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A Study on the Emission of Pollutants by Vehicles Produced by Different Companies: A Case Study in Dhaka Metropolitan City

Md. Abu Sayem

Department of Statistics, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh.

Abstract

Air pollution is the introduction into the atmosphere of chemicals, particulates, or biological materials that cause discomfort, disease, or death to humans, damage other living organisms such as food crops, or damage the natural environment or environment. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems. A substance in the air that can be adverse to humans and the environment is known as an air pollutant. In our study, we consider the characteristics such as year of manufacturing, types of makers, types of model, vehicle's weight, odometer readings and different pollutants (i.e., CO, CO_2, HC, AFR & Lambda) produced by different vehicle's. From the analysis it is observed that CO and CO_2 is the most influencing environmental components.

Keywords: Atmosphere, Environment, Planet Earth, Earth's ecosystems, Air pollution, AFR, Lambda, Odometer Readings.

1. Introduction

Air is indispensable for the survival of all living organisms on earth, including human beings. It is even more important than water - without water a person can survive for days, but without air no more than a couple of minutes.

Bangladesh is one of the least developed agrarian nations in the world. However, since its birth in 1971, there has been some growth in the industrial sector. Industries are mainly concentrated in major urban areas like Dhaka (the capital), the seaport cities like Chittagong and Khulna, the inland port city

Narayanganj, and other divisional towns. Naturally, the air pollution problem is more acute in these areas. Apart from unplanned industrial development in these areas, the severity of the pollution is increased mainly due to exhausts from two-stroke engine and diesel-run vehicles (See Alauddin, M. (1999)).

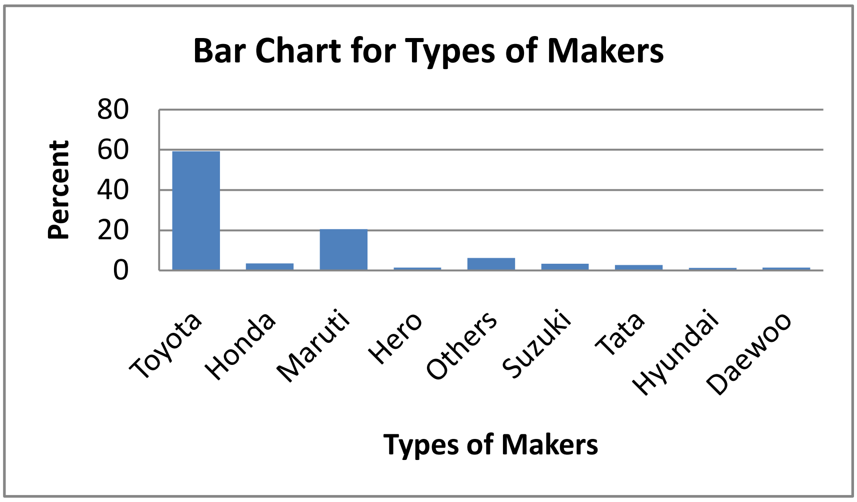
Due to rapid and unplanned urbanization the total number of vehicles has increased enormously. Most of the cars, jeeps, auto-rickshaws, motorcycles, etc., ply in the cities. This has really led to a deterioration of air quality, particularly in Dhaka (BBS, 2011). According to an assessment made by DoE, 90 percent of the vehicles that ply Dhaka's streets daily are faulty, and emit smoke far exceeding the prescribed limit. Black smoke which is primarily unburned fine carbon particles is emitted by diesel vehicles (DoE (2000) & Gain P. (1998)).

Atmospheric pollutants are responsible for both acute and chronic effects on human health (WHO, 2000). Air pollution is a major environmental health problem, affecting developed and developing countries in the world. According to the annual report-2004 of Bangladesh Road Transport Corporation (BRTC), the number of registered road vehicles has increased from more than 1.4 million in 1995 to over 3.5 million in June 2004, representing 133% increase. The composition of road vehicle fleet is 51% motorcycles, 32% cars, 7% vans and the remainder is buses, heavy goods vehicles and others. Most of vehicles in our country provide air pollutants which are exceed their normal level. Auto exhaust pollution has assumed a menacing proportion in the developing countries and its control should not be delayed any more especially in Dhaka.

