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Low Emission Scenarios Analysis In the Urban Transportation In Dhaka, Bangladesh

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Abstract: *For city residents, a sustainable city with sustainable mobility is now the most desired feature. This is a crucial necessity, especially for numerous places like Dhaka. Bangladesh's capital is Dhaka. It is the economic, cultural, and political hub of the country. Transportation expansion is outpacing the city's ability to sustain itself. Dhaka's transportation industry is one of the city's biggest contributors to GHG (greenhouse gas) and other air pollutants. The two low-emission scenarios for Dhaka's transportation sector are analyzed in this paper. This article discusses the co-benefits of Bangladesh's CNG regulations, as well as the willingness and impact of utilizing more non-motorized vehicles on the environment. It also emphasizes how much emissions we may minimize and future regulations for sustainable transportation in Dhaka.*

Keywords: CNG conversion; Low Fuel price; Co benefit assessment; Nonmotorized Vehicles; Logistic regression

1. INTRODUCTION

Economic, social, and environmental sustainability are the three main dimensions of sustainability. One of the most important parts of a sustainable city's concept is its transportation system. Transportation policy and people's travel patterns have significant implications for a country's social, economic, and environmental growth. Transportation is one of the most significant sources of pollution. This sector accounts for 24% of all direct CO_2 emissions. Road vehicle accounts for roughly three-quarters of all CO_2 emissions from transportation.

Dhaka is one of the world's most densely inhabited cities, with a population of 22.4 million and poor air quality. Dhaka's urban population is growing because of its status as the capital. The city's living conditions and work prospects are concentrated; hence, Dhaka is experiencing significant migratory pressure. The road network in Dhaka is around 3,000 kilometers long. There are 200 kilometers of principal road, 110 kilometers of secondary road, 50 kilometers of feeder road, and 2,640 kilometers of narrow road with few alternatives(Alam, 2018). The bus is the city's primary means of public transportation, carrying almost 1.9 million passengers every day. Public buses are unreliable, insufficient, slow, overcrowded, and dangerous, and fail to meet passenger demand. For women and the mobility-impaired, public buses and other modes of transportation could not provide secure, safe, and comfortable travel. The "BD Cyclists," a youthful social organization that managed to shift people's attention to the benefits of cycling, were primarily responsible for the cycle revolution. According to the same analysis, the group had significant success in 2014, with about 3.5 times more bicycle units sold than the previous year. Despite the fact that no metropolitan road has an official cycle lane, a survey from 2014 indicated that many people ride for their daily work travels, even if they are longer than 5 kilometers, in order to save time and money. The abundance of roadside sellers and hazardous objects along the tiny sidewalks makes pedestrians feel unsafe and uneasy. The leading causes of seriously exceeding air and noise pollution in the city include low fuel quality, congestion, poor road conditions, old and poorly maintained automobiles, and a lack of public awareness.

The city government has enacted various initiatives to improve traffic flow, management, and air quality. The adverse impact of air pollution on human health and welfare in Dhaka drew widespread media and public attention in 1990, resulting in a more substantial government commitment to decreasing air pollution and implementing the CNG (Compressed Natural Gas) fuel switch initiative. In 2010, CNG was used by over 83 percent of the cars surveyed. CNG buses and minibusses accounted for more than 70% of all buses and minibusses. This accounts for almost 75% of Dhaka motor vehicles (excluding motorcycles) (Wadud, 2014). CNG conversion was mandated for all government vehicles. The effect of CNG vehicles' lower fuel prices, was important to stimulate fuel switching behavior.

Following the above discussion, this paper aims to evaluate the environmental benefits of two scenarios of CNG vehicle-fleet and nonmotorized transportation in Dhaka.

The rest of this article is organized as follows: Section 2 shows the model development for both scenarios. The effect assessment model for CNG vehicles is shown in subsection 2.1 and subsection 2.2, the willingness assessment model for nonmotorized vehicles. Section 3 discusses the results. In Subsection 3.1, we discuss the result of the impact of CNG vehicles, and in 3.2, the result of the nonmotorized transport scenario. Finally, the conclusion and references are presented in sections 4 and 5, respectively.

