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IMPACT OF VARIOUS TRANSPORTATION MODES ON THE AIR QUALITY OF DHAKA CITY: A CASE STUDY AT MOTIJHEEL

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ABSTRACT

Transportation sector significantly contributes to air pollution. This study calculates the daily load of emission of some criteria pollutants (Nitrogen Oxides, Sulfur Oxides, Carbon Monoxide and Suspended Particulate Matter) and hydrocarbons from vehicular fleet at Toyenbee Circular Road, Motijheel, Dhaka. It also analyzes relative contribution of certain types of vehicles to emission of a specific type of pollutant. Primary volume data is collected from field video graphic survey and expansion factors and emission factors are taken from literature. Results show that different types of vehicles contribute to air pollution differently. For Carbon Monoxide and hydrocarbons pollution, motor cars are mainly responsible while bus is the main contributor of Nitrogen Oxides and Sulfur Oxides pollution. Motorcycle is the main contributor of Suspended Particulate Matter pollution in this case. These comparisons imply that it is necessary to determine the focus point of pollution reduction before taking any preventive measures.

Keywords: *Air Pollution, Vehicle Composition, Criteria Pollutants, Emission, Dhaka.*

1. INTRODUCTION

Ensuring a good and healthy air quality is the crying need of modern civilization. In this context, it is imperative to choose sustainable options for the betterment of the world rather than choosing alternatives that might go against the mother nature. As it can already be observed that the whole world is facing a catastrophic phenomenon of severe air pollution, majority of the world's population is breathing polluted air casing them a wide range of physical and financial crisis.

Air pollution is caused by the introduction of gases and particle contaminants into the atmosphere as a result of natural or human activity. Air quality is determined by the concentration and toxicity of these chemicals, which contribute to climate change in the long run. Through complicated interactions in the atmosphere, both air pollution and climate change influence each other (Ghude *et al.*, 2014).

It can be said that many agents are widely responsible for the current adverse situation of air pollution, but among them transportation sector is somehow very significant now-a-days (Hossain, 2004). Due to the onslaught of the ever-increasing multi-dimensional needs, there is no alternative to fast transportation modes to satisfy the client's need. As a result, motorization has become dominant and causing a severe level of air pollution without any proper control measures. In developing countries and Eastern Europe, there is still the possibility of a significant increase in car ownership and use, and it is unclear if these countries will take steps now to avoid severe transportation-related air pollution problems later in the twenty-first century (Colvile *et al.*, 2001). A motorization rate in India is 26 vehicles per 1000 population, and this is lower than many developing countries throughout the world (Brazil-222/1000 population in 2012, South Africa 153/1000 population.), but over the last three decades number of motor vehicles has been doubling against a 2-5% annual growth rate in Canada, the US, the UK and Japan (MoRTH, 2012). Transport sector emits an estimated 261 tons of CO_2, of which 94.5% is contributed by road transport (Shrivastava *et al.*, 2013).

To understand the true threat of motorization and different transport modes which are causing serious air issues, it is imperative to determine which of the modes are severely affecting the air around the city. So that, it can be concluded whether modal shift towards sustainable modes or other non-motorized options would be satisfactory to increase the air quality of Dhaka City.

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There is almost no study in the field of air pollution to understand the effect of different types of vehicles plying on the arterials especially in urban areas. Local emissions were estimated to contribute between 57% and 67% of the aerosol in Dhaka city (Foy *et al.*, 2021). But there is no mention about how much local emission is contributed from different types of vehicles. Salam et al. (2008) mentioned that that fossil fuel is the main source of PM in Dhaka.

concentrations but the relative amount of fossil fuel used in different vehicles is absent in the literature. Hasan (2008) studied different types of vehicular emission in Dhaka city but didn't build any link between vehicle composition and vehicle emission to air pollution.

This study shows a comparison of different modes and their impacts on air quality. Such studies will help the planners to understand the effect of a roadway on the surrounding air quality. The objective of this project is to make a detailed analysis of vehicle contribution on air pollution in the specific link of Toyenbee Circular Road at Dhaka.

2. METHODOLOGY

2.1 Collection of Vehicle Composition Data

2.1.1 Study Area

This study is done at Toyenbee Circular Road which is under the administrative division (Thana) Motijheel of Dhaka, Bangladesh's capital. This is very near to the economic hub of Bangladesh. This is Dhaka's major business and commercial hub and has more offices and business institutions than any other part of the city (Rahman and Noman, 2018). At our selected road section, there is also a reputed college named Notre Dame College Dhaka. In the study year (2019), there were about 6400 students in that institute (Notre Dame College, 2021). This road section is 1.5 kilometers long four-lane pathway with both-direction traffic flow. Figure 1 shows this road section along with the survey station (Google, n.d.).