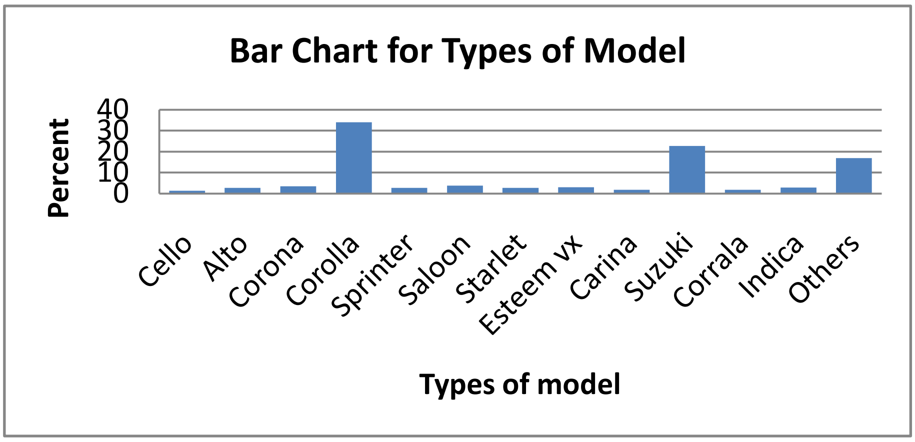
The problem air pollution has existed ever since our ancestors sat coughing around a smoky fire in a recessed cave. In fact, there probably never was an unpolluted atmosphere, since decaying vegetation and animal matter, smoke, vapors, dust soot, carbon fumes, gases, mist, odors, radioactive materials and other natural phenomena surely have emitted gaseous and particulate matter ever since world began. Starting from 14^{th} century, when coal was introduced as a fuel, atmospheric pollution becomes social problem. Hence there is a general interest in air pollution control.

2. Analysis and Discussion

Graphical Presentation of a Frequency Distribution

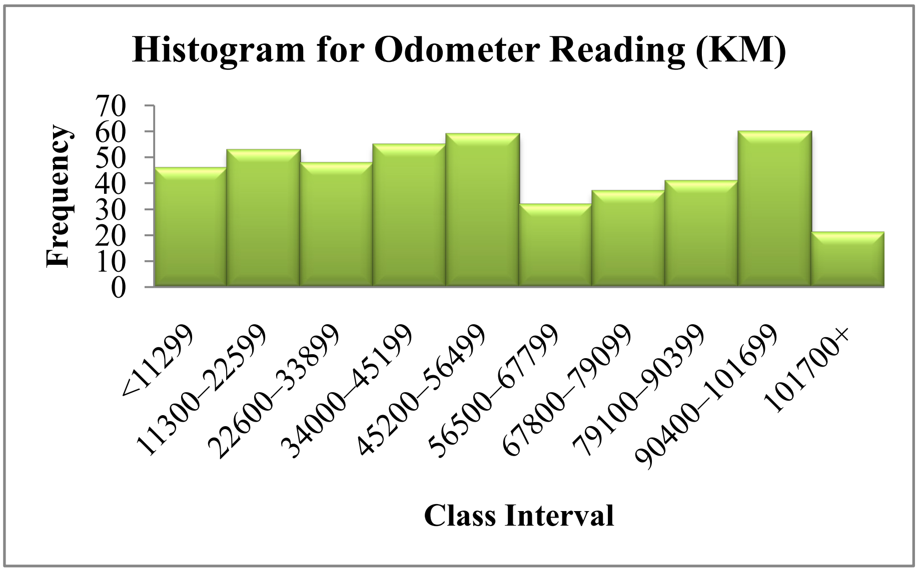


It is clear from the above figure that most of the makers, (i.e., 59.3 percent makers) are Toyota while the second highest makers (i.e., 20.6 percent makers) are Maruti. The percentage of other makers is comparatively small. So we can say that most of the makers among the different companies used in Bangladesh are Toyota and Maruti. This is a clear indication that Toyota and Maruti are the best makers of choosing a car.

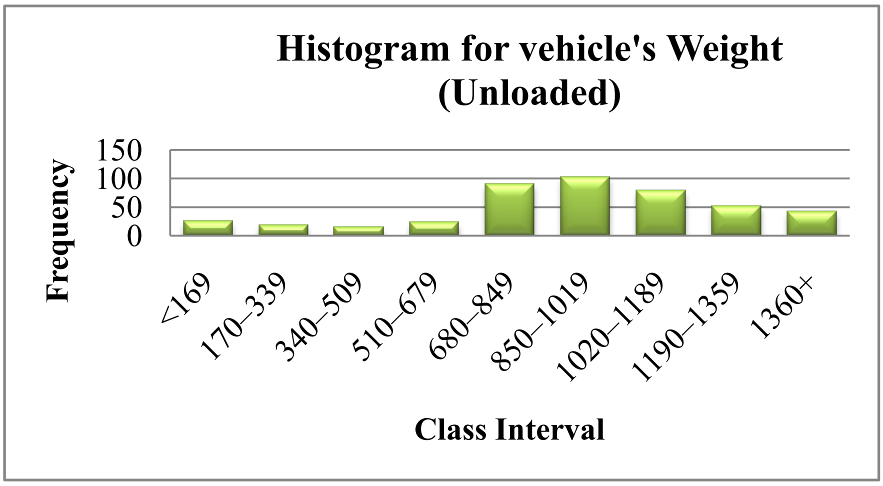


It is evident from the above figure that most of the models, (i.e., 34.1 percent models) are Corolla while the second highest models (i.e., 22.8 percent models) are Suzuki. The percentage of other models is comparatively small. So, it is clear that most of the models among the different companies used in