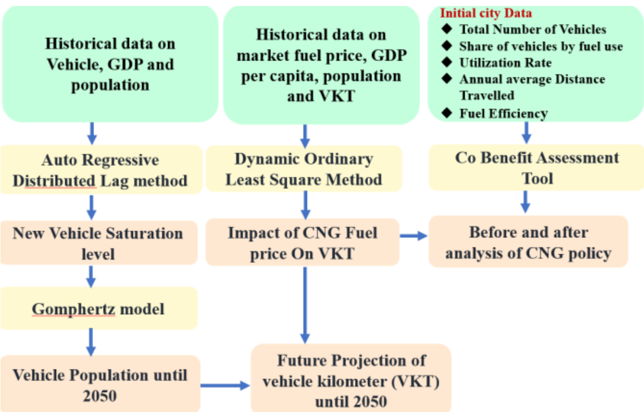

Fig. 1. Calculation steps used in the CNG vehicle impact assessment model

2. Methodology and Materials

2.1. CNG vehicle impact assessment model

The main steps of the research methodology used in analyzing the CNG vehicle scenario are shown in Figure 1. There are three steps to the research process. First, a new saturation level for CNG-fueled vehicles is estimated using the autoregressive distributed lag approach, and the vehicle population is calculated using the Gompertz model until 2050. The avoided emissions from replacing petrol and diesel-fueled cars with CNG until 2050 are also computed using a future VKT (Vehicle Kilometre Travel) projection. The impact of lower fuel prices on VKT is calculated using the distributed ordinary least square approach. Finally, the environmental impact of introducing the CNG policy of the Bangladesh Government will be evaluated.

The forecasting of CNG vehicles is essential for policy planning and analysis. The simple linear or polynomial data fitting theory underpins general prediction algorithms. They are straightforward and need simple calculations, but they are limited in prediction time. With the lengthening of the prediction time, more errors will be produced. Basic linear or polynomial data fitting approaches cannot reflect the system's fundamental development law. The main disadvantage of the logarithm model is that the elasticity coefficient is fixed and does not modify the position of the demand curve. Gompertz's model is more adaptable. It can, for example, allow for distinct curvatures to exist at different phases. The Gompertz curve is an S-shaped curve that estimates automotive growth in three phases: a slow growth period at the start (when economic levels are low), a boom time, and a saturated period (when vehicle population growth approaches the saturation level). GDP per capita is a key determinant in explaining the Gompertz, as follows:

$$V_{i=}Ve^{\delta e^{\mu GDP_i}} \quad (1)$$

Where,

V_i = Vehicles in use in the year i (vehicles per 1000 people)

V = Ultimate saturation level of vehicle ownership (Vehicles per 1000 people)

δ *and* μ = The two parameters that determine the shape of the S- shape curve of vehicle ownership growth over economic growth

This function predicts the vehicle ownership per 1000 people based on GDP per capita. On the basis of economic growth, the Gompertz function predicts automobile ownership per 1000 persons. As a result, based on the projected total population, the total motor vehicle stock in the city can be estimated using the projected automobiles per 1000 inhabitants. The model database includes 32 years of time series data, where the data on vehicles was collected from the BRTA [(Bangladesh Road Transport Authority, 2020)], and the data on GDP and population were collected from the World Development Indicator Database (World bank, 2020).

In this study, in order to estimate the ultimate saturation level of vehicle ownership (V), the multivariate dynamic regression approach was developed to estimate the upper limit of vehicle ownership in 2050 (Li et al., 2014).

$$lnV_t = \kappa + \sum_{i=1}^{l} \alpha_i lnV_{t-i} + \sum_{j=0}^{m} \beta_j \ln GDP_{t-j} + \sum_{k=0}^{n} \gamma_k lnP_{t-k} + \varepsilon_t \quad (2)$$

Where,

V = Number of vehicles,

GDP = GDP per capita,

P = population,

α, β, ϒ, k = parameters.

To solve the above regression model, the ARDL method was employed due to appropriate lag selection, and residual correlation. The ARDL approach gives unbiased results. The ability to host enough lags allows for the most accurate capture of the data generated by the process mechanism. The unit root test is the most significant part of the ARDL analysis. It provides information on the level of integration of each variable. Each variable must be I (0) or I (1) to satisfy the bound test assumption of the ARDL models. It should also be mentioned that the dependent variables should be I (1). The time series is I(o), which means that it is stationary at levels, I (1) means stationary at first difference.

