economic activity. Surabaya not only serves as a center of trade and industry, but also as a major transportation hub connecting areas in eastern Java and its surroundings. Rapid economic growth and the expansion of new residential areas have driven demand for private vehicles as an efficient means of mobility. Although public transportation is available, public perception of the comfort and convenience of private vehicles further reinforces the sustained increase in private vehicle ownership. In the long term, this situation has the potential to exert pressure on environmental quality, traffic congestion, and emissions that impact public health.

The disparity in JKB values between Pematangsiantar and Surabaya highlights the importance of a region-specific approach in transportation planning and sustainable mobility policies. Cities with low JKB, such as Pematangsiantar, can serve as models for developing efficient, adaptive, and inclusive public transportation systems that do not rely on private motor vehicles. Meanwhile, metropolitan cities with high JKB values, such as Surabaya, require more complex policy interventions, such as vehicle restrictions based on license plate numbers, the development of environmentally friendly mass transportation modes, and incentives for electric vehicles. Therefore, the results of this study emphasize the urgency of adopting differential and contextual transportation policies to address mobility challenges fairly and sustainably across various regions in Indonesia.

Statistical test results on the distribution of green open space (GOS) proportions in various urban areas of Indonesia reveal significant disparities between regions. Data analysis shows that Central Jakarta has the lowest GOS proportion at 5.2%, while Sorong City in Papua has the highest at 35%. These findings reflect fundamental differences in land use, urban planning policies, and the demographic and economic pressures faced by each region.

Central Jakarta, as the administrative heart of the national capital, faces extremely high development pressures due to high population density, commercial needs, and land constraints. Vertical building growth and economic expansion have caused green spaces to become increasingly marginalized. On the other hand, land constraints in Central Jakarta also limit the possibility of expanding urban parks, urban forests, or green corridors. Although national regulations mandate that at least 30% of a city's total area be allocated as green open space, implementation in metropolitan city centers often faces obstacles due to high land values and conflicts of interest among spatial planning stakeholders.

In contrast, Sorong City in Papua shows a very high proportion of green open space, reaching 35%. This city has a geographically larger area with lower population density compared to metropolitan areas like Jakarta. Additionally, the ecological characteristics of Papua, which is still rich in forest areas and natural vegetation, are a key factor in the high proportion of RTH. In the context of sustainable development, Sorong City has a comparative advantage in maintaining environmental sustainability and urban ecosystem balance, which also plays a crucial role in reducing microclimate temperatures and improving air quality through natural filtration of pollutants.

The stark contrast between Central Jakarta and Sorong underscores that the proportion of RTH is significantly influenced by a combination of structural, ecological, and spatial planning policy factors. The findings of this analysis highlight the importance of more inclusive and ecological urban planning, particularly in areas facing high development pressures. Large cities need to adopt innovative policies, such as incentives for vertical green spaces, converting non-productive built-up land into urban parks, and community involvement in community-based green space management. Thus, meeting ideal green space standards is not only a symbol of commitment to sustainable development but also a strategic investment in improving the quality of life for urban communities.

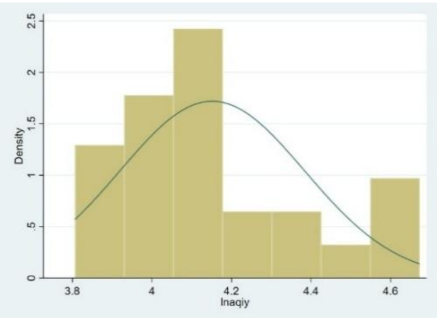


Figure 1.1 Distribution of AQI variables

Based on the results of the distribution analysis of the LnAQI variable, which is the natural logarithm of the Air Quality Index (AQI), it is known that the data distribution shows a pattern that tends to approach a normal distribution, although there are indications of right-skewedness. The LnAQI values are distributed in the range of approximately 3.8 to 4.6, which, when converted back to actual AQI values, ranges from approximately 45 to 100. This indicates that the majority of the areas observed in this study have moderate air quality, although a small portion of the areas show air quality conditions that are close to unhealthy for sensitive groups.

