Assessing the Relationship Between Traffic Activity and Urban Air Pollution in Dhaka Using QGIS and Emission Factor Methods

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Abstract: Bad air quality is one of the most serious issues cities are struggling with today, especially in rapidly growing megacities such as Dhaka. Increasing traffic volume and congestion make vehicular emissions one of the major sources of urban air pollution. This study examines the spatial correlation between traffic activity and air pollution concentration levels on selected road segments in megacity Dhaka. Traffic volume data were collected from six road segments along Mirpur Road and Kazi Nazrul Islam Avenue using videography-based surveys. Carbon monoxide (CO), nitrogen oxides (NOx) and particulate matter (PM_2. were simulated by using emission factor methods. We extracted air pollutant concentration data from the Open-Meteo Air Quality API for each of these respective times and locations. Spatial emission distribution was visualized using a grid framework of 250 m × 250 m by utilizing Quantum Geographic Information System (QGIS) tools. The relationship between emissions and pollutant concentration were analyzed using regression. The results show that there is a strong correlation between the daily traffic emissions and the concentrations of air pollutants, with $R^2 = 0.97$ for CO (carbon monoxide) and $R^2 = 0.93$ for $PM_{2.5}$ (particulate matter). The study highlights pollution hotspots on some major road segments where traffic density is high. The study emphasizes the significance of both traffic control methods and sustainable transportation planning especially for Dhaka in facilitating urban air quality challenges.

Keywords: *Air Pollution, QGIS Spatial Analysis, Traffic Density, Traffic Emissions, Urban Air Quality.*

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I. INTRODUCTION

Air pollution has become one of the most serious environmental and public health challenges in urban areas worldwide. Rapid urbanization, population growth, industrialization, and increased motorization have significantly intensified pollution levels, particularly in developing megacities. Among various pollution sources, vehicular emissions are widely recognized as one of the dominant contributors to urban air pollution due to increasing traffic volume, traffic congestion, and inefficient transportation systems. Pollutants emitted from road traffic, including carbon monoxide (CO), nitrogen oxides (NOx), and fine particulate matter (PM2.5), are associated with severe health impacts such as respiratory diseases, cardiovascular disorders, reduced lung function, and premature mortality [1], [2].

Dhaka, the capital city of Bangladesh, experiences severe air quality deterioration resulting from high traffic density, rapid urban expansion, and insufficient environmental monitoring infrastructure. Major transportation corridors such as Mirpur Road and Kazi Nazrul Islam Avenue carry a substantial volume of vehicles throughout the day, contributing significantly to traffic-related emissions. Although several air quality monitoring stations exist in Dhaka, their spatial coverage remains limited and often fails to capture localized pollution variations along major traffic corridors [3]. Therefore, alternative approaches integrating traffic analysis, emission estimation, and spatial mapping are necessary to better understand the distribution and characteristics of urban air pollution.

Geographic Information Systems (GIS), particularly Quantum Geographic Information System (QGIS), have become effective tools for environmental assessment and spatial analysis. GIS-based techniques enable the visualization and identification of pollution hotspots by integrating traffic information, emission estimation methods, and spatial datasets [4]. In addition, recent developments in open-access environmental data platforms and application programming interfaces (APIs) have provided cost-effective opportunities for obtaining air quality data in regions where ground-based monitoring systems are limited [5]. The integration of GIS tools and API-derived air quality information therefore offers a practical approach for analyzing urban air pollution patterns in data-scarce environments.

Several previous studies have investigated traffic-related emissions and their environmental impacts. Kawsar reported that compressed natural gas (CNG) is the dominant fuel used by cars, taxis, and auto-rickshaws in Dhaka, whereas diesel fuel remains prevalent among heavy vehicles such as buses, delivery vans, and trucks, which are major contributors to particulate matter and NOx emissions [6]. Begum and Hopke emphasized the importance of reliable traffic and emission data for understanding urban air quality conditions in Dhaka [7]. Emission factor-based approaches have also been widely used for estimating traffic-related emissions. Tsai observed that vehicle emission factors vary depending on driving conditions and travel characteristics [8], while Yang demonstrated significant differences in emission factors among gasoline and diesel vehicle categories [9]. Furthermore, Dhar and Rahman reported that CNG-powered vehicles may emit comparatively higher levels of carbon monoxide under certain operating conditions [10]. Studies by Badshah, Posada and Muncrief also revealed that heavy-duty diesel vehicles produce substantially higher NOx emissions during low-speed urban driving conditions compared to highway operations, highlighting the influence of congestion on pollutant emissions [11].

Among traffic-related pollutants, nitrogen oxides (NOx) are frequently used as indicators of urban vehicular pollution. However, ambient NOx concentration is strongly influenced by atmospheric and meteorological processes, including wind speed, atmospheric stability, vertical mixing, and photochemical reactions [12]. Consequently, short-term concentration measurements may occasionally exhibit anomalous values that do not directly correspond to local traffic emissions. Previous studies have emphasized the importance of data screening and outlier identification in air quality analyses, particularly when modeled or remotely derived datasets are used [13], [14], [15], [16]. Such anomalies may artificially weaken regression relationships and reduce the reliability of statistical interpretations if not properly addressed [17]. Despite the growing body of literature on urban air pollution, studies integrating traffic-based emission estimation, GIS-based spatial analysis, and API-derived air quality data at a fine spatial scale remain limited, particularly in the context of Dhaka. Most previous studies have focused either on emission estimation or on ambient air quality assessment separately, with limited integration of both approaches. Therefore, the aim of this study is to investigate the relationship between traffic activity and urban air pollution along selected road corridors in Dhaka using emission factor methods, QGIS-based spatial analysis, and API-derived air quality data.