Car ownership in Bangladesh has not increased due to CNG conversion. CNG is less expensive than diesel and gasoline. Therefore, Vehicle-Kilometer (VKT) is affected by lower fuel prices. The influence of the economic growth, fuel prices, and other demographic parameters on VKT was analyzed, using DOLS (Dynamic Ordinary Least Square) method as follows:

$$lnVKT = \beta_1 \ln PR + \beta_2 lnGDP + \beta_3 lnP + \varepsilon_t \quad (3)$$

Here,

VKT = vehicle kilometer travel,

PR = Fuel price (petrol),

GDP = GDP per capita,

P = population.

To analyze the effects, we take into account two different fuel prices. The cost of CNG fuel is another option using the same method.

$$lnVKT = \beta_1 lnCNG + \beta_2 lnGDP + \beta_3 lnP + \varepsilon_t \quad (4)$$

Here,

VKT = Vehicle Kilometre Travel,

CNG = Fuel price of CNG,

GDP = GDP per Capita,

P = Population.

VKT is calculated, and other data are from the world bank database (World bank, 2020).

The environmental changes after implementing the CNG policy were quantified, using the ASIF Framework, which calculates emissions by each mode according to the following formula:

$$\sum_{Modes} A * S * I * F \quad (5)$$

A = Total travel demand in passenger kilometers,

A defined as $\sum Vehicles * Utilization\ Rate * Annual\ distance\ travel * Occupancy\ rate$,

S = Percent share of each mode; Calculated from A,

I = Intensity of the mode defined as:

$I = \frac{1}{Fuel\ efficiency * Occupancy\ rate}$,

F = Emission factor for each pollutant for each fuel.

2.2. Nonmotorized transport willingness assessment model:

In this analysis, a comparison between Japan bicycling scenario and Bangladesh bicycling scenario has been conducted. PKM (passenger Kilometers) of bicycling is used as a dependent variable and observe the impact of different factors on dependent variables for both Japan and Bangladesh. The coefficients for bicycle trips in Japan are also used for Bangladesh. PKM indicates passenger mobility. The number of bicycle users of middle income, travel cost, the number of bicycle users from students, and the number of bicycle users from employees is considered as dependent variables, as explained in the following regression model:

$$PKM = \beta_1 MI + \beta_2 TC + \beta_3 ST + \beta_4 EM \qquad (6)$$

Here,
PKM = is the value of the utility of cycling,
β = is the coefficient of the independent parameter,
MI = the number of bicycle users of medium-income,
TC = Travel cost,
ST = number of bicycle users from students,
EM = number of bicycle users of employees.
The fully Modified Ordinary Least Square Method (FMOLS) is used for analysis. The time-series data (from 2000 to 2020) of each variable are taken (Bangladesh Road Transport Authority, 2020)(Japan, 2020). The FMOLS method produces reliable estimates for small size and checks for the robustness of the results. This method was originally introduced and developed by Phillips and Hansen for estimating a single co-integrated relationship that has a combination of I (1) (Hansen & Phillips, 1990).
An appropriate supply of facilities for non-motorized vehicles is required but motivating people to use them is a considerable issue. Comfort is the primary issue, although other factors such as age, gender, socioeconomic status, journey distance, rainfall, road laying pattern, social awareness, and driving cost have also been found to impact the decision. A binary logistic model is used to analyze the willingness to use nonmotorized vehicles:

$$P = \frac{1}{1+e^{-Z}} \qquad (7)$$

The model can be estimated by ordinary least square,

$$ln\left[\frac{P}{1-P}\right] = Z = \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad (8)$$

Where,
P = proportion of individuals who wants to use cycle,
Z = represents the relative attractiveness of cycling,
β = the coefficient of each independent variable of X,
e = Natural log.
To analyze the willingness to utilize nonmotorized, The five following parameters are considered:
1. Age
2. Having a Driving license
3. Income range
4. Travel mode for mandatory trips
5. Travel mode for non-mandatory
To analyze the willingness to use nonmotorized vehicles questionnaire was prepared to collect data. 122 people participated in that survey.

3. Results and Discussion

3.1. CNG vehicle scenario analysis

Table 1 shows the unit root test result for Eq. (2). All variables are stationary at first difference. The lags are selected based on the smallest number of Akaike Information Criteria (AIC). Table 2 shows the result of ARDL.