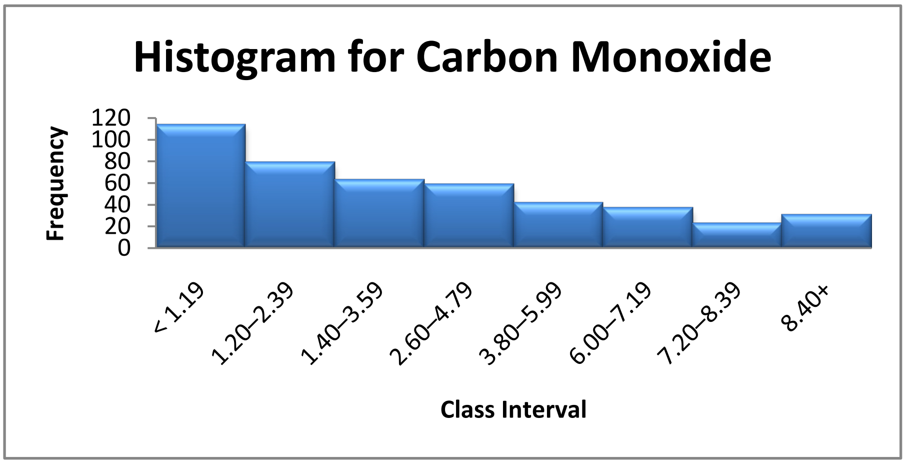
Bangladesh are Corolla and Suzuki, i.e., Corolla and Suzuki are the particular brand of vehicle's sold under a marque by a manufacturer, usually within a range of models, usually of different sizes or capabilities from an engineering point of view.



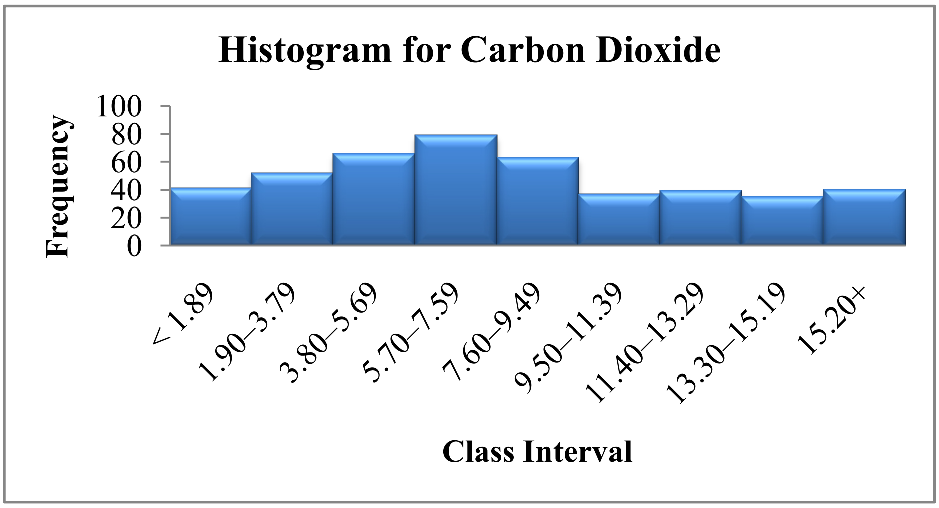
It is seen from the above figure that most of the odometer reading (i.e., 69.49 percent odometer reading) is less than the average value of the given odometer reading (i.e., 81482) while only 30.51 percent odometer reading is greater than the average value of the given odometer reading (i.e., 81482).So we can say that the detection of odometer tampering is well and most of the vehicles are in good condition. Here, the frequency distribution of the odometer reading is approximately normal.