II. METHODOLOGY AND DATA COLLECTION

The study area consists of six road segments along Mirpur Road and Kazi Nazrul Islam Avenue, as shown in figure 1. The detailed information of the selected road segments, including segment length and geographic coordinates, is presented in table 1. These roads are among the busiest transportation corridors in the city and experience heavy traffic congestion during peak hours. The surrounding land use includes residential areas, commercial establishments, and public institutions, which contribute to traffic congestion and pollution levels. The selected study area therefore represents typical urban traffic conditions in Dhaka.

Traffic data were collected using videography at the selected road segments during different time periods across four observation days. The recorded videos were later analyzed to determine traffic volume by counting the number of vehicles passing through each segment during the observation period. Vehicles were classified into five categories based on their fuel types, namely: Heavy-Duty Diesel Vehicles (HDV), Light-Duty Diesel Vehicles (LDV), Petrol vehicles, LPG vehicles, and Compressed Natural Gas (CNG) vehicles. The hourly vehicle counts for each road segment and observation day, categorized by fuel type, are presented in table 2.

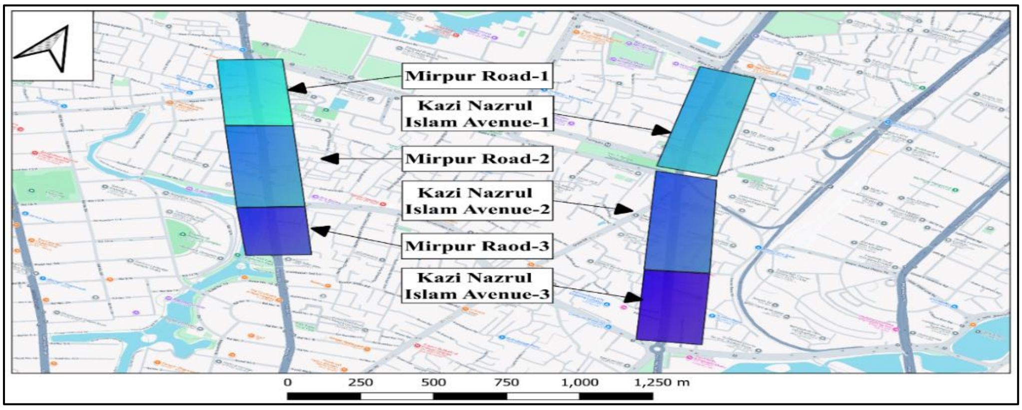

Fig 1 Road Segments of Study Area

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Table 1 Detail Information of Roads

Road Segments	Length (m)	Co-ordination	
		From	To
Mirpur Road - 1	360	23°45'28"N 90°22'27"E	23°45'18"N 90°22'33"E
Mirpur Road - 2	470	23°45'18"N 90°22'33"E	23°45'04"N 90°22'41"E
Mirpur Road - 3	440	23°45'04"N 90°22'41"E	23°44'51"N 90°22'49"E
Kazi Nazrul Islam Ave-1	540	23°45'50"N 90°23'20"E	23°45'33"N 90°23'23"E
Kazi Nazrul Islam Ave-2	540	23°45'30"N 90°23'23"E	23°45'13"N 90°23'30"E
Kazi Nazrul Islam Ave-3	430	23°45'13"N 90°23'30"E	23°45'00"N 90°23'35"E

Table 2 Vehicle Counts According to Fuel Types

Day	Road Segments	Vehicles per hour					
		HDV	LDV	Petrol	LPG	CNG	Total
Day-1	Mirpur-1	370	375	2193	999	2976	6913
	Mirpur-2	368	330	1818	532	1702	4750
	Mirpur-3	402	285	1474	448	1289	3898
	KNI -1	205	566	2398	610	2942	6721
	KNI -2	211	407	2725	566	2836	6745
	KNI -3	208	412	2067	524	2643	5854
Day-2	Mirpur-1	316	554	1524	526	1734	4654
	Mirpur-2	313	392	1177	382	1172	3436
	Mirpur-3	346	383	1292	307	1337	3665
	KNI -1	128	450	1642	329	2148	4697
	KNI -2	132	434	1615	333	2175	4689
	KNI -3	132	405	1426	305	1886	4154
Day-3	Mirpur-1	407	412	2412	1098	3274	7603
	Mirpur-2	406	363	1999	585	1872	5225
	Mirpur-3	430	329	1660	612	1856	4887
	KNI -1	255	589	2479	689	2916	6928
	KNI -2	244	600	2484	677	3052	7057
	KNI -3	246	602	2136	665	2946	6595
Day-4	Mirpur-1	296	452	2328	1019	3234	7329
	Mirpur-2	295	408	1401	504	1816	4424
	Mirpur-3	318	346	1607	645	2121	5037
	KNI -1	304	611	2600	768	2870	7153
	KNI -2	277	792	2323	789	3223	7404
	KNI -3	275	792	2205	806	3194	7272

Table 3 Emission Factors for Different Vehicles

Vehicles	Emission Factors (g/km)		
	CO	NO_x	$PM_{2.5}$
Diesel (HDV)	2.5	8	0.35
Diesel (LDV)	1.2	3	0.12
Petrol	3.5	0.9	0.015
LPG	1.1	0.45	0.006
CNG	0.6	0.6	0.004