Table 1. Result of Unit Root Test

Variables	p-Value (1st difference)	t-stat (1st difference)	Result
Number of Vehicles(lnV)	0.01<0.05	-3.6	Stationary
Ln GDP	0.2<0.05	-3.2	Stationary
Population (lnP)	0.25>0.05	-2.0	Stationary

Table 2. The result of ARDL

Variables	Coefficient	p-Value
LNV(-1)	0.74	0.0007<0.05
LNV(-2)	-0.08	0.68>0.05
LNP	0.99	0.11>0.05
LNGDP	0.1	0.08>0.05
C	-15.01	0.13>0.05
R-Squared 0.993	Adjusted R-Squared 0.992	Durbin-Watson stat 2.019

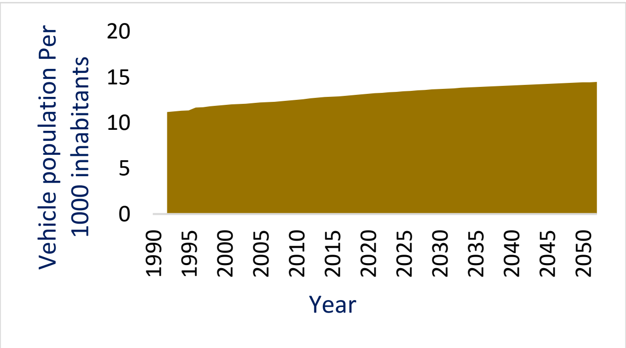

Fig. 2. Saturation Level of the vehicle population in Dhaka

From Table 2, It is noted that, the coefficient of the number of vehicles and GDP are significant, the R-square is 0.993 and the adjusted R-Squared is 0.922, which indicates the fitness of the model. Durbin-Watson stat is also in range. Using these coefficients, we calculate the new saturation level of 14.48 per 1000 inhabitants. Fig.2 shows the saturation level of the vehicle population of Dhaka city.
Based on the result shown in Fig (2), three saturation levels were used as the input values in the Gompertz equation (1) as low, mid, and high levels. The regression

results for three saturation levels are shown in Table 3. For the three levels, all coefficients are significant, and R-squared is 0.99.

Table 3. Results of the Gophertz Model

Variables	Coefficient	p-Value	
δ	1.13	<0.05	Low saturation level
μ	-0.00039	<0.05	
δ	1.2	<0.05	Mid saturation level
μ	-0.00036	<0.05	
δ	1.28	<0.05	High saturation level
μ	-0.00032	<0.05	

Fig. 3. shows the future projection of CNG run vehicles per 1000 inhabitants until 2050.In Fig.3 it shows the CNG vehicle ownership per 1000 inhabitants for three saturation level until 2050. In the lower satruration level 17 vehicles per1000 inhabitants and 28 vehicles per 1000 inhabitants for 1000 inhabitants. In medium saturation level it shows 21 CNG vehicles owner per 1000 inhabitants. This prediction is very important to understand the present situation and to make the future policies. Also, its easy to get clear idea about the emissions and future emissions also.

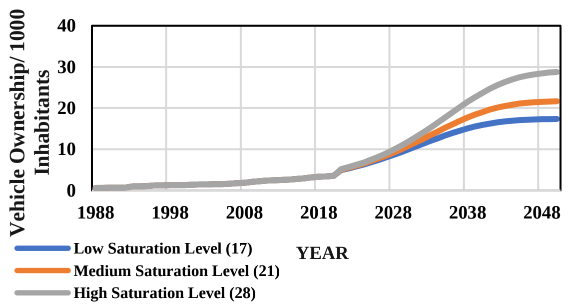

Fig. 3. Future projection of CNG run vehicles using the Gompertz equation

The impact of lower fuel prices on VKT was evaluated, using Eq. (3) and (4). Table 4 shows the result of the unit root test of each variable.

The result of selecting the optimal lag selection is shown in Table 5.

Table 6 shows the estimated regression coefficients for both fuel prices, which are significant in both cases. R-squared and adjusted R- Squared are 0.99 in both cases. The coefficient of gasoline price (LNPR) is -0.035063, and the P-value is noteworthy. If we lower the price of petrol by 1%, the VKT will rise by 0.3%. The coefficient of CNG fuel price is -0.223249, with a substantial P-value. It means that if we lower the price by 1%, VKT will rise by 0.22 percent.