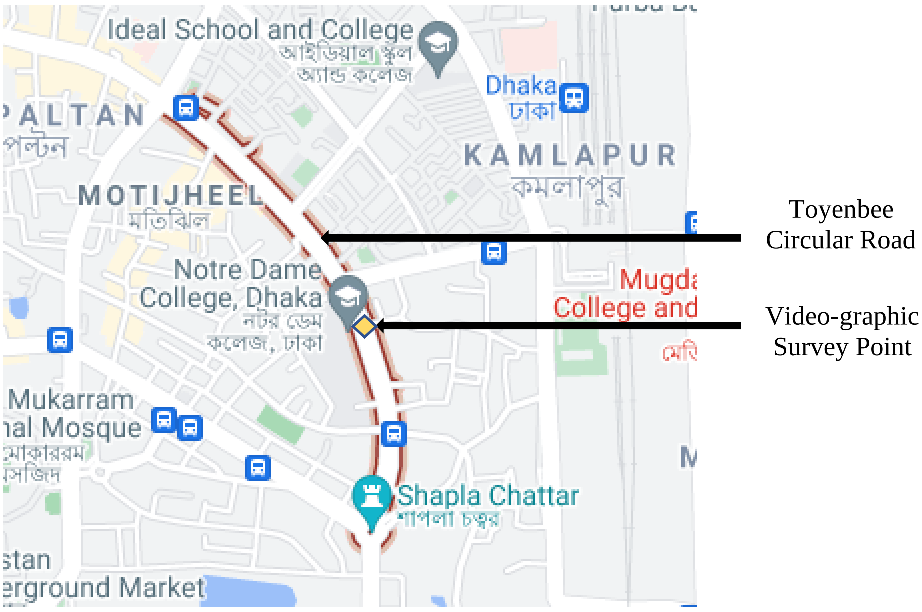

Figure 1: Layout of the Toyenbee Circular Road and Survey Station.

2.1.2 Video graphic Survey

A reconnaissance survey was done to select the point for the video-graphic survey. A foot-over bridge near the above-mentioned college's main gate was selected for positioning the video-capturing device. Pilot surveys were done to estimate the peak volume hours for that location. It was seen that the volume of traffic has two-peaks, morning peak and the evening peak. Among these two, morning peak (8.30 am to 9.30 am) is higher than the evening peak as it coincides with the office hour and college hour. This slot was selected for video-graphic survey. After video-capturing, manual counting was done to identify the numbers of different types of vehicles. This process was repeated each Tuesday for the same month at the same time. The arithmetic average was taken from the retrieved data.

2.2 Converting Vehicle Composition Data into AADT

To convert this hourly data into Annual Average Daily Traffic (AADT), expansion factors by Maiteh and Imam (2018) is used. Maiteh and Imam (2018) had their research at some urban arterials near their economic hub at Amman, the Capital city of Jordan. These road sections consist of four lanes in two directions. There are also two peaks of vehicle volume- one in the morning and the other in the evening. At peak hours que-building is a common phenomenon there. All these similarities and absence of proper expansion factors for the urban arterials in Bangladesh justifies the use of the mentioned expansion factors at Toyenbee Circular Road for calculating the value of AADT. Here, the data is taken on the month of July, for from 8.30 am to 9.30 am for four consecutive weeks at the same time. For this specification, expansion factors were chosen accordingly. Hourly Expansion Factor (HEF) is considered as 20.351378 for 9.00 am, Daily Expansion Factor (DEF) is considered as 6.342 for Tuesday and Monthly Expansion Factor (MEF) is considered as 0.991 for July. AADT is calculated using equation 1 and 2 stated below:

$$Average\ 24\ hr.Volume = \frac{(HEF * No.\ of\ Vehicle\ in\ a\ specified\ Hour) * DEF}{7} \quad (1)$$

$$AADT = MEF * Average\ 24\ hr.Volume \quad (2)$$

AADT count using the above-mentioned expansion factors and equations 1 and 2 are shown in Table 1.

Table 1: AADT calculation for various categories of vehicles on Toynbee Circular Road link, Motijheel.