Table 4 Emission of CO, NO_x and $PM_{2.5}$ from Traffic

Day	Time	Road Segments	Pollutants Emission (g/km/hr)		
			CO	NO_x	$PM_{2.5}$
Day-1	**8:00-9:00 AM**	Mirpur-1	11935	8294	225.3
		Mirpur-2	9286	6831	205.67
		Mirpur-3	7773	6373	204.86
		KNI -1	12021	7536	191.07
		KNI -2	12878	7318	178.31
		KNI -3	10412	6582	166.97
Day-2	**10:00-11:00 AM**	Mirpur-1	8408	6839	210.04
		Mirpur-2	6496	5615	181.23
		Mirpur-3	6987	6021	193.63

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		KNI -1	8258	5289	134
		KNI -2	8175	5267	133.21
		KNI -3	7275	4824	125.57
Day-3	**5:00-6:00 PM**	Mirpur-1	13127	9122	247.76
		Mirpur-2	10214	7523	226.65
		Mirpur-3	9067	7310	225.98
	4:00-5:00 PM	KNI -1	12529	8098	212.92
		KNI -2	12600	8124	210.93
		KNI -3	11313	7764	206.16
Day-4	**3:00-4:00 PM**	Mirpur-1	12492	8219	211.81
		Mirpur-2	7775	6162	183.52
		Mirpur-3	8817	6592	189.28
	9:30-10:30 AM	KNI -1	13160	8673	234.81
		KNI -2	12576	8972	244.47
		KNI -3	12159	8840	241.98

Pollutant emissions were estimated using the emission factor method. Since emission factors vary depending on vehicle type, fuel type, and driving conditions, appropriate emission factors were selected for each vehicle category operating in the study area. The primary emission factors for carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter ($PM_{2.5}$) were obtained from the Joteo.net - Vehicle Emission Calculator, which provides pollutant-specific emission factors for different vehicle fuel types. These values were subsequently verified against established literature and regional emission inventory studies relevant to South Asian vehicle fleets to ensure their suitability and consistency [6], [8], [9], [11], [18], [19], [20]**.** The final emission factors were calibrated to represent typical Bangladesh urban driving conditions, considering an average vehicle speed of 10–25 km/h. The emission factors used for different fuel types and pollutants (CO, NOx, and $PM_{2.5}$) are presented in Table 3.

The emission estimation formula used in this study is:

$$E = V \times EF \tag{1}$$

Where:

E = Emission rate (g/km/hr)

V = Number of vehicles per hour

EF = Emission factor (g/km)

Using eq. (1), pollutant emissions for CO, NO_x, and $PM_{2.5}$ were calculated for all road segments and observation days, and the results are presented in table 4.

Emission values were spatially represented using QGIS software. The study area was divided into grid cells of 250 m × 250 m, and emission values were assigned to each grid cell corresponding to the road segments. Spatial emission maps were generated to visualize the distribution of CO, NO_x, and $PM_{2.5}$ emissions across the study area. The spatial distributions of CO, NO_x, and $PM_{2.5}$ emissions for the four observation days are shown in figures 2, 3 and 4, respectively.

Ambient pollutant concentration data were obtained using the Open-Meteo Air Quality API, which provides air pollution data based on atmospheric models and observational datasets. Concentration values of CO, NO_x, and $PM_{2.5}$, along with the Air Quality Index (AQI), were extracted for the specific date, time, and location corresponding to the traffic observation periods [21]. The API-derived pollutant concentration data and AQI values corresponding to each observation period are presented in table 5.

Regression analysis was conducted to examine the relationship between pollutant emissions and air pollutant concentrations. The coefficient of determination (R^2) was used to evaluate the strength of correlation between emissions and concentration values.

Table 5 Pollutant Concentration Data from API

Day	Time	Road Name	Pollutants Concentration (µg/m³)			AQI
			CO	NO_x	PM2.5	
Day-1	9:00 AM	Mirpur Road	826	33.6	52.7	156
	9:00 AM	KNI Ave	826	33.6	52.7	156
Day-2	11:00 AM	Mirpur Road	635	29.3	20.8	151
	11:00 AM	KNI Ave	635	29.3	20.8	151
Day-3	6:00 PM	Mirpur Road	849	50.5	69.4	162
	5:00 PM	KNI Ave	746	39	55.2	162
Day-4	4:00 PM	Mirpur Road	823	30.4	39.1	161
	10:00 AM	KNI Ave	867	23.7	86.4	161

