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Curtailment of GHG Emission Due to Implementation of Metrorail Service: A Case Study in Dhaka City

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Abstract. Developing countries in Asia are investing in rapid transit systems as a response to the problems of urban traffic congestion and satisfying rapidly expanding transport demand, particularly in metro. Metros are completely segregated from other routes and are usually elevated or underground. It is the segregation that is necessary for delivering a quick service, as well as the technology that enables for a large number of passengers to be transported. Dhaka, the capital of Bangladesh having 8.9 million of people, is facing poor status in public transportation system. Motorcycles, rickshaws, public buses, human hauler, private cars, CNG, minibuses, and taxis are the most common and heterogenous modes of transportation in Dhaka City. From an environmental standpoint, Dhaka's current transportation situation is extremely precarious. In order to solve the problem, promotion of Electric/Hybrid vehicles have been started. For the purpose of withstanding the increasing passengers demand, the government of People's Republic of Bangladesh commissioned a comprehensive transport plan known as the Strategic Transport Plan (STP) for Greater Dhaka City and its surrounding districts in 2008. As a part of this, Bangladesh's government has set a schedule for constructing a road network of that includes six updated metro rail lines of 128.741km under the Dhaka Mass Transit Company Limited (DMTCL) which is expected to cost Tk 21,985.07 crore. The prime focus of this paper is to represent the curtailment of GHG emission due to implementation of mass transit railway systems where vehicles miles travelled data and emission factor of different vehicles have been used to calculated the GHG emission from currently available modes and the data of CO_2 emission due to electricity generation has been used in case of metro rail. The method followed are selection of study area, collection of data from primary and secondary sources and analysis. The equation used for the calculation of GHG emission from transportation facilities as well as metro rail system of Bangladesh is represented with the help of literature. Primary data are collected from site visit, field survey and questionnaire survey whereas Secondary data are collected from electronic assessment of the literature which included journals, books, reports from an international organization, and articles. It has been found that currently available modes of transport emits 71,330 tons/year of GHG for passing the passengers from Uttara to Motijheel. But when MRT Line-6 of mass transit railway system will be implemented then only 18,688 tons/year of GHG will be emitted due to electricity generation which will result into a curtailment of 52,642 tons of GHG emission yearly. So, it will result into the improvement of the air quality of Dhaka city which is surely positive contribution to cut global GHG emission.

INTRODUCTION

As a solution to the problems of urban traffic congestion and meeting rapidly increasing travel demand, developing countries in Asia are investing in rapid transit systems, particularly in metro rail system (Fox, 2000). Metros are completely segregated and are usually elevated or underground. It is the segregation that is necessary for delivering a quick service, as well as the technology that enables for a large number of passengers to be transported (Fox, 2000). This is also aimed at reducing environmental degradation and increasing economic growth. Observing projects in Hong Kong and Singapore, as well as cities in South Asian countries such as Delhi, Mumbai and Kolkata (India), till

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now metro is considered to be one of the final solutions for the expanding transport demand. Developed countries like Canada, France, Germany, United States adopted rapid transit systems due to some reasons among them one of each is environmental goal achievement. Cities that are experiencing increased economic growth intended for rapid transit to make it less congested, faster, and more dependable for people's movement (Walmsley & Perrett, 1992). Any new public transportation system should be designed with the desired outcomes in mind, such as greater public transportation market share, reduced automotive dependence, and favorable effects on the environment and urban growth (Golias, 2000). The most essential and common concern among them is to reduce car use and enhance public transportation use. Developing countries, on the other hand, prefer metro to accommodate increasing travel demand and reduce congestion (Godard & Lequeux, 1998).

Current Transportation Policy in Dhaka City

Dhaka is Bangladesh's capital and most populous city. With an estimated population of 8.9 million people, it is the world's ninth biggest and sixth most densely inhabited metropolis within the metropolis having an area of 302.92 square km (Anon., 2013). The increase has been aided by migration from other cities, towns, and, most importantly, villages. Because it has remained the focal point of most activities in the country due to the lack of decentralization, an increasing number of people are flocking to Dhaka in search of what they perceive to be easy access to jobs (Jahan & Oda, 2000). Many residents of Dhaka are poor; per capita income in the city is roughly US$ 900 per year, and around 30% of the population lives in poverty, with limited access to transportation (Ahmed, 2012).