The peak of the distribution density is around the LnAQI value of 4.1, equivalent to an AQI of around 60, indicating that most of the observed areas are at a fairly significant level of pollution but have not yet entered the generally dangerous category. This pattern also reflects spatial variations in air quality between regions, which are likely influenced by external factors such as motor vehicle traffic intensity and limited green open space (RTH). Therefore, this distribution pattern provides a strong initial basis for further testing through inferential statistical approaches, such as linear regression, to assess the extent to which traffic load and the proportion of RTH contribute to air quality differences between regions in Indonesia.

Table 1.1. Results of the LnAQI Descriptive Statistics Test:

LNAQI

	Percentiles	**Smallest**		
1%	3.806663	3.806663		
5%	3.871201	3.850147		
10%	3.912023	3.871201	**Obs**	50
25%	4.007333	3.912023	**Sum of Wgt**	50
50%	4.094345		**Mean**	4.151604
		Largest	**Std. Dev.**	0.2320944
75%	4.248495	4.60517		
90%	4.60517	4.60517	**Variance**	0.0538678
95%	4.60517	4.60517	**Skewness**	0.08254997
99%	4.672829	4.672829	**Kurtoris**	2.657348

Based on the descriptive analysis of the LnAQI variable, a total of 50 observations were obtained. The mean value of this variable was recorded at 4.151604, reflecting the central tendency in the data distribution. The standard deviation value of 0.2320944 indicates that the spread of data from the mean is relatively small, indicating a low level of variation between observations. In this distribution, the lowest value recorded was 3.806663 and the highest value reached 4.672829, indicating that the data range falls within this range. The data distribution was also analyzed using the skewness measure, which has a value of 0.8254997. This value indicates that the data distribution tends to be asymmetrical and skewed to the right (positively skewed), meaning there are extreme values on the right side of the distribution. Additionally, the kurtosis value of 2.657348 indicates that the data has a flatter distribution shape than a normal distribution (platykurtic), with less sharp peaks.

In terms of percentile distribution, the value at the 1st percentile is 3.806663, the 25th percentile (lower quartile) is 4.007333, the median (50th percentile) is 4.094345, and the upper quartile (75th percentile) is 4.248495. The value at the 99th percentile reached 4.672829. This distribution pattern indicates that most of the data is concentrated around the median to the upper quartile, consistent with the characteristics of a distribution that tends to be skewed to the right. Overall, these results provide a fairly informative initial overview of the trends and distribution of the LnAQI variable data.

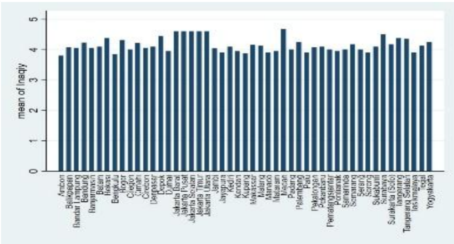


Figure 1.2 Bar Chart LnAQI

Based on the results of a bar chart analysis of the average LnAQI variable scores in a number of cities in Indonesia, it was found that the values obtained tended to show a relatively balanced distribution with a tendency toward high values. Almost all of the cities analyzed had average values in the range of 3.7 to 4.7, which generally reflects a positive assessment of the indicators measured by the variable. Cities such as East Jakarta, North Jakarta, Mataram, and Tasikmalaya rank at the top with the highest average values approaching 4.7. Meanwhile, cities such as Ambon, Cirebon, and Jayapura show lower average values, although they still fall within the “fairly good” category. These findings indicate that there are no significant disparities between regions in terms of perceptions or responses to the LnAQI variable. The high stability of scores in most cities suggests that the factors influencing this variable whether in the form of policies, services, or community experiences have been well-received by respondents across various regions. However, the variations that emerge, albeit relatively small, remain a consideration for further study to understand the contextual factors influencing public perception in cities with lower average scores.