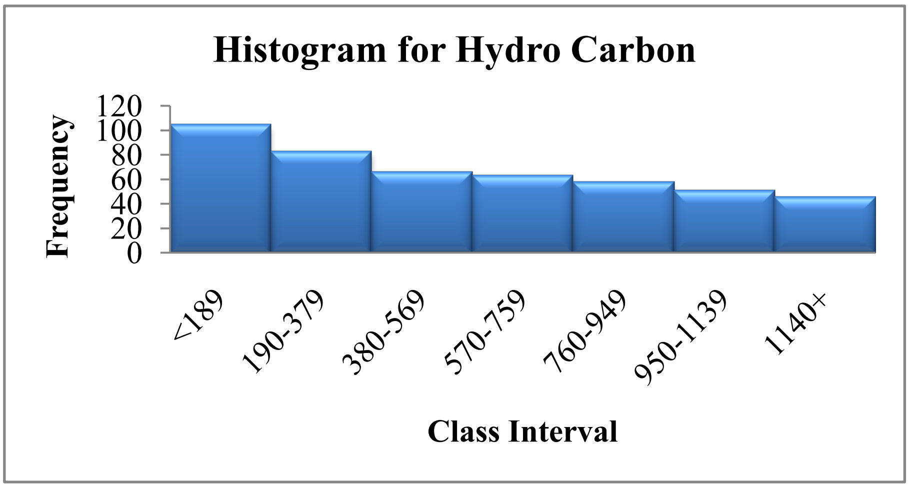
It is observed from the above figure that 38.27 percent vehicle's is less than the average value of the given vehicle's weight (Unloaded)(i.e., 871.15) and 61.73 percent vehicle's is greater than average value of the given vehicle's weight (Unloaded) (i.e., 871.15). So we can say that the detection of vehicle's weight tampering is not well (i.e., most of the vehicles are not in good condition). Here, the frequency distribution of the vehicle's weight is approximately normal.



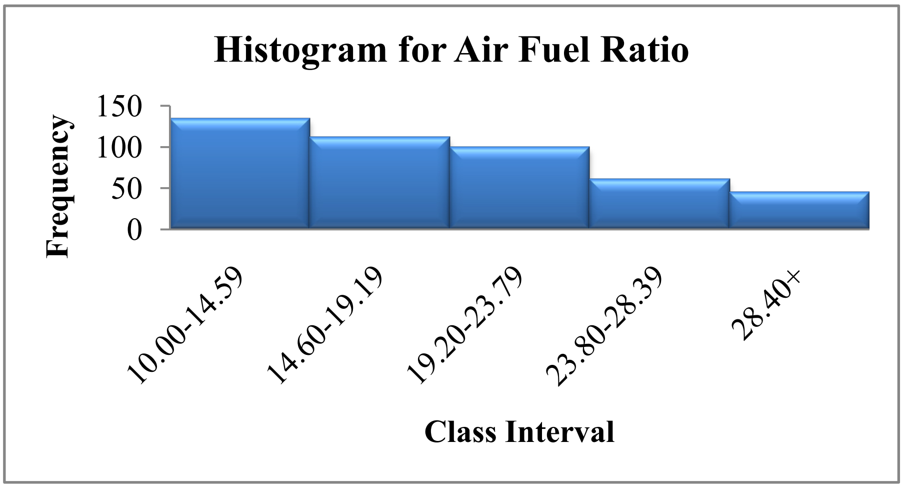
It is obvious from the above figure that 63.19 percent vehicle's Carbon Monoxide emission is under the standard limit (i.e., 4.5 (%v)) while 36.81 percent vehicle's Carbon Monoxide emission is over the standard limit (i.e., 4.5 (%v)).This implies that massive awareness among the vehicle owners and drivers must be built up urgently in such a way that they can go for regular check-ups and maintenance of their vehicles. Here, the distribution of the Carbon Monoxide emission is positively skewed.



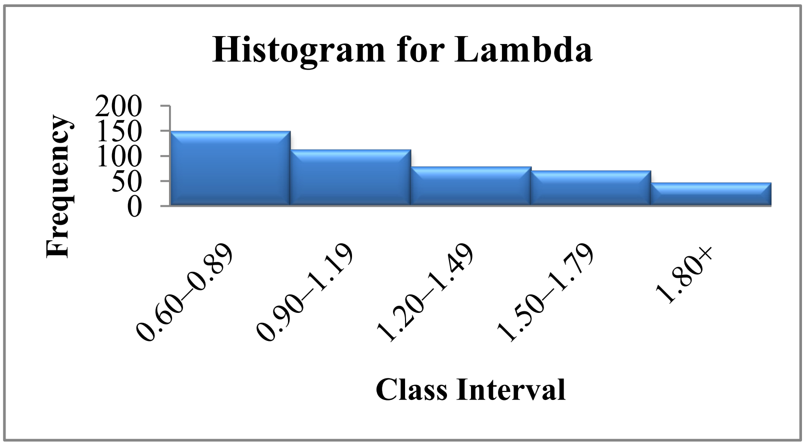
It is clear from the above figure that 71.90 percent vehicle's Carbon Dioxide emission is under the average value of Carbon Dioxide emission (i.e., 11.246) while 28.10 percent vehicle's Carbon Dioxide emission is over the average value of Carbon Dioxide emission (i.e., 11.246). This implies that motor vehicles also emit pollutants, such as Carbon Dioxide, that contribute to global climate change and this is very harmful on our human health as well as other factors for the sustainable environment. Here, the distribution of the Carbon Dioxide emission is approximately normal.



