EVALUATING THE RELATIONSHIP BETWEEN REGISTERED VEHICLE GROWTH AND AIR QUALITY IN DHAKA USING A STATISTICAL AND VEI BASED APPROACH (2013–2024)

Md. Shofiul Islam*[1], Md. Johirul Islam Khan[2] and Tayeba Islam[3]

[1] *Lecturer, Fareast International University, Bangladesh, e-mail: shofiul.cee@fiu.edu.bd*
[2] *Lecturer, Fareast International University, Bangladesh, e-mail: johirul.cee@fiu.edu.bd*
[3] *Lecturer, Fareast International University, Bangladesh, e-mail: lamia.tayeba@gmail.com*

***Corresponding Author**

ABSTRACT

Air pollution has now become one of the most rising concerns in Dhaka city. Its Air Quality Index (AQI) often exceeds the safe threshold. Among the key contributors, vehicular emissions play a dominant role, driven by a rapidly expanding and aging vehicle fleet with limited emission control. While previous research has assessed general pollution sources, few studies have quantitatively examined the link between specific vehicle-category growth and AQI, or developed a weighted indicator to estimate aggregate vehicular impact.This study investigates the relationship between vehicular growth and air-quality variation in Dhaka from 2013 to 2024. It integrates statistical analysis with a novel Vehicular Emission Index (VEI). The analysis considers three dimensions: yearly registered vehicles vs. AQI (short-term effect), cumulative registered vehicles vs. AQI (long-term effect), and the emission-weighted Vehicular Emission Index (VEI) vs. AQI (aggregate impact). Ten major vehicle categories were selected that are dominant on Dhaka's roads. Yearly registration data for these selected vehicles were collected from the BRTA (Bangladesh Road Transport Authority) website. After that, cumulative yearly registration data were compiled. Monthly AQI data were collected from the DoE (Department of Environment) website. Monthly AQI data were then averaged to get yearly AQI data.VEI was developed using $PM_{2.5}$ emission factors, as it can link vehicular emissions with AQI more accurately, and was collected from the European Environment Agency (EEA). Findings indicate that there are substantial positive relationships between AQI and yearly registered vehicles ($r = 0.60$, $p = 0.003$) and cumulative registered vehicles ($r = 0.91$, $p = 0.001$), which shows that the annual registered fleet growth and cumulative registered fleet growth have a direct correlation with air-quality degradation. VEI was calculated by multiplying cumulative counts by the emission factors and also gave a high correlation to AQI ($r = 0.91$, $p = 0.002$). Three categories of registered vehicles from the BRTA list are highly correlated: microbus ($r = 0.90$), motorcycle ($r = 0.94$), and private car ($r = 0.92$). The VEI framework was tested using multiple regression, which showed that emissions of these types of categories together explained 94.3% of AQI variation ($R^2 = 0.943$), which confirmed the VEI framework as a strong predictor model. The results demonstrate that the deteriorated air quality of Dhaka is tightly involved with the rapid growth of vehicular movements. The policy interventions should thus focus on category-based registration thresholds, weighted fees on emissions, frequent inspection schemes, and fleet-renewal or scrappage schemes for old vehicles. The proposed VEI is a low-cost, scalable framework for assessing the effect of vehicular emissions in data-limited cities, providing evidence-based support for sustainable air-quality management.

Keywords: *Vehicular Emission Index (VEI), Air Quality Index (AQI), Vehicle registration, Correlation analysis*

1. INTRODUCTION

Air pollution has become one of the most critical environmental concerns in the 21st century, and this aspect becomes more important because of the fact that South Asian Cities are urbanizing rapidly (Khatun et al., 2023). Dhaka, among other South Asian capitals, remains one of the worst culprits in air quality, ranking among the most tainted cities in the world, based on the Air Quality Index (AQI), which often exceeds the safe standards for public wellness (Hashem et al., 2024). The worsening air quality has some consequences. Cardiovascular disease, respiratory illness, and loss of life expectancy is increasing day by day (Samiullah et al., 2025). According to the Air Quality Life Index (AQLI), life expectancy could increase up to 6.9 years for the residents of Dhaka if the amount of $PM_{2.5}$ in the air meets the WHO guidelines (EPIC, 2025). Though various sources are responsible for the deteriorating air quality, emissions from the transport sector are among the major contributors, which emit nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter ($PM_{2.5}$ & PM_{10}), contributing to air quality degradation (Iqbal et al., 2020). The concentration of particulate matter increased by about 66% in the last 25 years in Dhaka (EPIC, 2025).