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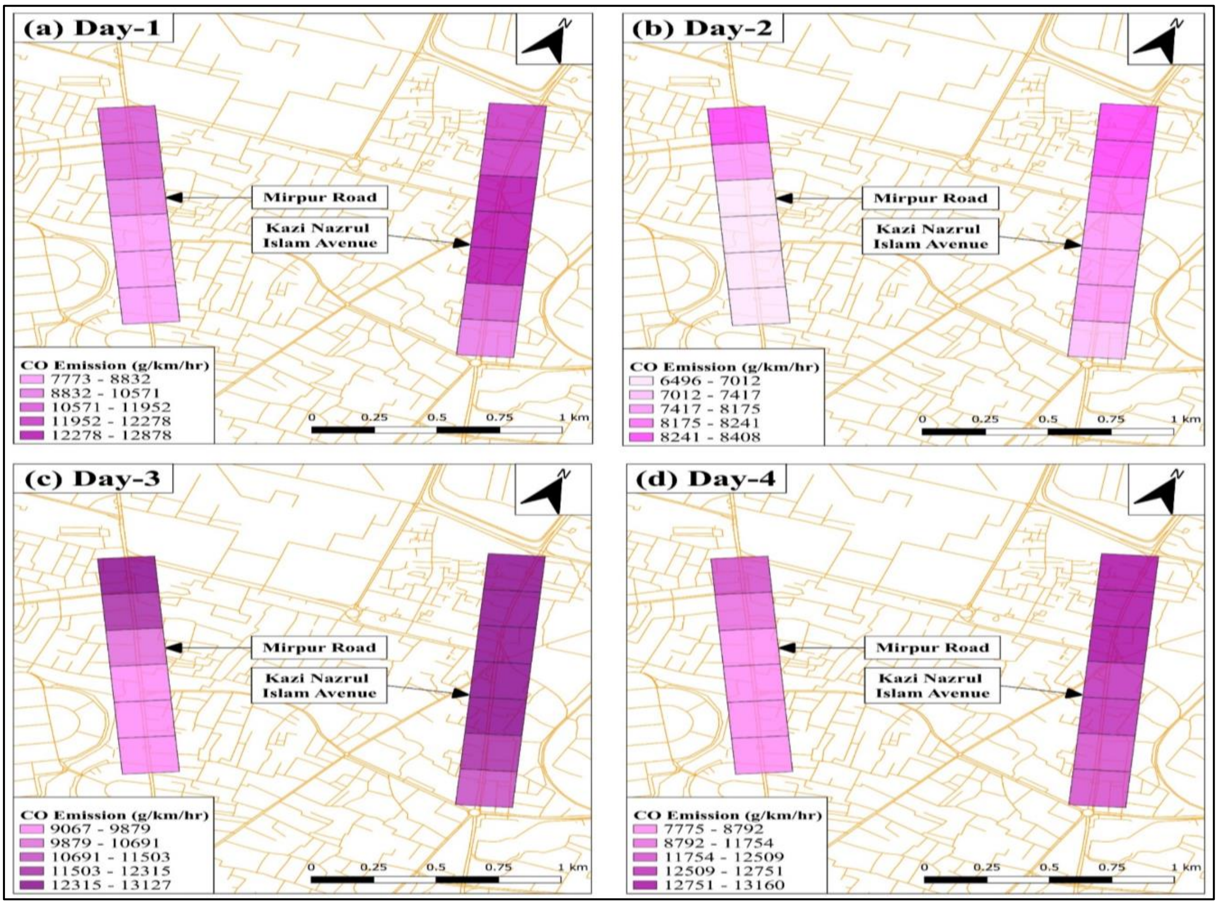