It is evident from the above figure that 92.69 percent vehicle's Hydro Carbon emission is under the standard limit (i.e., 1200 ppm) and 8.31 percent vehicle's Hydro Carbon emission is over the standard limit (i.e., 1200 ppm). So it is obvious that massive awareness among the vehicle owners and drivers should be built up urgently so they go for regular check-ups and maintenance of their vehicles. Here, the distribution of the Hydro Carbon emission is positively skewed.



It is evident from the above figure that 68.32 percent vehicle's Air–fuel ratio emission is under the standard limit (i.e., 20 LEDs) and 31.68 percent vehicle's Air–fuel ratio emission is over the standard limit (i.e., 20 LEDs). So we can say that most of the motor vehicles are in good condition. Here, the distribution of the Air–fuel ratio emission is positively skewed.



It is evident from the above figure that 53.54 percent vehicle's Lambda emission is under the standard limit (i.e., 1 ± 0.03) and 46.46 percent vehicle's Lambda emission is over the standard limit (i.e., 1 ± 0.03).So, we can say that if the exhaust chemistry varies from stoichiometric conditions emission control is decreased. If the exhaust chemistry is net "fuel rich," meaning there is an excess of HC and CO emissions in comparison to the oxidation potential of the NO_x and O_2 present in the exhaust, the excess HC and CO pollutants are emitted from the vehicle. Here, the distribution of the Lambda emission is positively skewed.

Test of Significance of the Pollutants

Table 1. Calculation of ANOVA of Carbon Monoxide (CO) Emission

ANOVA					
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	206.252	8	25.781	3.795	0.000
Within Groups	3009.417	443	6.793		
Total	3215.669	451			

It is evident from the table 1 that the p value (p = 0.000) is less than the level of significance (α = 0.05) so we reject the the null hypothesis that there is no difference of mean level of Carbon Monoxide (CO) emission among different types of motor vehicles.

Table 2. Post Hoc Test of CO Emission among Different Motor Vehicle's

(I) Types of Makers	(J) Types of Makers	Mean Difference (I-J)
Toyota	Maruti	0.308
	Suzuki	-0.362
	Tata	1.497
	Hyundai	0.857
	Daewoo	-0.767
	Honda	-2.706*
	Hero	-1.618
	Others	-1.006
Maruti	Suzuki	-0.670
	Tata	1.189
	Hyundai	0.549
	Daewoo	-1.075
	Honda	-3.014*
	Hero	-1.927
	Others	-1.314*
Suzuki	Tata	1.860
	Hyundai	1.220
	Daewoo	-0.404
	Honda	-2.343*
	Hero	-1.256
	Others	-0.643
Tata	Hyundai	-0.640
	Daewoo	-2.265
	Honda	-4.203*

	Hero	-3.116*
	Others	-2.503*
Hyundai	Daewoo	-1.625
	Honda	-3.563*
	Hero	-2.476
	Others	-1.863
Daewoo	Honda	-1.938
	Hero	-0.851
	Others	-0.238
Honda	Hero	1.087
	Others	1.699*
Hero	Others	0.612

*. The mean difference is significant at the 0.05 level.

Table 3. Calculation of ANOVA of Carbon Dioxide (CO_2) Emission

ANOVA					
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	1263.469	8	157.934	18.719	0.000
Within Groups	3737.710	443	8.437		
Total	5001.180	451			

It is evident from the table 3 that the p value (p = 0.000) is less than the level of significance ($\alpha = 0.05$) so we reject the the null hypothesis that there is no difference of mean level of Carbon Dioxide (CO_2) emission among different types of motor vehicle's.

Table 4. Post Hoc Test of CO_2 Emission among Different Motor Vehicle's

(I) Types of Makers	(J) Types of Makers	Mean Difference (I-J)
Toyota	Maruti	2.108*
	Suzuki	1.611*
	Tata	1.907*
	Hyundai	1.267
	Daewoo	3.528*
	Honda	5.449*
	Hero	6.822*
	Others	4.155*
Maruti	Suzuki	-0.497
	Tata	-0.200
	Hyundai	-0.840
	Daewoo	1.420
	Honda	3.341*
	Hero	4.714*
	Others	2.047*
Suzuki	Tata	0.296
	Hyundai	-0.343
	Daewoo	1.917
	Honda	3.838*
	Hero	5.211*
	Others	2.544*
Tata	Hyundai	-0.640
	Daewoo	1.620
	Honda	3.542*

	Hero	4.914*
	Others	2.247*
Hyundai	Daewoo	2.260
	Honda	4.182*
	Hero	5.554*
	Others	2.887*
Daewoo	Honda	1.921
	Hero	3.294*
	Others	0.627
Honda	Hero	1.372
	Others	-1.294
Hero	Others	-2.667*

*. The mean difference is significant at the 0.05 level.