The transportation sector in Dhaka is now a rapidly expanding sector, associated with the rising demographic density and financial growth, as well as the absence of a compact public transportation network in the city. Consequently, the sector's outgrowth has led to an upsurge in the registered vehicles, the majority of which are old, poorly maintained, and without proper emission controls. Evidence shows that private cars and motorcycles are the major sources of hydrocarbons and CO emissions in Dhaka, while diesel-fuelled buses and trucks are major sources of NO_x and particulate emissions (Iqbal et al., 2014). Some studies carried out in Dhaka's most congested roads revealed the presence of microbuses and asphalt-carrying heavy conveyances as major factors degrading air quality in the most congested road sections (Tabassum et al., 2022). A recent cross-sectional study among traffic police in Dhaka reveals that the increasing number of motor vehicles is significantly contributing to a rise in air pollution in Dhaka (Hashem et al., 2024)

Current literature indicates recent assessments of air attribute trends and their determinants for Dhaka through various statistical and econometric approaches. For example, sources of particulate emissions in the metropolitan area include discharges from vehicles, road dust, and industrial sites; additionally, a decline in the Air Quality Index from 2013 to 2023 showed a clear correlation between the growth of motorcycles and freight lorry emissions (Sultana et al., 2025; Baria et al., 2024). Other such metropolitan cities include Delhi, Bangkok, and Beijing, among others, where the rate of increasing emissions attributable to increasing motorization remains ahead of the capability for control over emissions (Srinivas et al., 2022; Zhao et al., 2023).

However, certain critical research gaps remain within the existing literature. Currently available studies are only measuring the total number of vehicles, without factoring in the relevance between the AQI level and the fleet size for a particular category of vehicles. Consequently, the category-specific correlation between the AQI level and the fleet size remains an unexplored aspect in the current literature. Additionally, most available studies are exploratory in nature and concentrate on the short-term or timely influences of the increasing size of the fleet on the annual AQI level, without consideration for the collective long-run influences of the increasing size of the fleet on the AQI level over the year. Furthermore, another measure quantifying the total emission level from different vehicles and their relationship with AQI still remains another unexplored aspect within the existing literature.

That's why this study investigates the relationship between registered vehicle growth and the air quality in Dhaka from 2013-2024 through an integrated statistical approach. It studies both short-term and long-term impacts and introduces the Vehicular Emission Index, an indicator that combines cumulative vehicle registration data with emission factors based on $PM_{2.5}$ emissions. Ten major vehicle categories were selected, and their registration data were analyzed to determine their individual and combined effects on AQI. The results are expected to provide some policy-relevant insights for sustainable transport management in Dhaka to prevent air pollution.

2. METHODOLOGY

2.1 Study Area and Periods

Dhaka, one of the most densely populated and polluted megacities in South Asia, has been chosen as the study area. In Dhaka, the urban transport system has been rapidly increasing over the last decade. This study observes the relationship between vehicular growth and air quality over a twelve-year period (2013-2024) to capture both short-term and long-term trends in air-pollution fluctuation. The analysis is intended to measure how the annual air-quality deterioration has been affected by the growth in the fleet of this city's vehicles, using registration data and AQI records.

2.2 Data Sources

Data on yearly registered vehicles were collected from the website of the Bangladesh Road Transport Authority (BRTA). Major types of vehicles, which are generally observed on Dhaka's roads and are mostly responsible for air pollution, were considered in this study. They include: bus, minibus, microbus, pickup, jeep, truck, private car, motorcycle, CNG, and taxicab. For each vehicle, both yearly and cumulative yearly registered vehicles were counted in order to analyze the long-term and short-term vehicular growth. Air quality index data were collected from the Department of Environment, under the Continuous Air Monitoring Stations (CAMS) network. Monthly AQI values were averaged to determine the yearly AQI for 2013–2024. The dataset was prepared on a yearly scale, thus creating a time-series dataset of twelve years (2013–2024) for consistency.