Physically, the city has not grown much and has remained largely confined within the boundaries of the Buriganga River on the south, the Turag River on the west, the Tongi Khal on the north, and the Balu River on the east (N. Hossain, et al., 2009). Despite the fact that it is bordered by four rivers, which could have offered a natural facility for the operation of circular canals, it was never completed due to budget restrictions and a lack of adequate planning for inter-connectivity among other modes. Sadarghat is the main waterway terminal, and offers mainly trips outside Dhaka. Water bus services run along the Buriganga River as well as the Hatirjheel and Gulshan lakes. The Buriganga River's water buses transport passengers along the Sadarghat-Gabtali route (News, 2010). The Hatirjheel and Gulshan Lakes Water Taxi offers connecting routes through two routes, one from Tajgaon to Gulshan and the other from Tejgaon to Rampura (Bdnews24, 2016).

Dhaka relies on its transport system based on roads, however Despite the low level of motorisation, Dhaka has a significant and deteriorated traffic congestion, mainly due to the absolute lack of roads, poor road network design and inadequate traffic management ((JBIC), 2000). Road networks of Dhaka mainly includes primary roads, secondary roads, collector roads, and access roads which have the length 199 km, 109 km, 152 km, and 2,540 km respectively (Alam & K. M. N. Habib, 2003). Dhaka's transport network comprises approximately 1868 km of highways and 163 km of sidewalks (Sultana, 2013). A few links are added yearly but not up to the mark. Over the decade from 1995, for example, 5% of roads were created, while the population rose by 50% and traffic increased by 134 percent (Rahman, 2008). Ideally, roads should take about 25% of the surface area, but in the case of Dhaka only 8% (Andaleeb, et al., 2007). With many broken connections causing serious connectivity problems, the roads are usually operated without control to allow direct access for vehicles from bogged lands. The road network is very irregular. In a city with a population of more than 10 million, it is unusual for Dhaka not be able to move an enormous number of people with high frequencies in any form of Mass Rapid Transit (MRT) (Hossain, 2004). There are 9311 registered busses and 8459 registered mini buses in the City of Dhaka (BRTA, 2018), which are the main type of mass transit systems in 170 different routes (BRTA, 2014). On a few selected routes serving a small portion of the city, the Bangladesh Road Transport Corporation (BRTC), a government body which has limited resources, operates busses. The privately owned and operated bus companies are disorganized and dispersed. The absence of correct bus and bus stops leads to traffic jams. Again, busses in Dhaka are generally considered unlikely to reach their destination and are time consuming (Hoque et al., 2012).

Railways are one of the oldest modes of public transportation, having initially been introduced in this country on November 15, 1862 (then British India) (Anon., 2014). However, as time passed, the country's partition and later Bangladesh's independence had a significant impact on the region's railway system. While the rail system was very popular and is still a relatively safer and cheaper transport system, it has been unable to play the expected role on the Dhaka public transport system without the proper initiatives and investments in the urban corridor. In addition, railway tracks run across the CBD and congested areas of the city with a lot of crossing level leading to huge congestion. In the Dhaka metropolitan city, there are 8 railway stations (Anon., 2013), although most trains do not stop at every station and are overcrowded by interstate passengers, city people may find it difficult to use.