Fig 2 CO Emissions in Each Grid in (a) Day-1, (b) Day-2, (c) Day-3 & (d) Day-4

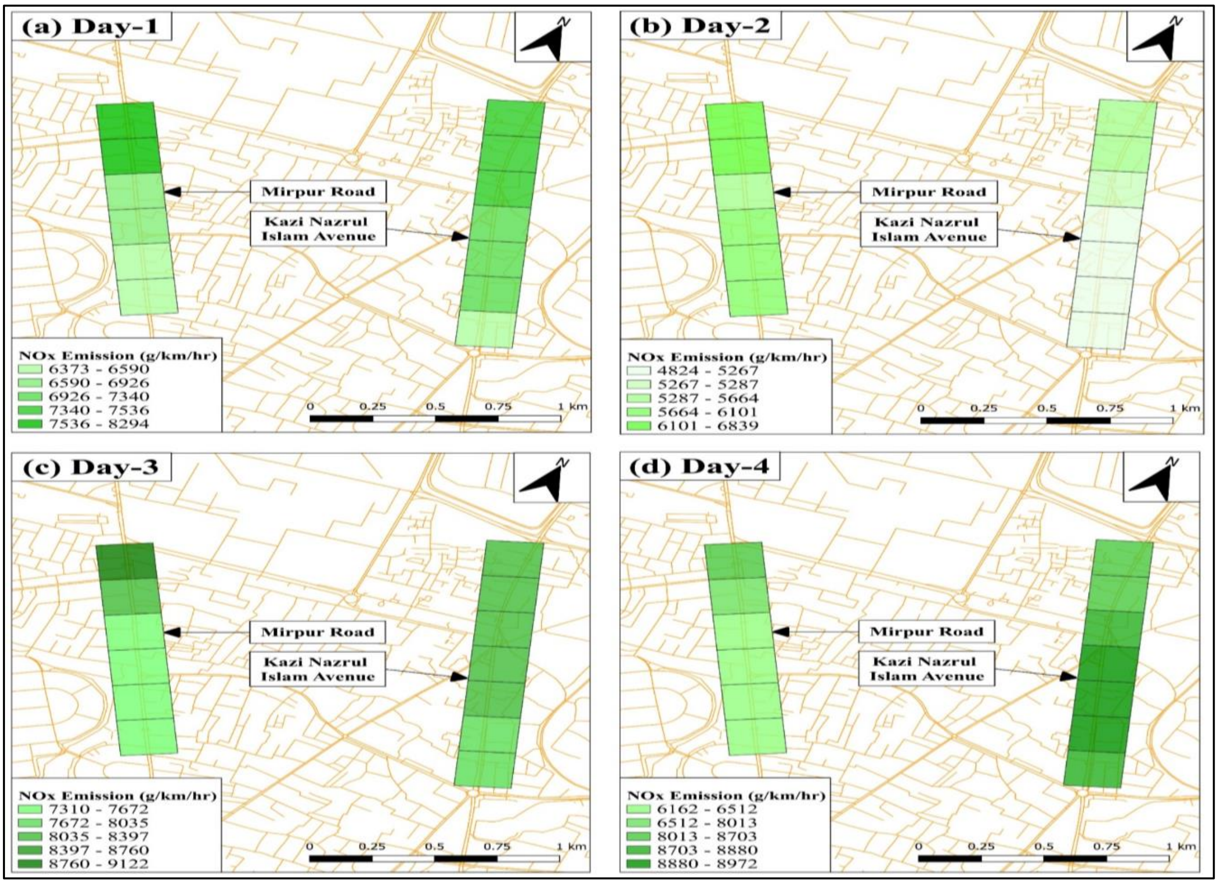

Fig 3 NO_x Emissions in Each Grid in (a) Day-1, (b) Day-2, (c) Day-3 & (d) Day-4

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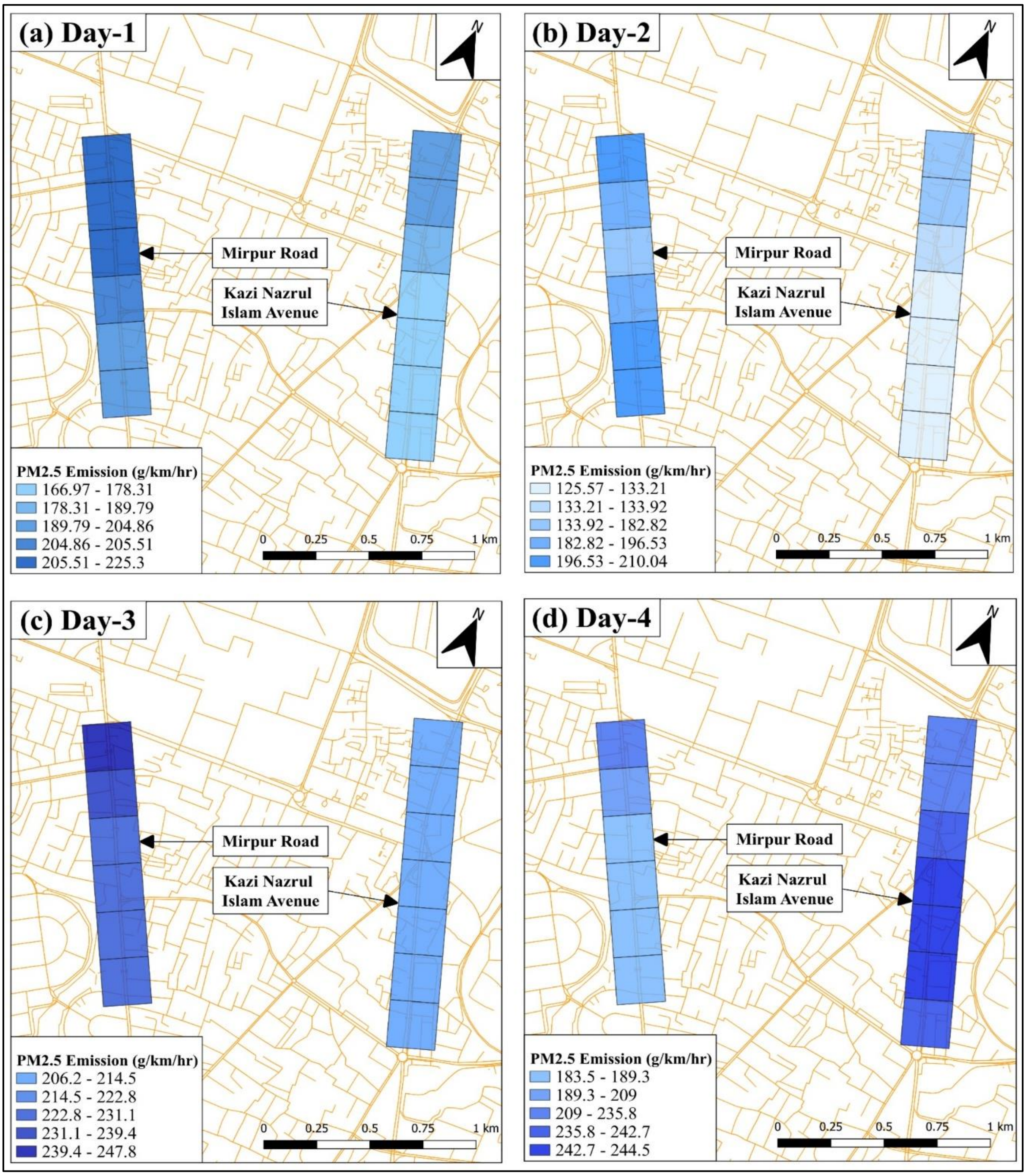

Fig 4 $PM_{2.5}$ Emissions in Each Grid in (a) Day-1, (b) Day-2, (c) Day-3 & (d) Day-4

III. RESULTS AND DISCUSSION

Figures 5, 6 and 7 illustrate the relationship between pollutant emissions (NO_x, CO, and $PM_{2.5}$) and their corresponding concentrations for each road segment based on observations from four different days. Figure 8 shows the relationship between traffic volume (vehicles/hr) and the Air Quality Index (AQI) for each segment during the same observational period. From the plotted graphs, regression line equations and R^2 values were obtained. However, the NO_x concentration recorded on Day-4 at all three segments of Kazi Nazrul Islam Avenue was unusually low compared to other observations. Therefore, the Day-4 NO_x values for these segments were excluded from the regression analysis. Consequently, the trendlines for NO_x emission–concentration relationships at Kazi Nazrul Islam Avenue were generated using the remaining three data points.

The regression analyses showing the correlations between emissions and ambient concentrations of CO, NO_x, and $PM_{2.5}$ are summarized in tables 6–8, respectively. The regression analysis between traffic volume and AQI for all road segments is presented in table 9.