2.3 Construction of Vehicular Emission Index

The Vehicular Emission Index was developed to provide a composite measure of the overall emission of the selected vehicles. Particulate matter ($PM_{2.5}$) was used to formulate the index as it was mostly responsible for AQI variations in Dhaka City. This pollutant contributes almost 80% of AQI variation and causes various diseases (WHO, 2021; DoE, 2024). The goal of the VEI formulation was not to quantify the absolute mass of pollutants but rather to analyze the relative trend and the influence of selected vehicle categories on air quality deterioration over the last 12 years. It serves as a proxy for vehicular contribution to air quality degradation by measuring the combined effect of cumulative registered vehicle growth and per-vehicle emission rates. The index was calculated as

$$VEI_{PM}(t) = \sum_{i}^{n} F_i(t) \times EF_i^{PM_{2.5}} \qquad (1)$$

VEI_{PM} = Vehicular Emission Index based on particulate emissions
$\boldsymbol{F_i(t)}$ = Cumulative number of registered vehicles in category i and in year t
$\boldsymbol{EF_i^{PM_{2.5}}}$ = emission factor assigned to that category
n = total number of vehicle categories (here, 10)

The emission factors were collected from the database of the European Environment Agency. These data are compiled from laboratory chassis dynamometer tests and on-road portable emission measurement systems under standard urban conditions (EEA, 2023). Emission factors were selected based on fuel type and engine conditions. The emission factor of buses and trucks was considered the same (0.30 g/km), as both operate with large diesel engines producing comparable particulate emissions. Microbus, minibus, jeep, and pickup share nearly diesel configurations, weight class and urban stop-and-go operation. So, they also have a common emission factor (0.08 g/km). CNG and LPG-based vehicles emit very low emissions. That’s why a low factor was used (0.001 g/km). These factors were considered according to Euro II-III technology, which is relatively older. The adopted factors, therefore, convincingly represent the older fleet composition during 2013–2024 and are internationally recognized (EEA, 2023). The representative emission factors are shown in Table 1.

Table 1. Emission factors used for VEI construction (g/km)

Vehicle Type	Emission Factor (g/km)
Bus	0.30
Microbus	0.08
Minibus	0.08
Jeep	0.08
Pickup	0.08
Truck	0.30
Private Car	0.001
Motorcycle	0.060
CNG	0.001
Taxicab	0.001

2.4 Analytical Framework

Data analyses were done using SPSS 26 and Microsoft Excel. Descriptive statistics provides an overview of yearly and cumulative yearly registered vehicles and how AQI pattern changes yearly. Further, correlation and regression analyses were done to quantify the strength of relationships.

2.4.1 Pearson's Correlation Analysis

Pearson's correlation coefficient was determined to assess the direction and strength of the relationships between three pairs of variables: Yearly registered vehicles and yearly AQI, Cumulative yearly registered vehicles and yearly AQI, Vehicle emission index and yearly AQI. Category-wise correlations between each of the ten vehicle types and AQI were also computed to identify which categories exhibited the strongest association with air-quality deterioration. The statistical significance of all correlations was tested at the 95% confidence level ($p < 0.05$).

2.4.2 Multiple Linear Regression

In order to assess the joint predictive effect of the most influential vehicle groups on AQI, a multiple linear regression model was constructed. As predictors, the VEI of three types of vehicles that had the strongest correlations with AQI were chosen. Finally, the model was evaluated using the coefficient of determination and the significance of the dominant vehicles.

2.5 Research Framework and Rationale

The analytical framework integrates both short-term and long-term perspectives to capture Dhaka's vehicular emission dynamics comprehensively.

- The relationship between yearly registered vehicles and AQI was analyzed to observe the impact of new vehicle inflows on AQI.
- The relationship between cumulative yearly registered vehicles and AQI explains the long-term impact of vehicles on AQI.
- The relation between VEI and AQI indicates how emission potential corresponds to the pattern of AQI.
- Category-wise analysis reveals the effect of specific vehicles on AQI.
- Regression modeling ensures the combined effect of dominant contributors responsible for air quality degradation.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

Descriptive analysis represents the trend of vehicle registrations and the air quality index in Dhaka, ranging from 2013 to 2024. The cumulative and yearly registration data show a rising trend with a steady rise in average annual AQI.

It can be observed from Table 2 that in 2024, the cumulative number of registered vehicles was approximately 2.9 times higher than in 2013. During the same period, the average AQI rose from 130 to 180, indicating persistent poor air quality conditions throughout the decade.