VKT has increased by 0.19 percent when CNG is used as a fuel. After analyzing the entire VKT of Dhaka, we observed that it has increased by 2.42 percent since 2001. As a result, it can be concluded that lower gasoline prices raise VKT. Self-selection is indicated by the difference in driving distances. Converting to CNG has a significant influence on reducing pollution. CNG conversion helped to reduce air pollution in Dhaka city, which had been extremely bad. 70% of buses and 83 percent of vehicles in Dhaka have been converted to CNG fuel. The VKT increased by 2.42 percent as a result.

Table 4. Result of Unit root test

Variables	p-Value (1st difference)	t-stat (1st difference)	Result
LNVKT	0.07>0.05	-3.1	Nonstationary
Ln GDP Population (ln P)	0.02<0.05	-5.96	Stationary
LNPR (Fuel price)	0.001<0.05	-5.7	Stationary
LNCNG	0.002<0.05	-5.52	Stationary

Table 5 : Result of selecting the optimal lag selection *(Lowest Value of Akaike Information Criteria)

	Lag	AIC
For petrol price	0	-10.52
	1	-24.93*
For CNG fuel price	0	-10.52
	1	-24.93*

Table 6: Estimation of the regression coefficients for both fuel price

	Variables	Coefficient	p-Value
For CNG fuel price	LNCNG	-0.22	0.000<0.05
	LNGDP	0.32	0.00<0.05
	LNP	3.54	0.04<0.05
	C	-45.92	0.06>0.05
For petrol fuel price	LNPR(Petrol)	-0.03	0.0518<0.05
	LNGDP	0.38	0.00<0.05
	LNP	1.85	0.00<0.05
	C	-14.03	0.078<0.05

The reduction of air pollutants from the implementation of the CNG vehicle scenario is shown in Fig 4. GHG, SO_2, NO_X, PM_{10}, CO, and HC have all decreased by 12%, 61%, 9%, 47%, 6.8%, and 6.2%, respectively.

3.2. Nonmotorized transport scenario analysis

The first section compares cycling in Japan with Bangladesh, intending to demonstrate the environmental benefits of adopting more non-motorized transportation. For nonmotorized vehicles, Equation (6) was used to calculate the impact of variables on PKM. Table 7 shows the result of the unit root test. In the FMOLS method, data must be stationary in 1st difference. Data on the number of bicycle users from students is stationary at level. Others all data are stationary at 1st difference.

Table 8 shows the result of the regression. Except for the number of employees that ride bicycles, the results show that all the independent factors are significant. The trip cost coefficient is negative. The finding indicates that when travel costs rise, the usage of that transport mode decrease.

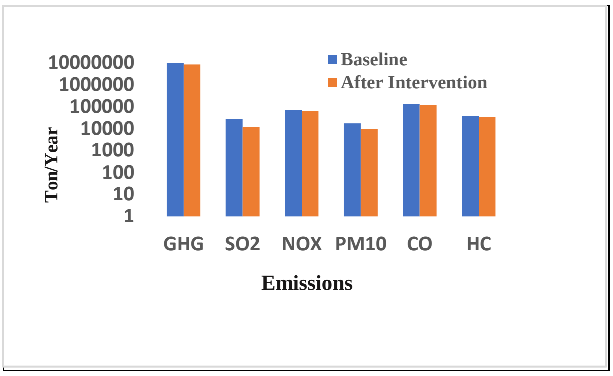

Fig. 4. Air pollutants reduction from the implementation of the CNG vehicle scenario in Dhaka

According to calculations, Japan is using 48 percent more bicycles in 2020 than Bangladesh. On the other hand, the bus is widely used in Bangladesh.

Table 7: Result of the unit root test

Variables	t stat	p-Value	Result (1st difference)
PKM	-5.11	0.01<0.05	Stationary
Monthly Income	-4.07	0.00<0.05	Stationary
Employees	-4.6	0.001<0.05	Stationary
Travel cost	-2.87	0.01<0.5	Stationary

Table 8: The Result of the FMOLS method

Variables	Coefficient	p-Value
Monthly Income	0.002499	0.0002
Employees	7.20E-05	0.3137
Travel cost	-44.896	0.0010
Students	0.001121	0.0279
R -squared	0.9923389	