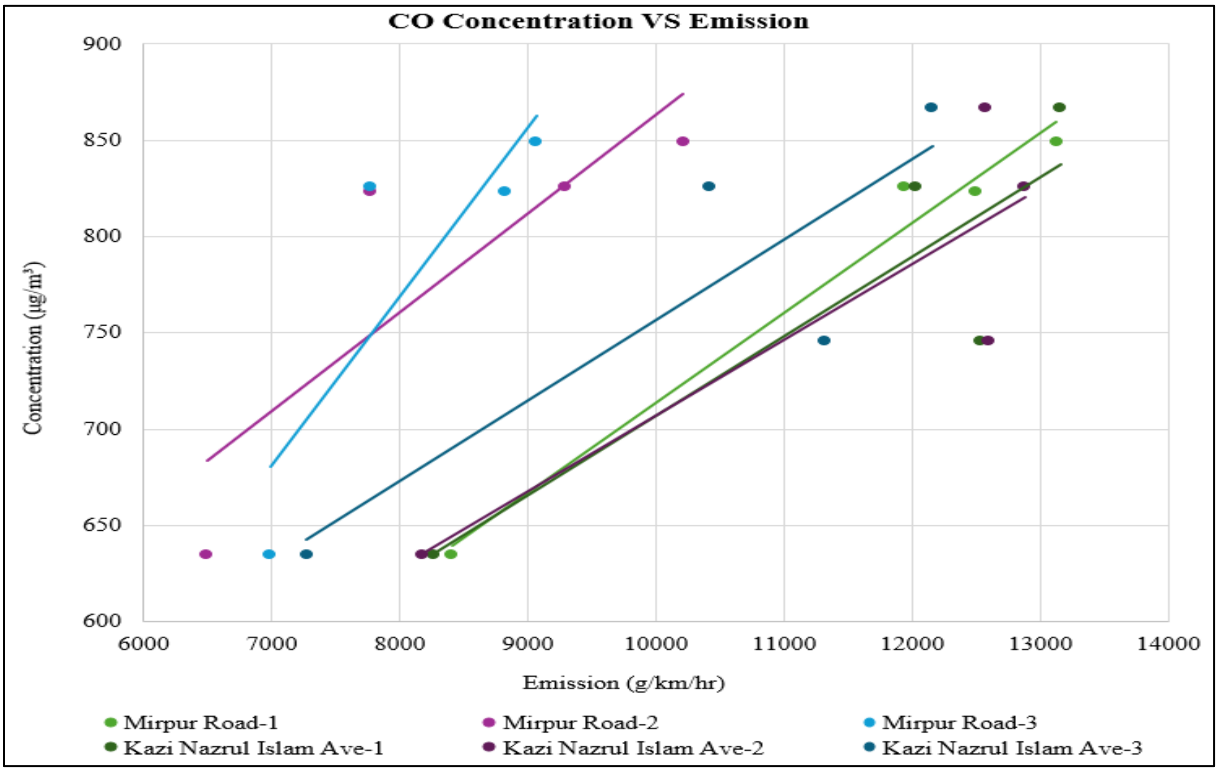

Fig 5 Relationship Between CO Emission and Concentration at Different Road Segments

Table 6 Correlation Between CO Emission & Concentration

Road Segments	R^2	Regression Equation
Mirpur Road -1	0.9776	y = 0.0466x + 247.91
Mirpur Road -2	0.7156	y = 0.0513x + 350.29
Mirpur Road -3	0.7156	y = 0.0874x + 69.589
Kazi Nazrul Islam Ave -1	0.7953	y = 0.0413x + 293.64
Kazi Nazrul Islam Ave -2	0.7613	y = 0.0395x + 312.26
Kazi Nazrul Islam Ave -3	0.7614	y = 0.0418x + 338.2

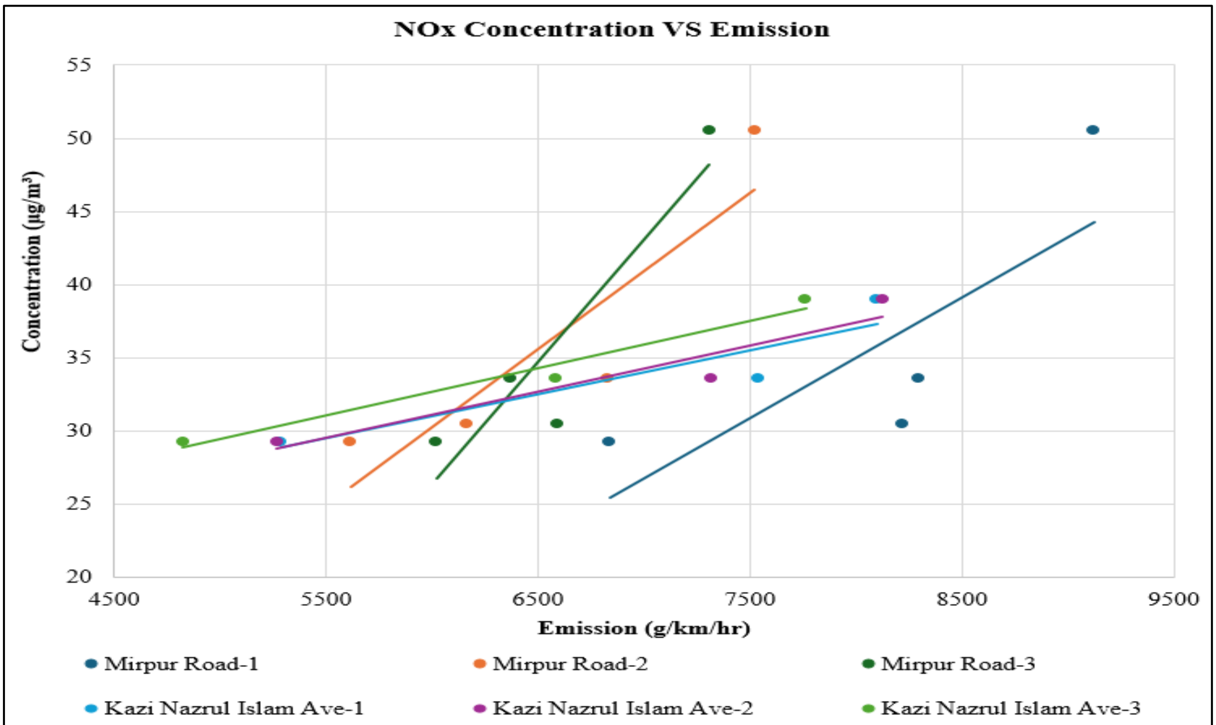

Fig 6 Relationship Between NOx Emission and Concentration at Different Road Segments