Table 2: Descriptive statistics of cumulative registered vehicles and AQI (2013-2024)

Year	Cumulative Yearly Registered Vehicles	AQI
2013	702967	130
2014	768990	135
2015	856692	140
2016	954732	150
2017	1079946	146
2018	1235322	153
2019	1382827	149
2020	1492775	143
2021	1632649	159
2022	1798079	163
2023	1919189	171
2024	2034404	180

Figure 1 illustrates that AQI values closely followed the rise in cumulative registrations. Both variables rose almost in parallel, suggesting that long-term fleet growth exerts a cumulative pressure on Dhaka's air quality.

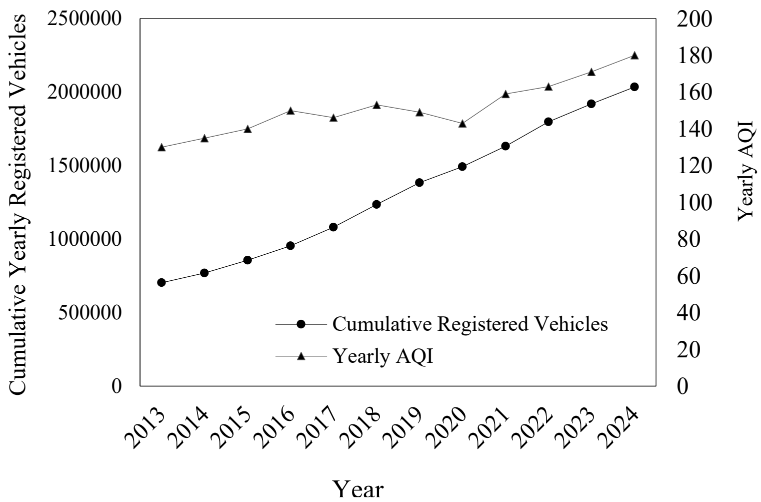

Figure 1: Trend of cumulative registered vehicles and AQI (2013-2024)

While cumulative data capture the overall emission load, yearly registration data reveal short-term variations. As presented in Table 3, annual registrations peaked in 2018 and 2022 (155376 and 165430 vehicles, respectively), with corresponding AQI spikes at 153 and 163. The lowest yearly registration occurred in 2013 (48,204 vehicles) when AQI was also at its minimum (130).

Table 3: Descriptive statistics of yearly registered vehicles and AQI (2013-2024)

Year	Yearly Registered Vehicles	AQI
2013	48204	130
2014	66023	135
2015	87702	140
2016	98040	150
2017	125214	146
2018	155376	153
2019	147505	149
2020	109948	143
2021	139874	159
2022	165430	163
2023	121110	171
2024	115215	180

Figure 2 confirms this co-movement pattern. AQI levels generally increased in years with higher new-vehicle inflows and showed minor declines when yearly registrations slowed (for example, 2020 during the COVID-19 period). These results highlight that both short-term vehicle additions and long-term fleet accumulation are strongly associated with declining air quality in Dhaka.

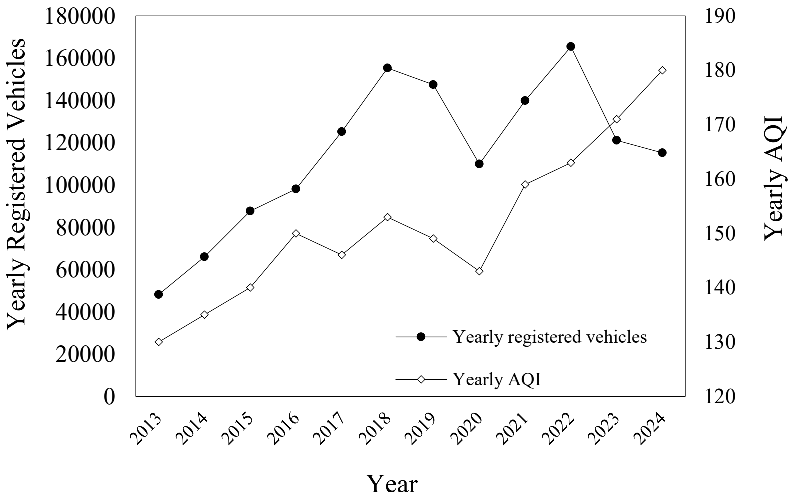

Figure 1: Trend of yearly registered vehicles and AQI (2013-2024)

Overall, the descriptive results demonstrate the definite visual and numerical connection between the rapid development of the vehicle fleet in Dhaka and the worsening air quality in the city. These observations establish the empirical basis of the following correlation and regression analyses in the subsequent sections.