Condition of Bus Services in Dhaka City

There are two types of bus services accessible in Dhaka namely counter bus service and local bus service. The counter bus service has designated stops for passenger boarding and alighting, and tickets are sold at the counters of certain stops. Passengers must purchase tickets at bus counters only before boarding the bus for such buses. Only a few of the counter buses are air-conditioned. Local bus service, on the other hand, has no set halt (customers can board and disembark at any point along the route) and passengers pay the fair fare to the bus conductor on the bus (after boarding). Both types of buses are frequently overcrowded, owing to a demand-supply discrepancy. However, there are a few seating services buses that operate on limited routes and only allow passengers to board if there is an empty seat available. These buses also board and alight passengers at designated stations (although some buses let passengers to alight wherever they wish), and passengers must pay for their tickets inside the bus. On an average there are 40 seats in a bus among them, only 9 seats on each bus have been set aside for female passengers, but no such seats have been set out for disabled or senior individuals. However, the current bus system's level of service is insufficient to meet public demand (Hasine, 2011). In terms of security, capacity, comfort, and convenience, Dhaka City is insufficient. Buses are also regarded as unreliable and time-consuming modes of transportation (Hoque, et al., 2012). In addition, insufficient light and air, entry and departure problems, a lack of discipline, and technical obstacles such as inadequate terminals and bus stops, the absence of distinct bus lanes, or even a bus accident are all too common in Dhaka. Excessive traffic delays exacerbate the situation, and passengers suffer considerably during peak periods as a result. It is clear that the current bus service is insufficient to meet the increasing demand for passengers.

GHG Emission from the Transportation System in Urban Areas

Carbon dioxide (CO_2) emissions from road transportation have received special attention due to their steadily increasing trend (Nejadkoorki, et al., 2008). CO_2 accounts for over 82 percent of GHG emissions, with the transportation sector contributing a significant amount (Triantafyllidis, et al., 2018). Although some industrialized and fast-growing countries have been able to minimize CO_2 emissions from the transportation sector through the use of environment friendly technologies and the execution of regulations and plans, many developing countries have fallen far behind (S.M. Labib et al, 2018). Previously transportation sector was not account for the majority of CO_2 emissions. But in 2008, road emissions accounted for 80% of overall emissions in the transportation sector and that has continuously climbed since then. Cities produced around 75% of global net CO_2 emissions, with intra-urban transportation accounting for 17.5 percent of those emissions (Fan & Lei, 2016). According to BPC data, the total annual petroleum product consumption is around 3.78 million metric tons (MT), with 2.03 million MT going to the transportation sector. The transportation sector accounts for around 54% of overall petroleum product consumption in Bangladesh, which is 2.5 times larger than the agricultural sector and 18 times higher than the industrial sector (BPC, 2008). The daily usage of petroleum products in transport sector of Dhaka city has been reported as diesel 526.04 thousand-liter, octane 175.97 thousand liter, and petrol 23.12 thousand liter (BPC, 2008). It is alarming that there is an increase in fuel consumption which is also the indication of the increase in GHG emission rates. Moreover, diesel, octane, and gasoline in Bangladesh are not as clean as in other affluent countries. In Bangladesh, gasoline contains 0.84 mg per litre of lead, which is added at refineries to improve anti-knock effectiveness and thereby adds to lead pollution. Because of low fuel quality utilized in motorized vehicles and inadequate local air quality management, people are suffering from a variety of health problems as a result of air pollution. As a result, for local air quality control, the proper implementation of policy guideline is required.