Table 7 Correlation Between NO_x Emission & Concentration

Road Segments	R^2	Regression Equation
Mirpur Road -1	0.6276	y = 0.0082x - 30.996
Mirpur Road -2	0.7988	y = 0.0107x - 33.618
Mirpur Road -3	0.8425	y = 0.0166x - 73.271
Kazi Nazrul Islam Ave -1	0.8492	y = 0.003x + 12.95
Kazi Nazrul Islam Ave -2	0.9059	y = 0.0031x + 12.288
Kazi Nazrul Islam Ave -3	0.9686	y = 0.0032x + 13.305

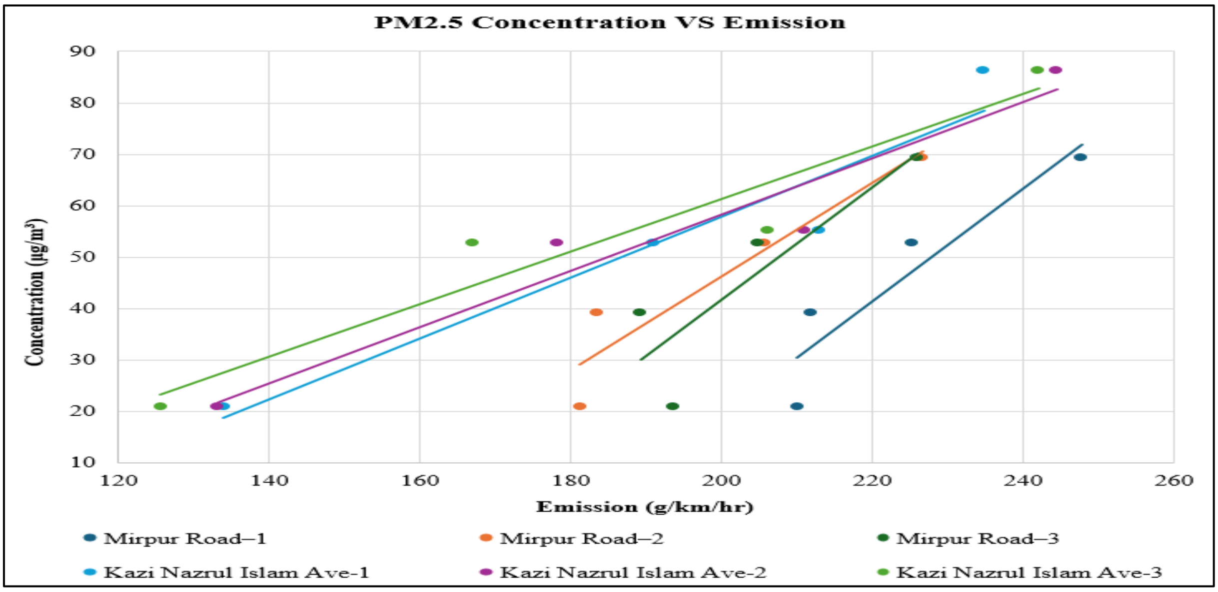

Fig 7 Relationship Between PM2.5 Emission and Concentration at Different Road Segments

Table 8 Correlation Between $PM_{2.5}$ Emission & Concentration

Road Segments	R^2	Regression Equation
Mirpur Road -1	0.8631	y = 1.0997x - 200.53
Mirpur Road -2	0.8945	y = 0.914x - 136.64
Mirpur Road -3	0.7565	y = 1.093x - 176.86
Kazi Nazrul Islam Ave -1	0.9196	y = 0.5933x - 60.854
Kazi Nazrul Islam Ave -2	0.9365	y = 0.5466x - 51.023
Kazi Nazrul Islam Ave -3	0.9195	y = 0.5123x - 41.079