3.2 Correlation Analysis

As discussed in the methodology, three types of relationships were analyzed with Pearson's correlation coefficient to capture both the long-term and short-term impact of vehicle registrations on the air quality of Dhaka. The results are discussed in the following sections.

3.2.1 Yearly Registered Vehicles and AQI

It was found that there was a moderate yet statistically significant positive relationship between the yearly registered vehicles and annual AQI, with $r = 0.60$ and $p = 0.003$ (significant at 95% confidence level). This implies that years with more new vehicles registered also measured high levels of air pollution. The trend is observed in Figure 3, where the values of AQI are in a steady upward trend as the values increase with the yearly inflow of vehicles. It also reveals that the highest number of vehicles was registered between 2018 to 2022 when the AQI levels were also comparatively high, which highlights the direct effect of the addition of new vehicles on the air quality.

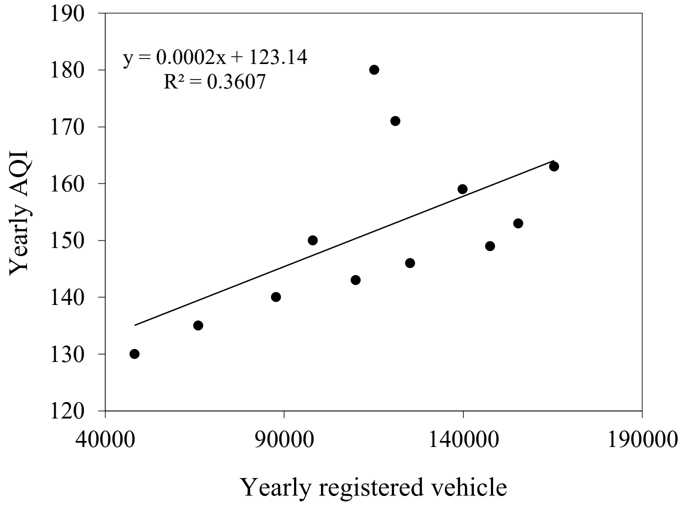

Figure 3 : Positive correlation between yearly registered vehicle and AQI

3.2.2 Cumulative Yearly Registered Vehicles and AQI

The cumulative relationship reveals a much stronger association. The correlation between cumulative registered vehicles and annual AQI reached r = 0.91, p =.001 (significant at 95% confidence level), signifying an exceptionally strong linear connection between total fleet expansion and worsening air quality. Over the twelve-year period, as the total number of registered vehicles increased from 702,967 in 2013 to over 2 million in 2024, the average annual AQI rose from 130 to 180. This pattern, shown in Figure 4, demonstrates that long-term accumulation of vehicles exerts a persistent and compounding pressure on air quality. The near-parallel upward lines for cumulative registrations and AQI confirm that Dhaka's air-quality deterioration is largely the outcome of sustained vehicular growth rather than isolated yearly fluctuations.

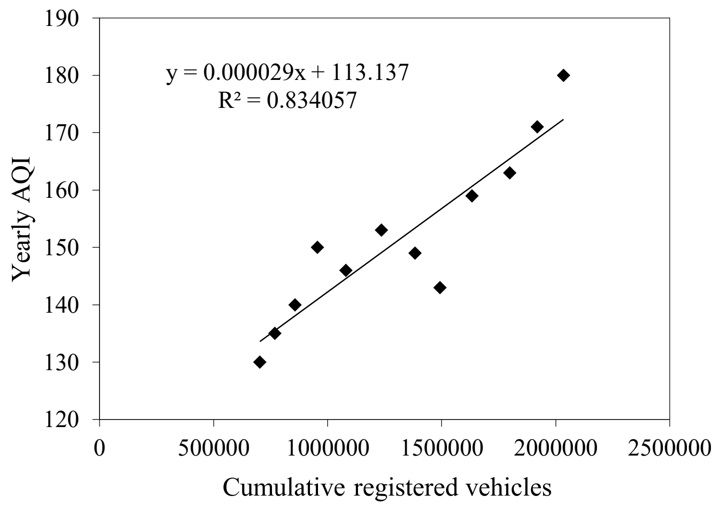

Figure 4 : Positive correlation between cumulative yearly registered vehicles and AQI