Multiple Linear Regression Test

Source	SS	df	MS
Model	2.31286979	2	1.15643489
Residual	.326652226	47	.006950047
Total	2.63952201	49	.053867796

Number of obs	50
F (2,47)	166.39
Prob>F	0.0000
R-squared	0.8762
Adj Rsquared	0.8710
Root MSE	.08337

LnAQI	Coef.	Std.Err	t	P>ltl	95% Conf.Interval	
JKB	2.18e-07	2.72e-08	8.03	0.000*	1.64e-07	2.73e-07
PRTH	-.0132876	.0018893	-7.03	0.000*	-.0170884	-.0094869
_cons	4.23003	.0577783	73.21	0.000*	4.113795	4.346265

Description: *(1%), **(5%), ***(10%)

Based on the results of multiple linear regression analysis, it is known that the model built is statistically significant. This is proven by the F-value of 166.39 with a probability value (p-value) of 0.0000, which is smaller than the significance level of 5%. Therefore, it can be concluded that the variables jkbx1 and prthx2 simultaneously have a significant effect on the variable lnaqi. The coefficient of determination (R-squared) value of 0.8762 indicates that approximately 87.62% of the variation in the lnaqi variable can be explained by the two independent variables in the model, while the remaining 12.38% is influenced by other factors not included in the model. Individually, jkbx1 shows a significant positive effect on lnaqi with a coefficient of 2.18e-07 and a p-value of 0.000, meaning that an increase in this variable tends to increase the value of lnaqi. Conversely, prthx2 has a significant negative effect, with a coefficient of -0.0132876 and a p-value of 0.000, meaning that an increase in this variable tends to decrease the value of lnaqi. In other words, both variables play an important role but have opposite directions of influence on air quality.

This finding aligns with the Environmental Kuznets Curve (EKC) theory, which states that in the early stages of economic growth, an increase in the number of motor vehicles tends to worsen environmental conditions, including air pollution. Conversely, the variable proportion of green open space (PRTH) shows a significant negative effect on LnAQI, with a coefficient of -0.0132 and a p-value of 0.000. This indicates that the larger the proportion of green open space, the lower the

LnAQI value, meaning that air quality improves. These results align with the principles of sustainable development in economic development theory, which emphasizes a balance between economic progress and environmental conservation.

The research Hao *et al*. (2023), in Environmental Science and Pollution Research reveals that the growth in the number of motor vehicles in urban areas significantly worsens air quality due to high particulate emissions and vehicle exhaust, supporting the significant positive results for the JKB variable. Thus, these results empirically reinforce development economics theory, which emphasizes the importance of controlling negative externalities resulting from economic growth through restrictions on private transportation and the expansion of green open spaces as strategies to improve air quality in urban areas.

Normality Test

JB LNAQI
Jarque-Bera normality test: 5.923 Chi (2) .0517
Jarque-Bera test for Ho: normality

JB JKB
Jarque-Bera normality test: 9.712 Chi (2). 0078
Jarque-Bera test for Ho: normality

JB PRTH
Jarque-Bera normality test: 1.564 Chi (2). 4578
Jarque-Bera test for Ho: normality

The Jarque-Bera normality test results analyzed using Stata show distribution variations in the three variables studied. For the Air Quality Index (INAQI) variable, the JB test value was recorded at 5.923 with a p-value of 0.0517. Since this value slightly exceeds the significance threshold of 0.05/5%, the INAQI data can still be categorized as normally distributed, although it is at a relatively critical threshold. In contrast, the Motor Vehicle Number (JKB) variable produced a JB value of 9.712 and a p-value of 0.0078, which is below the critical value of 0.05. This indicates that the distribution of JKB data deviates from normality. Meanwhile, the Green Open Space Proportion (PRTH) variable obtained a JB value of 1.564 with a p-value of 0.4578, which is well above the significance threshold. Therefore, it can be concluded that the PRTH data follows a normal distribution. Based on these results, in statistical analyses requiring the assumption of normality, the inaqi and prth variables can be used without additional transformation, while the jkb variable is recommended to undergo transformation to meet the requirements of the relevant analytical model.