Vehicle Type	Total No. of Vehicles	Avg. 24 Hr. Volume	AADT
Bicycle	90	1659	1645
Motorcycle	544	10030	9940
Rickshaw	1648	30386	30113
Pickup Van	74	1364	1352
Auto Rickshaw	352	6490	6432
Bus	128	2360	2339
Passenger Car	700	12907	12791
Micro-bus	82	1512	1498

2.3 Selection of Emission Factors

Emission factors are taken from the study of Hasan (2008) as shown in Table 2. There he studied emission factors for different Asian countries and selected specific values for Dhaka city. "EXOTOX 60" atmosphere monitor was used to measure the emission of SO_2, NO_2, and CO in ppm from different service vehicles. The value of ppm is then converted to g/km of vehicles running. As the vehicle condition of Dhaka city and Toyenbee Circular Road Link can be considered as having similar pattern during the study period, emission factors selected by Hasan (2008) is used in the current study. Here, emission of Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Hydrocarbons (HC), Carbon Monoxide (CO), and Suspended Particulate Matter (SPM) are measured for different types of vehicles are considered as they are chiefly emitted from vehicles (Hossain, 2004).

Table 2: Emission factors of different air pollutants for various categories of vehicles.

Category of Vehicle	Emission Factors (gm/km)				
	CO	NO_x	SO_x	HC	SPM (Suspended Particulate Matter)
Motor Car	25	1.5	0.4	4	0.1
Microbus	28	1.6	0.5	4	1
Bus	20	17	2	4	1.6
Truck	30	17	3	4	1.6
Auto-rickshaws	5	1.5	-	2	0.03
Pickup Van	25	10	2	4	1.6
Motorcycle	5	0.3	0.2	4	0.75

Among the above-mentioned five types of pollutants, Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), Carbon Monoxide (CO), and Suspended Particulate Matter (SPM) are termed as criteria air pollutants (CAP) for their abundances as pollutants in the atmosphere and ability to harm human health, plants, and properties (Rana and Biswas, (2018).

2.4 Selection of variables and Formation of Equation

For relating emission factors to vehicle composition, simple mathematical function is used with three independent variables such as, No. of a certain type of vehicle on that road (AADT value), length of the road in kilometers and their emission factors in grams per kilometer. Dependent variable is the amount of a certain type of pollutant emitted on daily basis.

Below-mentioned equation 1 is used to calculate the amount of pollutant in kg/day.

$$\text{Amount of pollutant (kg/day)} = (\text{No. of vehicles (AADT)} * \text{Length of road (km)} * \text{EF (gm/km)}) / 1000 \qquad (3)$$

For comparing the effect of different types of vehicles, they are converted to percentage values. Pie charts and bar-diagrams is provided to understand the total scenario.

3. DATA ANALYSIS

For data analysis, six categories of motorized vehicles are selected from Table 1 and their corresponding emission factors for five types of air pollutants from Table 2. Here all the motor cars and microbus are assumed as gasoline driven (Hasan, 2008). Using the selected values from Table 1 and Table 2, equation (3) is used to estimate the daily load of a pollutant. The calculated estimation of vehicular emission is shown in Table 3.

Table 3: Estimation of vehicular emission in Toynbee Circular Road link, Motijheel.

Category of Vehicle	**CO (kg/day)**	**NOx (kg/day)**	**SOx (kg/day)**	**HC (kg/day)**	**SPM (kg/day)**
Motor Car	479.66	28.78	7.68	76.75	1.92
Microbus	62.92	3.60	1.12	8.99	2.25
Bus	70.17	59.64	7.02	14.03	5.61
Auto-rickshaws	48.24	14.47	0	19.30	0.29
Pickup Van	50.7	20.28	4.06	8.11	3.24
Motorcycle	74.56	4.47	2.98	59.65	11.18
Total	786.25	131.24	22.85	186.82	24.50

4. RESULT & DISCAUSSION

4.1 Relative Contribution of CO from Vehicular Fleet

Carbon Monoxide (CO) emission by different types of vehicles at the Toyenbee Circular Road is provided below in the pie diagram (Figure 2). Here it can be seen that the maximum CO is generated by Motor cars (Private Cars) which is about 61%. Motor cycle is another contributor having 10% of the emission.