3.2.3 Correlation between VEI and AQI

In order to measure the association between the growth of emission-weighted vehicles and the change in air quality, the Vehicular Emission Index (VEI) was calculated using Equation (1). The relationship of these annual VEI estimates with annual average AQI showed a statistically significant positive correlation ($r = 0.91$, $p = 0.002$). The validity of this index lies in its formulation as a technology-based, emission-weighted proxy. By utilizing internationally standardized emission factors from the EEA Guidebook (2023) representative of the Euro II–III technologies dominant in Dhaka's Urban fleet, the VEI serves as a reliable indicator. Furthermore, using $PM_{2.5}$ as the core pollutant is justified as it explains the majority of AQI variation in Dhaka, as discussed in the methodology. This finding proves that AQI degradation is directly related to the total emission potential of the vehicle stock. Figure 5 demonstrates the relationship with upward linear correlation between VEI and AQI. The fact that the data points are clustering closely around the regression line is a strong indication that the VEI is a highly effective, data-driven proxy that may be used to estimate the impact of vehicular emissions on a limited resource environment in an urban setting.

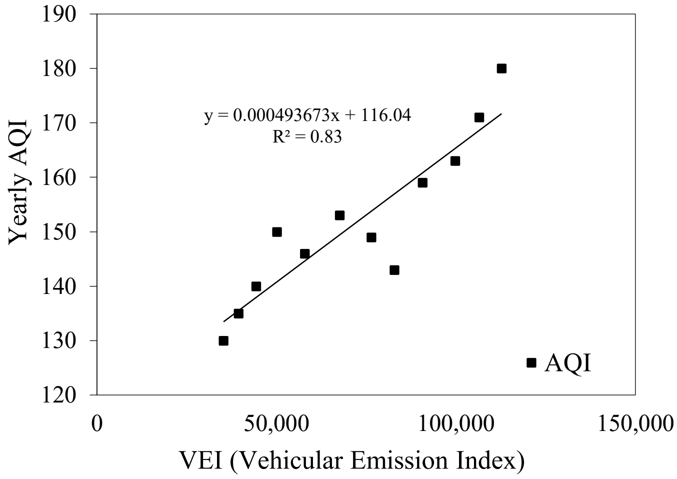

Figure 5 : Correlation results of VEI and AQI

3.2.4 Category-Wise Correlations

A further analysis of the types of individual vehicles showed that there were significant differences in their association with AQI. Microbuses ($r = 0.90$), motorcycles ($r = 0.94$), and private cars ($r = 0.92$) had the highest correlations, followed by buses and trucks with positive and lower coefficients, respectively. Figure 6 represents all the results that are statistically significant at a 95% confidence level.

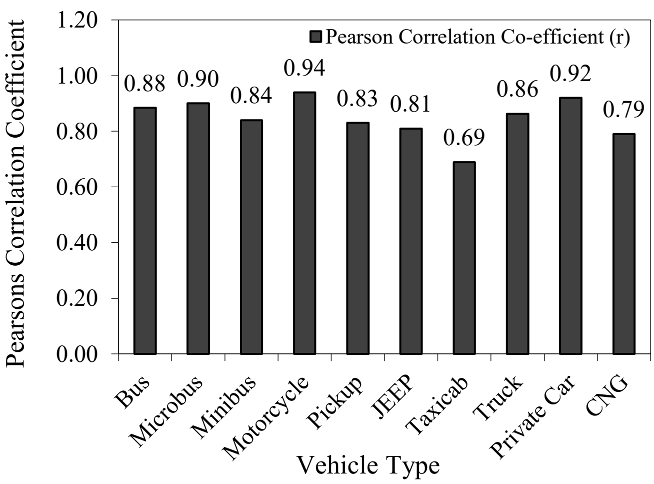

Figure 6 : Pearson's correlation coefficient for different types of vehicles

These results highlight the point that smaller and more heavily used vehicles contribute to the air-quality impact in the city disproportionately. Motorcycles and microbuses are responsible for higher emissions due to their high frequency of use, fuel inefficiency, long-term use without proper management, and limited emission control, whereas the private car contributes through uncontrolled registration growth and persistent congestion effects. Fleet-management strategies and emission-reduction policies should be implemented by focusing on those vehicles.

In all correlation studies, a clear and consistent pattern is observed. The larger the vehicle fleet in Dhaka in terms of volume per year, cumulative volume, or weighted by the volume of emissions, the worse the air quality. Yearly correlation with AQI reflects sensitivity to new registrations, whereas both cumulative and VEI relationships with AQI reflect the structural burden of accumulating vehicles and long-term emission burden. The results in the categories determine the most powerful segments of the fleet and provide a tangible foundation for category-specific controls of emissions and registration. Overall, the results confirm that both the yearly registered vehicles and cumulative yearly registered vehicles significantly contributed to Dhaka's deteriorating air quality. The VEI framework also predicts AQI variations successfully and can serve as an effective model for urban assessment.