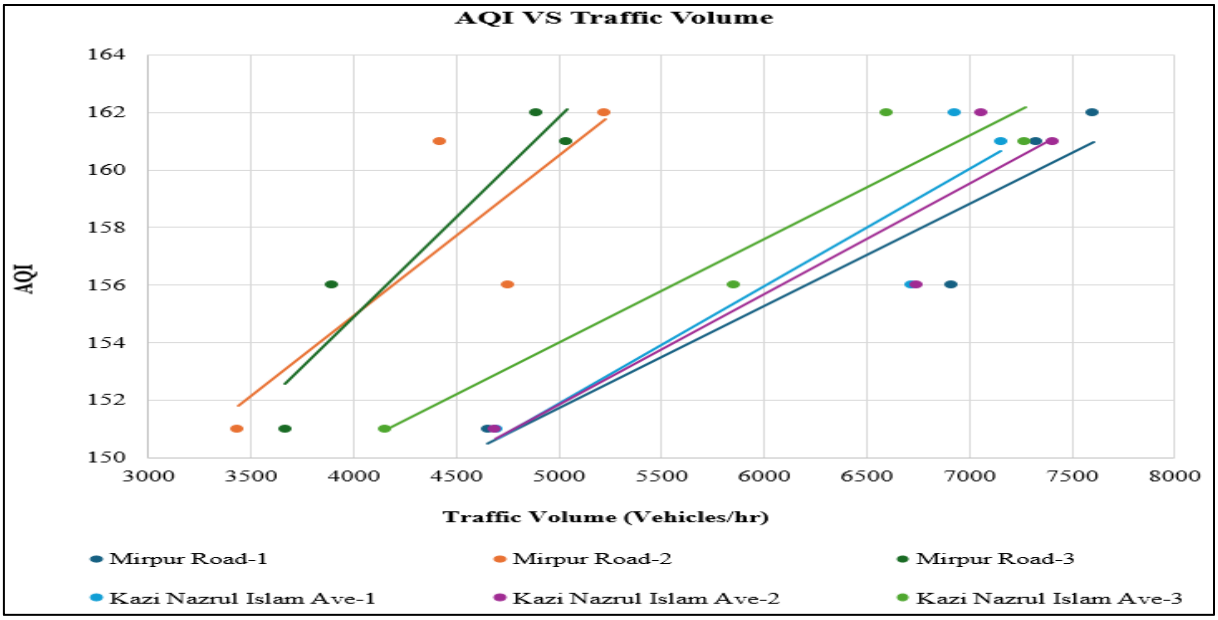

Fig 8 Relationship Between Traffic Volume and AQI at Different Road Segments

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Table 9 Correlation Between Traffic Volume & AQI

Road Segments	R^2	Regression Equation
Mirpur Road -1	0.8874	y = 0.0036x + 133.98
Mirpur Road -2	0.6872	y = 0.0055x + 132.76
Mirpur Road -3	0.8982	y = 0.0069x + 127.12
Kazi Nazrul Islam Ave -1	0.8216	y = 0.0041x + 131.65
Kazi Nazrul Islam Ave -2	0.8481	y = 0.0038x + 132.74
Kazi Nazrul Islam Ave -3	0.9007	y = 0.0036x + 136.1

Regression analysis indicated strong relationships between traffic activity and air pollution levels across most road segments. The coefficient of determination (R^2) values ranged between approximately 0.68 and 0.90 for the relationship between traffic volume and AQI, indicating a strong correlation between traffic density and urban air pollution levels. Similarly, regression analysis between estimated emissions and measured pollutant concentrations showed strong relationships for most pollutants. For example, CO emission–concentration relationships showed R^2 values as high as 0.97 for certain road segments, indicating a very strong positive correlation between traffic emissions and ambient CO concentration. $PM_{2.5}$ emission–concentration relationships also exhibited high R^2 values in several cases, suggesting that vehicular emissions significantly contribute to particulate matter levels in the study area.

During the analysis of NO_x emission–concentration relationships, an anomaly was observed in the Day-4 data for all three segments of Kazi Nazrul Islam Avenue. The NO_x concentrations recorded for that day were significantly lower than those observed during other monitoring periods, despite comparable traffic activity. Such unusually low concentrations may occur due to short-term meteorological influences, including higher wind speeds, increased atmospheric dispersion, vertical mixing of pollutants, or localized atmospheric chemical reactions that can rapidly reduce NO_x concentrations [22]**.** Additionally, since the concentration data were obtained from an API-based modeled dataset, temporary inconsistencies between modeled concentrations and localized traffic emissions may also occur. Including these anomalously low values in the regression analysis would have artificially weakened the emission–concentration relationship and distorted the regression trendline, potentially leading to misleading interpretations of the traffic–pollution relationship. Therefore, the Day-4 NO_x values for the Kazi Nazrul Islam Avenue segments were excluded from the regression analysis, and the trendlines for NO_x were generated using the remaining three observational data points. After excluding the anomalous values, the resulting correlations more accurately reflected the relationship between traffic-related emissions and ambient NO_x concentrations.

The QGIS-based spatial analysis further helped identify pollution hotspots along the studied corridors. Areas with higher traffic density consistently exhibited higher emission levels and elevated pollutant concentrations. These findings highlight the significant contribution of traffic activity to urban air pollution in Dhaka. The results also demonstrate the usefulness of GIS-based spatial analysis tools in visualizing pollution distribution and identifying critical pollution zones within urban transportation corridors.

IV. CONCLUSION

This study analyzed the relationship between traffic activity and air pollution levels along selected road corridors in Dhaka using QGIS-based spatial analysis and API-derived air quality data. The results demonstrate that vehicular traffic plays a significant role in determining urban air pollution patterns. Emission estimation revealed substantial levels of CO, NO_x, and $PM_{2.5}$ emissions along the studied road segments, particularly during periods of high traffic density. QGIS-based spatial analysis successfully identified pollution hotspots, highlighting areas with elevated emission intensity [23].

Regression analysis showed strong correlations between traffic volume, emission rates, and ambient pollutant concentrations, confirming that traffic congestion significantly influences urban air quality conditions. The exclusion of anomalous NO_x observations on Day-4 for Kazi Nazrul Islam Avenue improved the reliability of the regression analysis and demonstrated the importance of carefully evaluating outlier data in environmental studies, especially when atmospheric dispersion and model-based datasets are involved.

Overall, the integration of traffic data, emission estimation, GIS mapping, and API-based air quality information provides a practical and cost-effective approach for assessing urban air pollution, particularly in cities where ground-based monitoring infrastructure is limited. The findings of this study may support urban environmental management and transportation planning strategies aimed at reducing traffic-related pollution in Dhaka. Future research may incorporate meteorological parameters such as wind speed, temperature, and atmospheric stability, extend the monitoring period, and apply advanced dispersion or chemical transport models to further improve the accuracy of urban air pollution assessments [24].

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