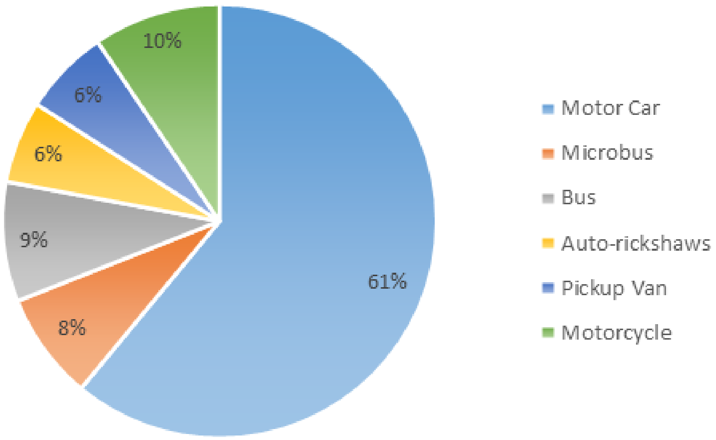

Figure 2: CO Emission by Different Modes.

4.2 Relative Contribution of NO_x Emission from Vehicular Fleet

In case of Nitrogen Oxides (NO_x), the scenario changes completely having 45% of emission by the buses having AADT of 2339. Though motor cars have the highest AADT, it contributes to only 22% of the NO_x emission. Motor cycle contribute 10% of emission. That is shown in Figure 3.

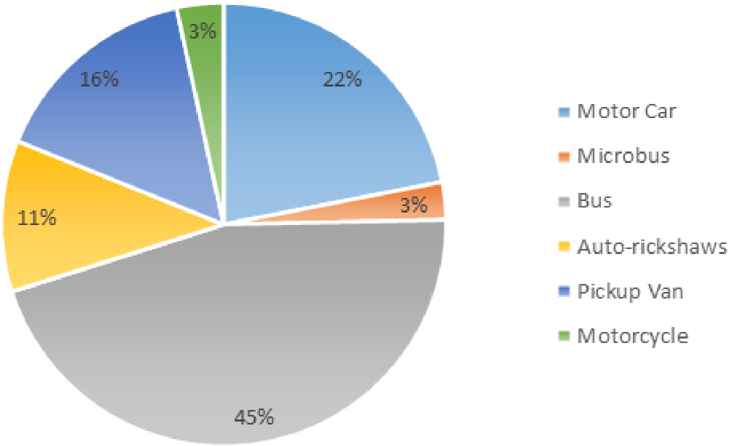

Figure 3: NOx Emission by Different Modes.

4.2 Relative Contribution of SO_x Emission from Vehicular Fleet

Motor cars dominate while we consider Sulfur Oxides (SO_x) emission with 33% of emission. Local buses are also a significant polluter having 31% emission of SO_x gases. CNG driven green auto-rickshaws have almost insignificant SO_x emission according to the emission factors used here for analysis which is shown in Figure 4.

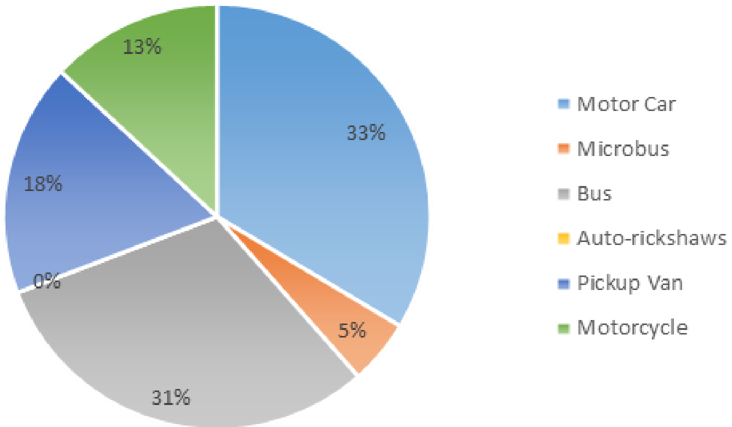

Figure 4: SO_x Emission by Different Modes.

4.3 Relative Contribution of HC from Vehicular Fleet

Figure 5 shows that Hydrocarbons (HC) emission has been a serious problem causing air pollution. Motor cars have the highest overall percentage having 41%. The second highest percentage is 32% by Motor cycles.

4.4 Relative Contribution of SPM Emission from Vehicular Fleet

Suspended Particulate Matter is mostly emitted by Motor-Cycles. Another source is Buses. As these both runs on diesel and petrol these have a larger amount of suspended particulate matter emitted than gasoline driven motor cars. Moreover, CNG auto rickshaws have the least emitted SPM compared to the others modes are shown in Figure 6.