3.3 Multiple linear regression results

To assess the combined effect of the most dominant vehicles on the Air Quality Index (AQI), a multiple linear regression model was developed. This was done by using AQI as the dependent variable and the values of Vehicular Emission Index (VEI) of microbus, private car and motorcycle as independent variables, which are the most influential sources of emission found after correlation analysis. SPSS (Version 26) was used to execute the model. The regression results are summarized in Tables 4, 5 and 6.

Table 4: Model Summary

Model	**R**	**R^2**	**Adjusted R^2**	**Std. Error**
1	0.971	0.943	0.924	2.57

Table 5: ANOVA Summary

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	872.4	3	290.8	44.2	0.000
Residual	52.7	8	6.58	-	-
Total	925.1	11	-	-	-

The model has an excellent predictive ability as it explains 94.3 percent of the variation in AQI. The overall significance of the model ($F(3,8) = 44.2$, $p < 0.001$, significant at 95% confidence level) was verified through the ANOVA test, and it was found that vehicular emissions have a statistically significant impact on AQI together.

Table 6: Coefficients of the regression model

Predictor	**Unstandardized Coefficient (B)**	**Std. Error**	**Standardized Coefficient (β)**	**t**	**Sig. (p < .001)**
Constant	71.22	4.35	-	16.36	0.000
VEI Microbus	0.289	0.122	0.314	2.37	0.000
VEI_Private Car	0.433	0.108	0.421	3.99	0.000
VEI_Motorcycle	0.512	0.095	0.489	4.22	0.000

All coefficients were positive as shown in Table 6, which means that the growth of emissions by any of these types of vehicles increases the values of AQI. Motorcycles had the most significant influence ($\beta = 0.489$), and they were followed by the private cars ($\beta = 0.421$) and the microbuses ($\beta = 0.314$).

The outcomes of the regression model indicate that the emissions of the three groups of microbuses, personal cars, and motorcycles explain greater changes in AQI levels in 2013-2024. The motorcycle and the private car segments became the most significant contributors, which is consistent with the trends in Dhaka's traffic and the rising trend in the ownership of personal vehicles. Even though buses demonstrated less individual effect, their large emission rates are also vital contributors to the cumulative effect. The justification of this novel index is also evidenced by the regression performance. This model confirms VEI as a good proxy to measure the emission-related air quality degradation in a data-constrained city like Dhaka.

4. CONCLUSIONS AND RECOMMENDATIONS

Since the air quality in Dhaka has been deteriorating on a daily basis, this research adopted a statistical method to examine the effects of the selected vehicles on the quality of the air in Dhaka city. The systematic development of the Vehicular Emission Index has been made in accordance with $PM_{2.5}$ emission factors in order to understand the long-term effect of growth in vehicle registration on the air quality in Dhaka. After the assessment of vehicle registration data against the air quality index over twelve years, a moderate to strong correlation has been observed in the three-dimensional analysis. From the variable relationship assessment, the correlation coefficient for yearly and cumulative vehicle registrations is found to be 0.60 and 0.91, respectively. Cumulative registered vehicles are more correlated than yearly registered vehicles. Vehicular Emission Index (VEI) has shown similar results with a correlation coefficient of 0.91, indicating a consistent relationship with air quality. Regression analysis has identified the combined effect of the vehicles responsible for the variations in the air quality index ($R^2 = 0.943$).

Although the findings reveal the relationship between urban air quality and vehicle registration, there are certain limitations that should be considered. This study did not include other air quality degradation sources, which include brick kilns, industrial emissions, construction activities, waste burning, and many more. Future research should include these sources in developing a model. Meteorological variables such as humidity, precipitation, wind speed, and temperature should also be included in the model, as these factors may alter air pollutant concentrations in the atmosphere, specifically in drier months. Though some vehicles are registered in Dhaka, not frequently seen moving on Dhaka's roads. Some vehicles that are registered outside Dhaka also operate in the city. The correlation study was based on only twelve data points, but each value was derived from a large and representative dataset.