Table 5. Calculation of ANOVA of Hydro Carbon (HC) Emission

ANOVA					
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	613400000	8	76680000	28.328	0.000
Within Groups	1199000000	443	2706667.904		
Total	1812000000	451			

It is evident from the table 5 that the p value ($p = 0.000$) is less than the level of significance ($\alpha = 0.05$) so we reject the the null hypothesis that there is no difference of mean level of Hydro Carbon (HC) emission among different types of motor vehicle's.

Table 6. Post Hoc Test of HC Emission among Different Motor Vehicle's

(I) Types of Makers	(J) Types of Makers	Mean Difference (I-J)
Toyota	Maruti	145.332
	Suzuki	63.082
	Tata	315.149
	Hyundai	278.815
	Daewoo	199.577
	Honda	-5594.413*
	Hero	-2666.993*
	Others	-1913.636*
Maruti	Suzuki	-82.249
	Tata	169.817
	Hyundai	133.483
	Daewoo	54.245
	Honda	-5739.745*
	Hero	-2812.325*
	Others	-2058.968*
Suzuki	Tata	252.066
	Hyundai	215.733
	Daewoo	136.495
	Honda	-5657.495*
	Hero	-2730.076*
	Others	-1976.719*
Tata	Hyundai	-36.333
	Daewoo	-115.571
	Honda	-5909.562*

	Hero	-2982.142*
	Others	-2228.785*
Hyundai	Daewoo	-79.238
	Honda	-5873.229*
	Hero	-2945.809*
	Others	-2192.452*
Daewoo	Honda	-5793.991*
	Hero	-2866.571*
	Others	-2113.214*
Honda	Hero	2927.419*
	Others	3680.776*
Hero	Others	695.22

*. The mean difference is significant at the 0.05 level.

Table 7. Calculation of ANOVA of Air-Fuel Ratio (AFR) Emission

ANOVA					
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	1886.897	8	235.862	9.127	0.000
Within Groups	11448.013	443	25.842		
Total	13334.909	451			

It is evident from the table 7 that the p value (p=0.000) is less than the level of significance ($\alpha = 0.05$) so we reject the the null hypothesis that there is no difference of mean level of Air-Fuel Ratio (AFR) emission among different types of motor vehicle's.

Table 8. Post Hoc Test of AFR Emission among Different Motor Vehicle's

(I) Types of Makers	(J) Types of Makers	Mean Difference (I-J)
Toyota	Maruti	-4.238*
	Suzuki	-2.150
	Tata	-5.170*
	Hyundai	-2.686
	Daewoo	-4.232*
	Honda	0.727
	Hero	-6.732*
	Others	-3.264*
Maruti	Suzuki	2.088
	Tata	-0.931
	Hyundai	1.552
	Daewoo	0.007
	Honda	4.966*
	Hero	-2.493
	Others	0.974
Suzuki	Tata	-3.020
	Hyundai	-0.536
	Daewoo	-2.081
	Honda	2.877
	Hero	-4.581*
	Others	-1.114
Tata	Hyundai	2.483
	Daewoo	0.938
	Honda	5.897*

	Hero	-1.561
	Others	1.905
Hyundai	Daewoo	-1.545
	Honda	3.414
	Hero	-4.045
	Others	-0.577
Daewoo	Honda	4.959*
	Hero	-2.500
	Others	0.967
Honda	Hero	-7.459*
	Others	-3.991*
Hero	Others	3.467

*. The mean difference is significant at the 0.05 level.

Table 9. Calculation of ANOVA of Lambda Emission from Motor Vehicle's

ANOVA					
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	8.740	8	1.092	9.146	0.000
Within Groups	52.915	443	0.119		
Total	61.655	451			

It is evident from the table 9 that that the p value ($p = 0.000$) is less than the level of significance ($\alpha = 0.05$) so we reject the the null hypothesis that there is no difference of mean level of Lambda emission among different types of motor vehicle's.

Table 10. Post Hoc Test of λ Emission among Different Motor Vehicle's

(I) Types of Makers	(J) Types of Makers	Mean Difference (I-J)
Toyota	Maruti	-0.288*
	Suzuki	-0.145
	Tata	-0.352*
	Hyundai	-0.183
	Daewoo	-0.287*
	Honda	0.053
	Hero	-0.457*
	Others	-0.221*
Maruti	Suzuki	0.143
	Tata	-0.064
	Hyundai	0.104
	Daewoo	0.001
	Honda	0.341*
	Hero	-0.168
	Others	0.066
Suzuki	Tata	-0.207
	Hyundai	-0.038
	Daewoo	-0.141
	Honda	0.198
	Hero	-0.311*
	Others	-0.076
Tata	Hyundai	0.169
	Daewoo	0.065

	Honda	0.406*
	Hero	-0.104
	Others	0.131
Hyundai	Daewoo	-0.103
	Honda	0.236
	Hero	-0.273
	Others	-0.037
Daewoo	Honda	0.340*
	Hero	-0.170
	Others	0.065
Honda	Hero	-0.510*
	Others	-0.274*
Hero	Others	0.235

*. The mean difference is significant at the 0.05 level.