The impact on the environment was evaluated, considering that, Bangladesh adopts the Japan bicycle scenario and replaces 48 percent of buses with non-motorized vehicles. The year 2020 is used as a starting point. The fleet size of buses has fallen by 81% in the tool in the policy intervention portion of activity change. Fig.5 demonstrates the reduced emissions because of the increased use of non-motorized vehicles. NO_X, PM_{10}, CO, HC, and SO_2 emissions have decreased by 49%, 36%,4.4%, 16%, and 56 %, respectively.
The binary logistic model was used to analyze the willingness to use nonmotorized vehicles based on survey data. A total of 122 replies were received in the data survey. The survey has 41.5 percent female and 58.5 percent male participants. We used three age ranges (5 – 25, 26 – 40, and 41 – 60). 22.4 percent of students, 27.6% of private-sector employees, and 50% of government employees participate in the survey. We consider three income range low (10,000 - 20,000 Taka), mid (21,0000 -40000tk) and high (41,000tk – above). We consider the mean of the income. According to the survey, 52% of respondents want to use nonmotorized vehicles, and 47% do not want to use them. People prefer nonmotorized vehicles for mandatory trips such as going to schools and offices. However, people prefer cars for non-mandatory trips such as shopping or visiting family.

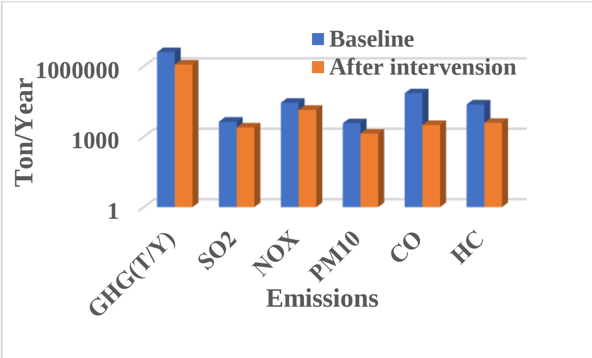

Fig. 5 . The reduction of air pollutants after using more nonmotorized vehicles

The categorical values are: if male 1, woman 0. Consider 1 if the age range is 15-25, 2 if the age range is 26-40, and 3 if the age range is 41-60. Mandatory and non-mandatory travel modes were: 1 if the bus, 2 if cycle, 3 if rickshaw, 4 if car, and 5 if motorcycle. Driving license is 1 if yes, 0 if no. The willingness to use nonmotorized vehicles is 1 if yes and 0 if no. Table 10 shows the result of binary logistic regression. We calculate the odds ratio for willingness to use the nonmotorized vehicle.

Table 9: Result of binary logistic regression

Variables	Coefficient	P-value	Odds ratio
Age	0.1555	0.0001	16%
Driving license	-0.2583	0.7006	22%
Income range	-0.0001	0.000	1%
Travel mode for mandatory trips	0.8265	0.0123	100%
Travel mode for nonmandatory trips	-1.2260	0.0003	70%

From Table 9 the following points can be concluded:

1. For a 1 unit increase in dependent variables (age), the odds of willingness to choose nonmotorized vehicles will increase by 16%.
2. The log of odds of willingness for driving license holders will be 22% lower than those who don't have a driving license.
3. For a 1 unit increase in income, the odds of willingness will decrease by 1%.
4. If the mandatory trips have increased 1 unit, the log of odds of willingness will increase 100%
5. If the nonmandatory trips have increased by 1 unit, the log of odds of willingness will decrease by 70%.

4. CONCLUSION

This is the era of high pollution and energy consumption. Bicycles might be a suitable option for persons with little to moderate-income who want to increase their mobility. In Bangladesh, encouraging the use of non-motorized vehicles could be the first step toward achieving environmental sustainability. In Bangladesh, cycling is a cost-effective mode of transportation. Nonmotorized transportation is the world's future sustainable mode of transportation. Lowering the CNG fuel price in Bangladesh could have a significant positive impact on public health. However, the added congestion costs should be weighed against the environmental costs and advantages of CNG conversion to make appropriate policy decisions. Due to lower particle emissions from CNG vehicles compared to the petroleum vehicles they replaced, over 2000 lives have been saved. This equates to a yearly savings of roughly $400 million. The urban population needs access to reasonably priced, high-quality public transportation, especially in low-income communities on the periphery of cities with poor public transportation options. For Dhaka's transportation system, particularly walking and rickshaw, play a key role. It is also discussed whether people are willing to use nonmotorized vehicles and expected benefits to acheive a sustainable transportation system in Dhaka. Clearly, a model must be developed to get a sustainable transport system with the combination of non-motorized transport system and well-organized public transportation system. Both the government and the general people should be aware.

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