Due to the poor status of public transportation system in Dhaka and also to improve the air quality, various ideas are being proposed. The Dhaka Transport Coordination Authority was established by the Bangladesh government in 1998. In 2008, the government commissioned a comprehensive transport plan known as the Strategic Transport Plan (STP) for Greater Dhaka City and its surrounding districts. Safety, pedestrian preferences, public transportation, non-motorized transportation, travel demand management, mass transit systems, and other Key Policy concerns were all examined in the plan. Ten comprehensive transportation options were reviewed from 70 different policy recommendations under the STP (DMTCL, 2019). The introduction of better bus service, such as Bus Rapid Transit (BRT), Light Rail Transit (LRT), and Metro. In BRT, Buses with a high capacity and frequent service use dedicated lanes on the road and are given precedence at intersections (Hoque & Hossain, 2004). LRT vehicles operate on completely segregated tracks with grade-separated right-of-ways (Rahman, 2008). This system's trucks and rails are lighter than typical railway vehicles and tracks (Hoque & Hossain, 2004). Government of Bangladesh has set a schedule for constructing a road network that includes six updated metro rail lines under the Dhaka Mass Transit Company Limited (DMTCL) as illustrated in Table 1. The project's goals are to reduce traffic congestion and improve air quality in Dhaka City by building a mass rapid transit system, thereby contributing to the economic and social development of Dhaka city and also to improve the urban environment. It has long been proposed for, along with a separate light rapid transit (LRT) system, to help ease the daily traffic jams and congestion that plague the city, making it one of the most congested in the world. It is part of the Dhaka Transport Coordination Authority's (DTCA) 20-year Strategic Transport Plan (STP) (DMTCL, 2019). The overall length of the network will be 128.741 kilometers, with 67.569 kilometers of elevated railway and 61.172 kilometers of underground railway as shown in Table 1. There will be a total of 104 stations in this project (elevated stations 51 and underground stations 53) (DMTCL, 2019). The metro rail project is expected to cost Tk 21,985.07 crore. The Japan International Cooperation Agency (JICA) would provide project funding of Tk 16,594.59 crore. Rest will be provided by Government of Bangladesh (DMTCL, 2019).

This paper will represent the curtailment of the GHG gas emission in future due to implementation of Metrorail service by analyzing the current emissions from conventional bus service in Dhaka city. Different methods for measuring CO2 emissions have been utilized in previous studies. One approach estimates the rate of CO2 emissions based on vehicle type and speed (Gharineiat & Khalfan, 2011), while another method calculates the rate of CO2 emissions based on the amount of fuel consumed and the distance traveled (Kan & Tang, 2018).

Air quality monitoring tools can also be used to measure CO_2 emissions (Obanya, et al., 2018). In order to acquire a more precise measurement, researchers used a variety of methodologies to compute CO_2 emissions. In terms of data, time, and measuring cost, each of these methods offers advantages and downsides (Gharineiat & Khalfan, 2011). In this paper, GHG emission from the vehicular activities will be calculated by using Vehicles Miles Travelled Data (Breisinger, 2012). It is also known as distance travelled method where the individual travel distance is multiplied by the CO_2 emissions factor of the transport mode. This is a rather simple model that has been utilized in a number of applications (Yuan-yuan, et al., 2015).

TABLE 1. Basic Information on MRT Lines. After: **(DMTCL, 2020)**

Serial No	**MRT Line Name**	**Phase**	**Length (Km)**			**Number of Stations**		**Probable Time of Completion**
			Elevated	Underground	Total	Elevated	Underground	
1.	MRT LINE-6	1st	20.10	-	20.10	16	-	2024
2.	MRT LINE-1	2nd	11.369	19.872	31.241	7	14	2026
3.	MRT LINE-5: Northern Route	2nd	20.00	6.50	13.50	5	9	2028
4.	MRT LINE-5: Southern Route	2nd	4.60	12.80	17.40	4	12	2030
5.	MRT LINE-2	3rd	9.00	15.00	24.00	4	18	2030
6.	MRT LINE-4	3rd	16.00	-	16.00	15	-	2030

METHODOLOGY

In this paper, the current situation of GHG emission from the available modes of transportation is represented and compared with scenario after the implementation of metro rail service. The method followed are selection of study area, collection of data from primary and secondary sources and analysis. The model used for the estimation of GHG emission from transportation facilities as well as proposed metro rail system of Bangladesh is represented. Primary data are collected from site visit, field survey, questionnaire survey and personal communication. Secondary data are collected from electronic assessment of the literature, which included journals, books, reports from an international organization, and articles. The publications were discovered in the Science Direct, Elsevier, and Google Scholar databases, as well as the Google database using keywords: CO_2 emissions; greenhouse gases; CO_2 emissions from transportation etc. For the data required for Metrorail in Bangladesh, the website of DMTCL was used.