Multicollinearity test results:

Vif

Variable	Vif	1/vif
jkbx1	1.77	0.566179
prthx2	1.77	0.566179
Mean vif	1.77	

Based on the results of the Variance Inflation Factor (VIF) analysis, it was found that the variables Number of Motor Vehicles (JKB/X1) and Proportion of Green Open Space (PRTH/X2) each had a VIF value of 1.77, with a reciprocal value (1/VIF) of 0.566179. The average VIF value is also the same, namely 1.77. In the context of linear regression, the VIF value is used to detect whether there is multicollinearity, namely a strong linear relationship between independent variables in the model. In general, if the VIF value is below 10, it can be concluded that there is no significant multicollinearity problem. In fact, stricter standards often use a threshold of 5. Therefore, with a VIF value of 1.77, it can be said that the model is free from multicollinearity, and both independent variables (JKB and PRTH) can be used together in the regression model without affecting the validity of the interpretation of the resulting regression coefficients.

Heteroscedasticity Test Results:

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
H0: Constant Variance
Variables: Fitted values of LnAQI
Chi2(1) = 12.98
Prob > chi2 = 0.0003

Based on the results of the Breusch-Pagan/Cook-Weisberg test displayed through the estat hettest command, it is known that the chi-square (χ^2) value is 12.98 with a probability value (Prob > χ^2) of 0.0003. This test was conducted to detect the presence of heteroscedasticity in the regression model. The null hypothesis (H_0) of this test states that the regression model satisfies the assumption of homoscedasticity, i.e., the residual variance is constant. Conversely, the alternative hypothesis (H_1) states that there is heteroscedasticity, i.e., the residual variance is not constant. Since the test probability value is less than the 5% significance level ($0.0003 < 0.05$), H_0 is rejected.

Ovtest: Used to detect specification bias in the model created.

Test Results:
Ramsey RESET test using powers of the fitted values of LnAQI

H0: The model has no omitted variables.
F (3, 44) = 0.87
Prob > F = 0.4664

The test results show a statistical value of F (3, 44) = 0.87 with Prob > F = 0.4664. Since this probability value is much greater than the general significance level (e.g., 0.05), there is insufficient evidence to reject H_0. This means that, statistically, the regression model used does not contain any incorrect specifications and no important variables have been omitted. Therefore, the regression model has been specified appropriately and is suitable for further analysis.

Robust regression test results

LnAQI	Coef.	Std. Err	t	P>ltl	95% Conf.Interval	
					Number of obs	50
					F (2,47)	125.75
					Prob>F	0
					R-squared	0.8762
					Root MSE	.08337
JKB	2.18e-07	3.94e-08	5.54	0.0000	1.39e-07	2.97e-07
PRTH	-.0132876	.0020683	-6.42	0.0000	-.0174485	-.0091268
_cons	4.23003	.0672311	62.92	0.0000	4.094778	4.365281

Description: *(1%), **(5%), ***(10%)

The regression results show that the model has a total of 50 observations. The F-statistic value is 125.75 with a probability (Prob > F) of 0.0000, which means that the regression model as a whole is significant at the 99% confidence level. The R-squared value of 0.8762 indicates that approximately 87.62% of the variation in the dependent variable lnaqi (logarithm of air quality index) can be explained by the variation in the independent variables jkbx1 and prthx2. The remaining 12.38% is explained by factors outside the model. Individually, the variable jkbx1 (probability of motor vehicle count) has a coefficient of 2.18e-07 with a t-value of 5.54 and a p-value of 0.000, indicating statistical significance. This means that each one-unit increase in JKB will increase LNAQI by 2.18e-07, assuming all other variables remain constant. This indicates that an increase in the number of motor vehicles is associated with a decrease in air quality (since a higher AQI value indicates poorer air quality). Conversely, the variable prthx2 (probability of green open space or similar) has a negative coefficient of -0.0132876 with a t-value of -6.42 and a p-value of 0.000, which is also significant. This means that each one-unit increase in prthx2 reduces lnaqi by 0.0133, indicating that an increase in green open space improves air quality. The constant (_cons) value of 4.23003 indicates the average value of lnaqi when the values of jkbx1 and prthx2 are zero. However, the interpretation of the constant is not always practically meaningful, as zero may not be a realistic value for both independent variables. The results of this study align with the Environmental Kuznets Curve (EKC) theory in development economics, which states that environmental degradation tends to increase in the early stages of economic growth due to high levels of transportation activities, such as the use of motor vehicles. However, in later stages, environmental quality can improve through the implementation of effective environmental policies, such as the development of green open spaces.