Determination of Factors Influencing Environmental Components

Table 11. Correlation Matrix of Different Variables of Vehicular Emissions

		CO	CO_2	HC	AFR	Lambda
Correlation	CO	1.000	-0.409	0.298	-0.395	-0.395
	CO_2	-0.409	1.000	-0.462	-0.486	-0.486
	HC	0.298	-0.462	1.000	-0.138	-0.139
	AFR	-0.395	-0.486	-0.138	1.000	1.000
	Lambda	-0.395	-0.486	-0.139	1.000	1.000
Sig. (1-tailed)	CO		0.000	0.000	0.000	0.000
	CO_2	0.000		0.000	0.000	0.000
	HC	0.000	0.000		0.002	0.002

	AFR	0.000	0.000	0.002		0.000
	Lambda	0.000	0.000	0.002	0.000	

❖ Determinant = 0.0000138

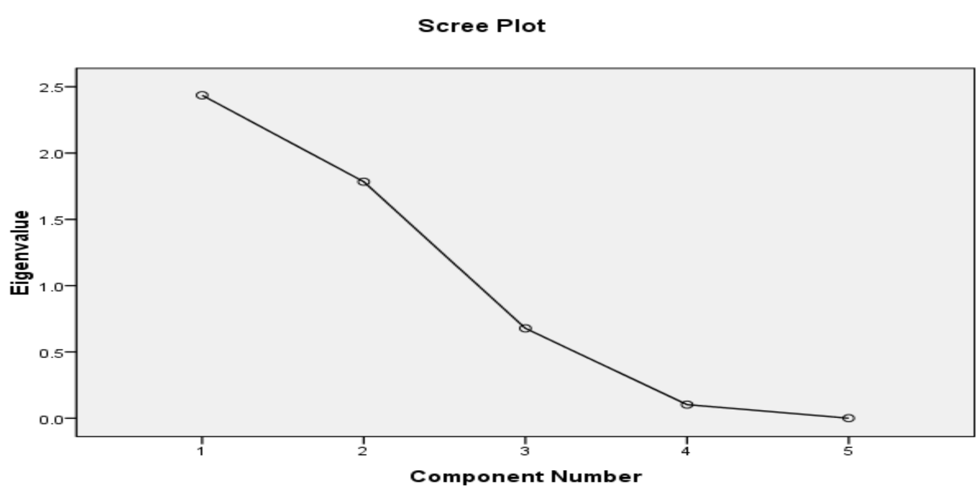
For these data the determinant value is 0.0000138 which is greater than the necessary value of 0.00001. Therefore, multicollinearity is not a problem for these data and there is no need to consider eliminating any variables at this stage.

Table 12. Kaiser-Meyer-Olkin and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.516
Bartlett's Test of Sphericity	Approx. Chi-Square	5020
	df	10
	Sig.	0.000

It is observed from the table 12 that Kaiser-Meyer-Olkin Measure of Sampling Adequacy is 0.516 so we should be confident that factor analysis is appropriate for these data. Again, for these data, Bartlett's test is highly significant ($p < 0.001$), and therefore factor analysis is appropriate.

Determination of the optimal number of Components by Graph



It is seen from the above graph that an elbow occurs in the plot in the figure at about $i = 3$. That is, the Eigen values after $\hat{a}_2$ are all relatively small and about the same size. In this case, two sample principal components effectively summarize the total sample variance.

Table 13. Total Variance Explained by Different Variables

Variables	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
CO	2.43	48.720	48.720	2.43	48.720	48.720	2.43	48.639	48.639
CO_2	1.78	35.672	84.392	1.78	35.672	84.392	1.78	35.754	84.392
HC	0.67	13.554	97.946						
AFR	0.10	2.053	99.999						
λ	.000045	0.001	100.000						

Extraction Method: Principal Component Analysis.

It is observed from the table 13 that about 49 % of the total variance explained by the first factor and 84 % of the total variance explained by the first two factors and therefore we extract only two variables because only two eigen values are greater than 1. That is, they explain nearly 84% of the variability in the original five variables, so we can considerably reduce the complexity of the data set by using these components, with only a 16% loss of information.