Study Area

The study was done basically on Mass Transit Line-6 (MRT Line-6). To deal with rising traffic demand and congestion, as well as a lack of adequate public transportation in the Dhaka metropolitan area, the MRT Line-6 project was prioritized and decided to be built in the first phase. The MRT Line-6 will travel from Uttara to Motijheel and serve 16 stops along the way once it is completed. MRT Line-6 runs from Uttara 3rd Phase to Bangladesh Bank through Pallabi, Rokeya Sarani, Khamar Bari, Farm Gate, Hotel Sonargaon, TSC, Doyel Chattar, and Topkhana Road as shown in Figure 1. On February 20, 2013, the Government of Bangladesh and the Japan International Cooperation Agency signed a $2.8 billion deal for the construction of line-6 (DMTCL, 2019). Line profile is shown in Table 2. Till Actober 31, 2021 the average progress is 72%, progress in the construction work from Uttara third Phase to Agargaon is 89.61%, Agargaon to Motijheel 70.57% and progress in collection of electrical and mechanical equipments is 67.01% (DMTCL, 2021). Again Bangladesh conducted first trial for the metro rail in 11 May, 2021 (Metrorailnews, 2021). The MRT Line-6 will use a total of 24 trains with 144 carriages. By 2022, the Dhaka Metro is expected to service more over 60,000 people per hour, with average wait times of 4 minutes. The full route will be able to be completed in under 40 minutes at a speed of 100 km/h (62 mph), reducing the number of private cars on Dhaka's streets and potentially avoiding 7-hour-long traffic jams. On an average, MRT Line-6 will serve 483,000 passengers per day (DMTCL, 2019). For everyday operation, metro rail will require 160 megawatts of electricity.

Model Used

For CO_2 emission due to electricity generation to operate metro rail, Model Equation (1) was used. In order to calculate the amount of GHG emission by currently available mode of transport Model Equation (2) was used (Breisinger, 2012).

$$CO_2\ \textit{emission (t): Annual Amount of Electricity Required (KWh/yr)} \times \textit{Amount of } CO_2 \textit{ created per kWh} \quad (1)$$

$$CO_2\ \textit{emission (t):} \sum_i \textit{[(Total Distance travelled by vehicle type (Km/yr)} \times gCO_2 \textit{ Vehicle type } EF_1) + \textit{(Total Distance travelled by vehicle type (Km/yr)} \times gCH_4 \textit{ Vehicle type } EF_1 \times 25) + \textit{(Total Distance travelled by vehicle type (Km/yr)} \times gN_2O \textit{ Vehicle type } EF_1 \times 298)] \div 1000000 \quad (2)$$