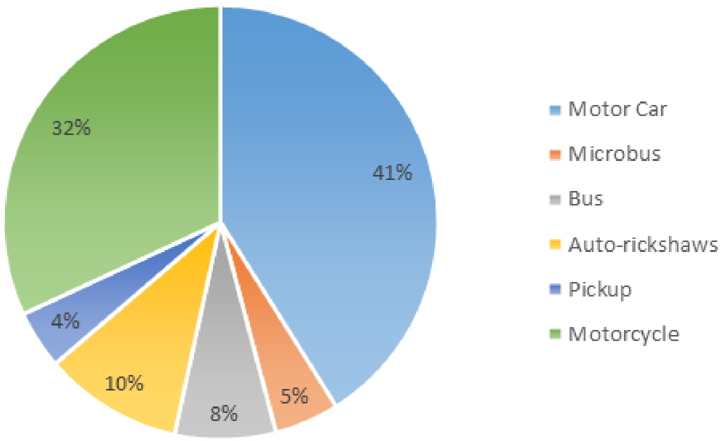

Figure 5: HC Emission by Different Modes.

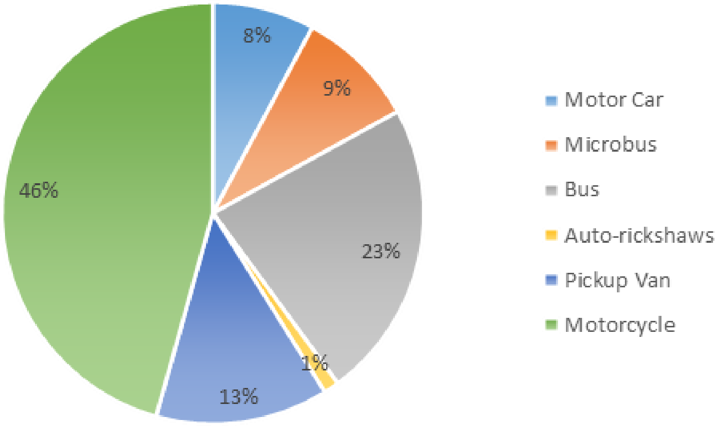

Figure 6: SPM Emission by Different Modes.

4.5 Comparative Study with the Vehicular Emission in Different Cities of India

Shrivastava *et al.*, (2013) studied emission from different vehicles and estimated pollution load in different cities of India. He summarized data taken from Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Kanpur and Agra. In Kolkata, 2 wheelers (Motorcycles) are main contributor of CO emission whereas in our study area, motor cars are the main contributors. For NOx emission, Bus is the highest contributor in both Dhaka and Kolkata. Motor cars plays insignificant role in the emission of SOx in Kolkata which is opposite to the report found in Motijheel area. For HC pollution, Motorcycles are the main contributors in Kolkata whereas it is only 32% in Dhaka. Motorcycles are mainly responsible for SPM pollution in the study area which is the second highest contributor in Kolkata.

Among different cities of India, amount of CO pollution is highest in each city. In case of Motijheel, Dhaka, similar trend is found. Second highest pollution is mainly by HC in our study area which differs from the condition of Kolkata. On other cities, HC is the second highest pollutant. SPM is the least present pollutant in all the Indian cities taken in the study of Shrivastava (2013), which is similar to the condition of Motijheel, Dhaka.

5. CONCLUSION & RECOMMENDATION

This research tries to show the current air pollution scenario on urban link. It is found that no. of vehicles doesn't replicate the true scenario of its contribution to air pollution. Comparative study with a city which has similar traffic pattern like Dhaka, it is evident that the concern is not only limited to our study area, but should be considered as a global concern.

Moreover, this research helps us to understand that the ever-increasing volume of private car is a serious threat to air quality. A single car unit might not be a concern but this number of private vehicles collectively pollutes the air quality to a great extend specially with respect to CO, SO_x and HC emission. Bus and microbuses are also major source of concern for some pollutants. So, before taking any preventive measure for any sort of vehicle, specific focus point of pollutant should be identified. If the focus is on reduction of NO_x and SO_x pollution, increasing the number of buses and imposing control over private motor cars may not be significantly effective while it can be a great solution if we want reduce CO emission. Another way of reducing overall air pollution can be changing the current fuel and burning type into a less harmful one. This can be validated by this study. CNG driven auto-rickshaws are positioned in the third place in terms of AADT, but their contribution to pollutant emission is not that much significant.

For more detailed and accurate results, more data can be analyzed using the exact expansion factor for that roadway. Rigorous research on different categories of vehicle emission can help to select up-to-date emission factors that will pave the way for more precision in results.

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