Table 14. Component Score Coefficient Matrix of Different Variables

	Factor	
	1	2
CO	-0.141	0.422
CO_2	-0.247	-0.440
HC	-0.013	0.431

AFR	0.406	-0.039
Lambda	0.406	-0.039

Rotation Method: Varimax with Kaiser Normalization.

The resulting two component score variables are representative of, and can be used in place of, the five original variables with only a 16% loss of information.

Regression Analysis

Table 15. Regression of Air Pollutant Emissions

Factor	Model Summary	Coefficient	Std. Error	t value	Sig.
CO	Constant	1.885	0.068	27.918	0.000
	Ratio Factor	-0.974	0.068	-14.415	0.000
	Carbon Factor	2.032	0.068	30.056	0.000
	Adjusted R^2	0.711			
CO_2	Constant	11.246	0.041	275.769	0.000
	Ratio Factor	-1.926	0.041	-47.168	0.000
	Carbon Factor	-2.575	0.041	-63.084	0.000
	Adjusted R^2	0.932			
HC	Constant	680.874	60.000	11.348	0.000
	Ratio Factor	-106.870	60.067	-1.779	0.076
	Carbon Factor	1545.103	60.067	25.723	0.000
	Adjusted R^2	0.595			
AFR	Constant	17.059	0.027	636.142	0.000
	Ratio Factor	5.385	0.027	200.597	0.000
	Carbon Factor	-0.492	0.027	-18.332	0.000
	Adjusted R^2	0.989			
Lambda	Constant	1.161	0.002	633.391	0.000

	Ratio Factor	0.366	0.002	199.567	0.000
	Carbon Factor	-0.034	0.002	-18.355	0.000
	Adjusted R^2	0.989			

It is observed from the above table that the impact of "Ratio Factor" and "Carbon Factor" on CO, CO_2, HC, AFR, and Lambda is statistically highly significant. The value of Adjusted R^2 indicates that the regression models fit well in all the cases. Other checks of Goodness-of-fit of the regression model such as Normality Plots of residuals also confirmed that the models fitted well. The values of the constants are significant, indicating that a constant should be incorporated in all models.

3. Conclusions

Motor vehicles are significant sources of pollution that can damage the environment and pose public health issues.

From the distribution of pollutants we find that most of the frequency distribution of amounts of emission of different pollutants (i.e., CO, HC, AFR & Lambda) are positively skewed while the others are approximately normal (i.e., CO_2). Primary observation reveals that about 69.93% of the Petrol/Octane and CNG based motor vehicles are satisfying standard value while 30.07% of the Petrol/Octane and CNG based motor vehicles are not satisfying standard value. Petrol/Octane and CNG based private cars and microbuses are frequently found faulty which is not at all acceptable. Private type vehicles with cleaner fuel should be more promising to environment.

From the test of significance of the pollutants we find that Honda discharges highest amount of CO and HC among all of the alternative motor vehicles while Toyota discharges highest amount of CO_2 and at the same time Hero discharges the highest amount of AFR and Lambda. Conversely, Tata discharges lowest amount of CO and HC among all of the alternative motor vehicles while Hero discharges lowest amount of CO_2 and at the same time Honda discharges the lowest amount of AFR and Lambda according to the makers of the motor vehicles.

From the determination of factors influencing environmental components, Scree plot suggests that at least two factors should be taken to do the further analysis. Instead of using five factors one can use just two factors. Factor analysis supports the necessary reduction of total factors. Also, we find that about 84% of the total variation is explained by the two factors (i.e., CO & CO_2) in place of the five original factors (i.e., CO, CO_2, HC, AFR & Lambda) with only a 16% loss of information.

4. Recommendations of the Study

Several recommendations are made to improve the air quality of Dhaka Metropolitan City, among them:

- Vehicular emission can be reduced by replacing old, worn-out vehicles. It can also be done by appropriate engine design, control strategies and maintenance services. The engines of the existing petroleum fuel based vehicles are to be modified so that they can use CNG. Catalytic converter, efficient filters and absorbers can be used for vehicular exhaust gas treatment for new model vehicles having appropriate control systems.
- Appropriate transportation planning is to be adopted to introduce efficient mass transit. Rickshaws are to be gradually phased out from the main roads. They may be allowed to operate in lanes and by-lanes only.
- Department of Environment (DoE) and Bangladesh Road Transport Authority (BRTA) should enforce their regulations strictly. Government has to ensure effectiveness of control programs through ambient air quality monitoring.
- Coordination between DESA, DWASA and BTTB is needed to reduce the concentration of suspended particulate matter in the air of Dhaka metropolitan city.
- If sufficient manpower or equipment is not available at Government agencies for enforcement work, some type of distributed system should be developed through the private sector.
- Social awareness about the consequences of environmental degradation is to be created through mass media such as TV, radio and newspaper.

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