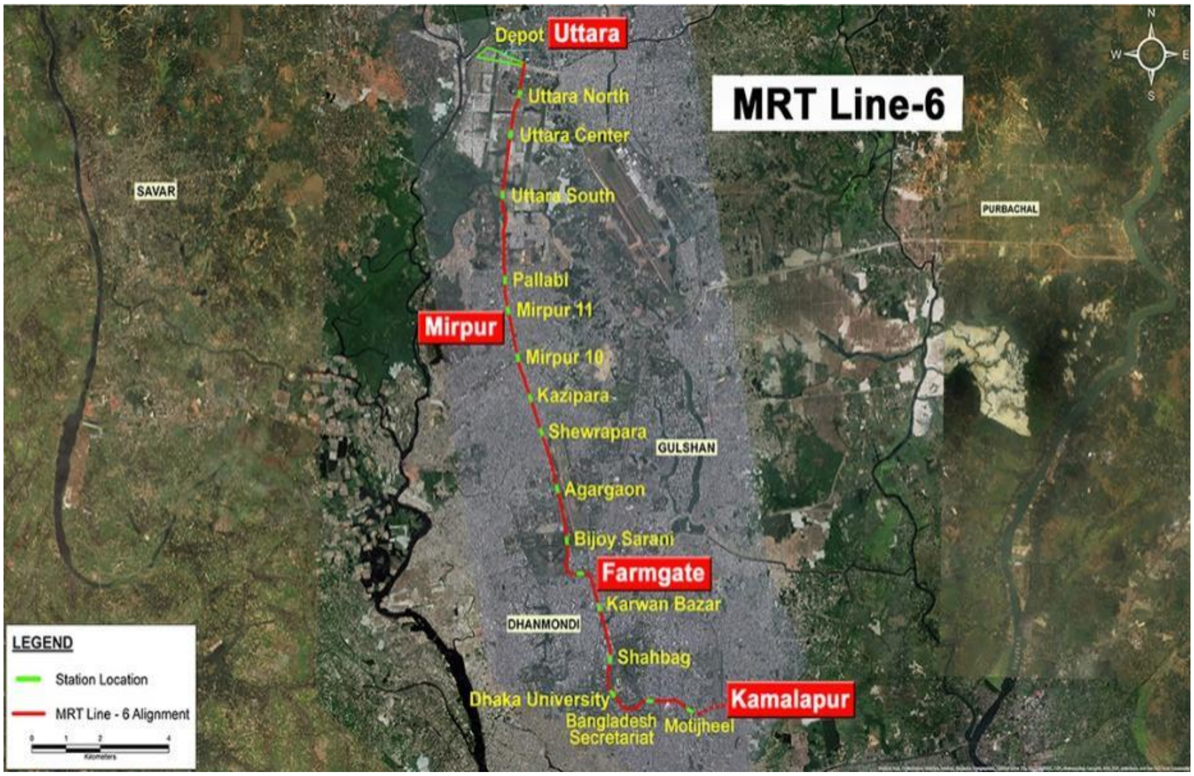

FIGURE 1. Route map for MRT Line-6. Source: **(DMTCL, 2020)**

TABLE 2. Line Profile of MRT Line-6. After: **(DMTCL, 2020)**

No.	Item	Specification
1	Truck Gauge	1435mm
2	Minimum curve radius on a main track	160m
3	Steepest gradient in a running area of Rolling Stock	35/1000
4	Design speed	110 Km/hr
5	**Maximum train operating speed** At the elevated section and At the underground section	 100 Km/hr 90 Km/hr
6	The train loading for civil structure	16 tons/axle

The required Default value of EF for application in Model Equation (2) is provided in Table 3.

TABLE 3. Default EF Values per Vehicle Type. After: **(Breisinger, 2012)**

CO_2 Emissions	g CO_2/mile	gCH_4/mile	g N_2O/mile
Motorcycle	57.7875208	0.0672	0.0069
New small gas/electric Hybrid	62.1992563	N/A	N/A
Gasoline light dutyAutomobile	144.088212	0.0704	0.0647
LPG light dutyAutomobile	165.284737	0.037	0.067
Diesel light duty Automobile	144.779487	0.0005	0.001
Gasoline vans & pickup Truck	196.151351	0.0813	0.1035

CO_2 Emissions	g CO_2/mile	gCH_4/mile	g N_2O/mile
Gasoline light Truck	248.548476	N/A	N/A
Diesel light truck	232.392825	0.0011	0.0017
Gasoline heavyTruck	574.146981	0.3246	0.1142
Diesel heavy truck	540.592937	0.0051	0.0048
Diesel bus	642.877670	N/A	N/A

Collection of Primary Data

From the previous study it is clear that MRT Line-6 will serve 483,000 passengers daily (DMTCL, 2019) and 80MW or 80×10^3 KW electricity will be required to operate metro rail. For using Model Equation (1) amount of CO_2 created per KWh is required. According to a study, the amount of CO_2 created per kWh of electricity generated in Bangladesh is around 0.64 kg (Das et al., 2017). In order to use Model Equation (2) and thus estimating the curtailment of GHG emission by Metrorail, it is required to know about currently available modes of transport in the study area, average using rate of these mode by the passengers, passenger carrying capacity of each mode of transport thus calculating the number of trips required.

A field survey was done to determine the available modes of transport and capacity of each mode whose outcome is tabulated in Table 4. As the capacity of various bus services varies, an average bus capacity has been used to reduce computation complexity. The average bus capacity was calculated by averaging the seat capacities of the five bus services that travel to Shahbag via Agargaon, Bijoy Sarani and Farmgate.