This finding is reinforced by the research of He *et al*. (2019) in the Journal of Cleaner Production, which proves that the application of environmentally friendly technology in the industrial sector contributes to reducing greenhouse gas emissions and air pollutants. This is in line with the results of this study, which show that an increase in the proportion of green open spaces can improve air quality.

CONCLUSION

This study shows that air quality in major cities in Indonesia is significantly influenced by the number of motor vehicles and the proportion of green open space (RTH). The results of multiple linear regression using the robust method indicate that an increase in the number of motor vehicles causes an increase in the Air Quality Index (AQI) value, indicating a decline in air quality. This is consistent with research by Salih & Báthoryné Nagy (2024), which found that an increase in the number of vehicles in urban areas drives up emissions of pollutants such as CO_2, NOx, and $PM_{2.5}$, thereby reducing air quality. Conversely, the proportion of RTH can reduce pollution through absorption and deposition by plants, which has a positive impact on improving air quality. Conversely, the proportion of RTH has a significant negative effect on the AQI, where the larger the proportion of green space, the lower the AQI value or the better the air quality. Athokpam *et al*. (2024), found that urban green spaces, such as parks and urban forests, play a crucial role in reducing pollutant particles by up to 30% in areas with heavy traffic, and function as ecological buffers to mitigate the impacts of pollution from transportation activities. Additionally, research conducted by Dmitrović *et al*. (2025), shows that a high number of vehicles without adequate green space contributes significantly to the decline in urban air quality. This finding underscores the importance of balanced spatial planning between transportation needs and green space development to improve air quality and public welfare. Meanwhile, Ashinze *et al*. (2024), reveal that Urban Green Infrastructure (UGI), which includes elements such as urban parks, urban forests, and permeable surfaces, plays a crucial role in improving urban environmental conditions.

These findings support the validity of the Environmental Kuznets Curve (EKC) theory and the concept of sustainable development in the spatial context of Indonesia. Based on the discussion, the recommended policies include strengthening regulations on motor vehicle restrictions in densely populated areas, incentives for low-emission vehicles, and the integration of environmentally friendly public transportation systems. Local governments also need to prioritize meeting the minimum RTH requirement of 30% of the total city area through conservation, rehabilitation of green areas, and development of urban parks. Additionally, air quality monitoring systems need to be strengthened using digital technologies such as the Internet of Things (IoT) and artificial intelligence to enhance real-time policy responses.

For future research, it is recommended that spatial and temporal approaches be combined in a panel data model to analyze air quality change patterns more dynamically. Additional variables such as industrial emissions, building density, and city topography can also be included to improve the accuracy of predictive models. Future research should also test the effectiveness of urban environmental policies that have been implemented, as well as their holistic impact on community welfare and health.

RECOMMENDATIONS

1. Strengthening Transportation Regulations: Local governments are advised to implement motor vehicle restrictions, such as odd-even systems, incentives for environmentally friendly vehicles, and improvements to public transportation services as strategic measures to reduce emissions.
2. Optimization of Green Open Spaces: City governments need to expand and preserve green open spaces to meet the minimum requirement of 30% of the total area, through spatial planning that integrates the ecological and social functions of green open spaces.
3. Region-Based Environmental Policies: Given the variations in geographical and socio-economic conditions between regions, air pollution control policies must be designed contextually and specifically according to the characteristics of each region.
4. Use of Monitoring Technology: Air quality monitoring systems need to be strengthened with digital technologies such as the Internet of Things (IoT) and artificial intelligence to improve the accuracy and speed of decision-making.
5. Inter-sectoral Collaboration: Addressing air quality requires cross-sectoral synergy, including the transportation, environment, health, and spatial planning sectors, in order to be in line with sustainable development goals.

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