Despite all the limitations, the results still show a positive outcome. The benefits of such a model cannot be underestimated, as it offers several practical implications. Based on the outcomes, certain emission strategies can be proposed. For instance, the government can enforce taxes on different vehicles based on their rate of pollutant emissions, and a more controlled registration system can be implemented for different vehicles. Policies should focus on strengthening the public transportation system to reduce reliance on private vehicles. This will help to decrease the pollutant levels in Dhaka city.

Overall, this study has analyzed how the air quality of Dhaka city is affected by the influence of uncontrolled vehicular growth. It has also taken a statistical and VEI-based approach to understand the relation between vehicular growth and air quality deterioration. By taking proper actions from the results of the model, sustainable and long-term solutions can be found, which can build a healthy environment for the residents of Dhaka city.

DECLARATION OF USE OF AI

The authors used AI only as a supporting tool during the writing process. It was mainly used to check grammar and typographical mistakes, reduce repetitive sentence structures, assist with simple calculations, and improve the overall clarity of the language. The technical content, data analysis, interpretation of results, and conclusions were entirely developed by the authors. AI did not generate original research ideas or experimental results and was used only to help polish the presentation of the manuscript.

REFERENCES

Baria, E., Biswas, A., Sultana, S., & Saha, T. (2024). Does vehicular growth affect Dhaka's air quality? *Evidence from time-series analysis*. SSRN Preprint No. 5214383.

Department of Environment (DoE). (2024). *Air Quality Status of Dhaka City – Annual Report 2024.* Dhaka, Bangladesh: Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh.

Energy Policy Institute at the University of Chicago (EPIC). (2025). Bangladesh Fact Sheet – *Air Quality Life Index (AQLI) 2025 update*. University of Chicago.

European Environment Agency (EEA). (2023). *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2023: Road Transport (NFR 1.A.3.b).* Luxembourg: Publications Office of the European Union.

Hashem, R. B., Siddique, A. B., Rasel, S. M., & Hossain, M. S. (2024). Assessment of knowledge, attitudes and practices regarding air pollution among traffic police in Dhaka city, Bangladesh. *BMC Public Health, 24*, 3593.

Intergovernmental Panel on Climate Change (IPCC). (2006). *2006 IPCC guidelines for national greenhouse gas inventories, Volume 2: Energy (Chapter 3: Mobile combustion)*. Geneva, Switzerland: IPCC.

Iqbal, A., Allan, A., & Afroze, S. (2014). On-road vehicular emission inventory in view of its distribution over Dhaka City, Bangladesh: A bottom-up modelling approach to support sustainability assessment. *Journal of Economics and Sustainable Development, 5*(18), 34–44.

Iqbal, A., Afroze, S., & Rahman, M. M. (2020). Vehicular PM emissions and urban public health sustainability: *A probabilistic analysis for Dhaka City. Sustainability, 12*(15), 6284.

Khatun, F., Saadat, S. Y., & Ashraf, K. (2023). *Air pollution in Bangladesh: Drivers, impacts and solutions*. Dhaka: Centre for Policy Dialogue (CPD).

Samiullah, M., Khanum, R., Ahmed, A., Rahman, S., Galib, M. I. R., Hossain, M. A., Hossain, E., Rahman, H., & Aktari, A. A. (2025). Air pollution in Bangladesh: A systematic review of trends, health impacts and policy responses. *International Journal of Ecosystems and Ecology Science (IJEES), 15*(6), 127–138.

Srinivas, V., Gupta, M., & Mohan, D. (2022). Vehicular growth, emissions and air quality in Delhi: Trends and implications. *Sustainable Cities and Society, 83*, 103971.

Sultana, S., Rahman, M. H., & Parvin, R. (2025). Spatial distribution and diurnal variation of particulate matters and gaseous pollutants in Dhaka City. *Environmental Science and Pollution Research*.

Tabassum, N., Rahman Khan, A. F. S., & Arefin, A. (2022). Impact of various transportation modes on the air quality of Dhaka city: A case study at Motijheel. *Journal of Engineering Science, 13*(2), 83–89.

World Health Organization (WHO). (2021). Global Air Quality Guidelines: *Particulate Matter ($PM_{2.5}$ and PM_{10}), O_3, NO_2, SO_2 and CO*. Geneva, Switzerland: World Health Organization.

Zhao, Y., Hu, J., Zheng, H., & Yao, Z. (2023). Urban vehicle stock, emission control, and air-quality dynamics in Beijing, China. *Atmospheric Environment*, *307*, 119779.