In order to achieve the research goal, passengers were asked to complete a questionnaire survey in order to know which mode of transportation they preferred. A total of one thousand (1000) passengers were interviewed at random. The survey was conducted in five key locations: Agargaon, Bijoy Sarani Farmgate, Karwan Bazar and Shahbag. In September 2021, passengers were interviewed between the hours of 7:00 a.m. and 5:00 p.m. on weekdays and weekends. The response of individuals are represented in Table 5. After assembling all the required data, number of trips required by each mode to carry 483,000 passengers based on their average using rate was calculated. Then distance travelled by each mode was calculated by using trip numbers and distance between origin and destination (21.4 Km in roadway). Model Equation (2) and Table 3 was used for the calculation of annual emission of GHG by these current modes.

DISCUSSION

The data of the capacity of bus service are presented in Table 4. In order to calculate the number of trip, the capacity of each mode is required to be known. Other modes have a more or less specified passenger carrying capacity. But, there are buses of various capacity running from Uttara to Motijheel point or vice-versa. So, a field survey was done to determine the capacity of bus services available in the study area and by averaging the seat capacities, an average capacity value was used due to simplicity of calculation.

TABLE 4. Average Capacity of Bus

Bus Service	Seat Capacity
VIP 27	50
Trust Transport Service	45
Lal Sobuj AC Bus	30
BRTC Bus Service	50
Mirpur Link	45
Average	210/5=42

A brief calculation of CO_2 emission (t) from transport facilities is represented in Table 5. Here, using rate of each mode was determined from the questionnaire survey as described before. The center of attention is that to calculate the number of trips required by the currently available modes to pass the equal amount of passenger which will be served by metro rail and thus calculate the distance traveled in Kilometer per year. The number of trips is at first calculated and then multiplied by 21.4 which is the distance between Uttara and Motijheel by roadway in Km. Then CO2 emission is calculated by using Model Equation (2) and Table 3.

TABLE 5. Calculation of GHG emission from Various Transportation Mode.

Mode of Transport (1)	**Using Rate (%) (2)**	**Capacity (No's) (3)**	**Passengers Served (No's) (4) (2)×483,000**	**No. of Trips Required (No's) (5) (4)÷(3)**	**Total Distance Travelled (Km/yr) (6) (5) × 21.4× 365**	**CO_2 Emission (t) From Equation (1)**
Bus	60	42	289800	6900	53895900	34649
Walking	17	-	-	-	-	-
CNG/Auto Rickshaw	10	3	48300	16100	125757100	23413
Tempo/Leguna	4	14	19320	1380	10779180	1564
Taxi/Car	4	4	19320	4830	37727130	6230
Rickshaw	3	-	-	-	-	
Motor Cycle	2	2	9660	4830	37727130	5474
Total						**71,330**

Now, from Model Equation (1), Emission from metro rail is = (80×10^3) KW×365 × (0.64×10^{-3}) t =**18,688 ton.**

CONCLUSIONS

This article examines potential for the development of mass transit railway systems in the Dhaka metropolitan area, with the goal of reducing GHG emissions. From the study, it has been found that the available transportation modes in the study area emits about 71,330 tons of GHG annually as CO_2. On the other hand, emission of CO_2 due to the operation of metro rail is only about 18,688 ton per year. So, if the metro rail is implemented which is electrically operated, then there will be the approximate curtailment of 52,642 tons of GHG in Uttara to Motijheel point as estimated by using Model Equation 1 and 2. From the findings, it is noticeable that, when Dhaka city will be covered totally by Metrorail system then it will bring a positive changes both in the view of fuel consumption and GHG emission. As a result, replacing buses with Metrorail in any specified route is becoming the norm. Residents and passengers in the city should heartily welcome the Metrorail system.

This study only reflects the phenomenon of area surrounding MRT Line-6. Due to unavailability of authorized data of this ongoing project, it was impossible to represent the phenomenon of entire Dhaka city. For further study, overall GHG emission will be estimated for three different scenarios: running year (datum case), forecasted year without metro-rail and forecasted year with metro-rail and then changes will be shown which may help individuals to realize the impact of metro-rail on improvement of air quality.

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