【Article】

Land Transport Sector in Bangladesh: An Analysis towards Motivating GHG Emission Reduction Strategies

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Abstract

Traditionally, road transport has been the dominant mode of transportation in Bangladesh, causing not only a burden on the economy through the import of gasoline, but also aggravating the environment through increased emission of greenhouse gasses. Road based energy-intensive transport system in Bangladesh has mainly evolved in absence of vision for long-term transport policy. Emission of green house gases (e.g. mainly CO_2, N_2O and CH_4) resulting from transport fuel have been estimated in this study. Future transport performance has been projected using a cointegrating econometric model. The model predicts that passenger traffic in Bangladesh is likely to grow at more than 7% per year and freight traffic at more than 17 percent per year during the period 2008-2025. This will cause proportionate increase in energy consumption and CO_2 emissions. The effects of various policy options aimed at reducing energy consumption and CO_2 emission have also been analysed using a scenario approach. The results show that combining modal shift, promoting energy efficiency, switching to CNG and using low emission vehicle can

potentially reduce about 40 percent emission from the land transport of Bangladesh.

1. Introduction

The interface between transportation investment and economic development has broad ramifications that go beyond transporting goods and people from one place to another. Whereas there is no doubt that transportation is essential for operation of a market economy, much still needs to be understood about ways in which an efficient transportation system can improve the development of the economy, especially when environmental pollution comes into consideration. Global emissions of Green House Gasses (GHGs) rose 70% from 1970 to 2004 or roughly 1.6% per year and CO_2 emissions largely dominate and have risen 80% between 1970 and 2004 (1.9% /yr). Of the estimated 49 Gt of GHGs emitted globally in 2004, approximately 56.6% resulted from the combustion of fossil fuel. Transport sector was responsible for 23% of world CO_2 emissions from the fuel combustion (30% for OECD countries) with the road sector largely dominating. When factoring in all GHG emissions, transport CO_2 emissions accounted for approximately 13% of global GHG emissions.

Transport accounts for a major share of energy consumption in Bangladesh, especially the petroleum products. The consumption is likely to grow up further with economic and population growth, rapid industrialization, urbanization and agricultural development. Increase freight and passenger transport, and higher real incomes stimulate leisure-related travel. There exists only a limited possibility for fuel switching at least in the short run of a decade or so. Hence, this sector can aggravate foreign exchange burden by demanding huge oil imports. Thus, it is necessary to understand the complexities associated with this sector: changes in the demand patterns, modal split, performance and their trends, conservation potential, effect of fuel switching from conventional to new energy sources, and so on. In this connection, this paper aims to answer the key policy questions pertaining to the transport sector of Bangladesh like future transportation behaviour, alternatives for sustainability and how they can be implemented.

With these questions in the background, a brief review of past trends in transport sector of Bangladesh is provided in this article. The likely impacts of continuing past trends are estimated by projecting future transport requirements using a cointegrating econometric model. Future projections show a sharp growth in transport performance, which is likely to lead to a huge increase in energy consumption and environmental emissions. The effects of certain policy alternatives to minimize the negative impacts of such a growth are then studied using a scenario approach.

The rest of paper is organized as follows. In Section 2, the current profiles of transportation and the issues of energy consumption and environmental emissions from transport sector in Bangladesh are summarized. In Section 3, the methodology of future prediction and scenario analysis are explained and the prediction results of future energy consumption and an emission are shown. In Section 4, the results of policy scenario analysis are described and discussed. In the final section, some major findings are summarized along with a discussion about future research issues.

2. Current issues of transportation in Bangladesh

2.1. Performance of transport sector

In the last three decades, transportation has been one of the priority sectors to the government and donor agencies for investment (Alam et al., 2008). During this period about US$40 billion has been invested in transport sector of the country. Particularly, the road sector has attracted a major share of the allocation, far exceeding investments in other modes (Table 1). Currently, about 90 percent of transport sector budgetary allocation is invested for road sector development. Consequently, roadway inventory and number of registered vehicles have been experiencing a very high growth rate. Table 2 presents the growth rates of various vehicle types and shows that average growth rate in the number of registered vehicles is 8 percent. Table 3 shows that road networks currently serve about 80 percent of passenger (passenger-km) and 65 percent of freight movement (ton-km). As the total transportation demand increased from 17 billion passenger-km and 2.6 billion ton-km in 1975 to 150 billion passenger-km and 28 billion ton-km in 2002, rapid modal shift towards road is more apparent in terms of aggregate values.

Because of indiscriminate investment in road sector, the volume of road network in the country has increased from 3764 km in 1971 to 270,711 km in 2006 with 50,736km of paved road. Moreover National Land Transport Policy, which has been approved by the government in 2005, sets a vision for further enhancement of road network. Plans have

Table 1: Annual development expenditure of road and rail transport of Bangladesh.

Year	Annual Development Expenditure (TK in Million) of Bangladesh	Transport Sector Share (As % of ADP)	Road Sector Share (As % of ADP)	Rail Sector Share (As % of ADP)	Transport Sector Expenditure (Tk in Million)	Road Sector Expenditure (Tk in Million)	Rail Sector Expenditure (Tk in Million)
1972	2810	10.5	3.50	3.30	295	98	93
1977	12570	13.05	4.66	3.71	1640	586	466
1982	26880	11.2	4.79	4.21	3011	1287	1132
1987	41500	10.95	5.23	3.60	4544	2171	1494
1992	65500	14.8	10.86	2.42	9694	7113	1585
1997	110370	19.7	9.60	3.14	21743	10596	3466
2002	154340	16.15	13.32	2.15	24926	20558	3318
2005	194730	14.3	9.92	3.11	27846	19317	6056
2007	184310	11.34	8.72	2.00	20901	16072	3686

Source: Bangladesh Economic Review 2008, statistical appendix-17, p.253

Table 2: Number of registered vehicles in Bangladesh.

Year	MCar	Jeep	Taxi	Bus	Minibus	Truck	CNG	MCycle	Others	Total
1997	80858	33778	2009	27972	26753	36152	69069	201145	10281	488017
1998	86734	36483	2112	28258	27355	38885	73472	215670	11529	520498
1999	91720	38752	2328	28525	27834	40903	75612	232181	14146	552001
2000	95807	40269	2908	28862	28238	43628	78747	246795	15511	580765
2001	102394	43337	3679	29456	29456	46203	79144	271204	18402	623275
2002	109151	47119	5912	30196	31770	48580	84623	300251	20550	678152
2003	116196	49364	10932	30617	33364	51375	98479	321347	25726	737400
2004	121606	51878	11472	31474	33986	53958	107453	346288	28487	786602
2005	128037	55841	11987	32257	34347	56749	112330	389514	31418	852480
2006	136484	61381	12262	33277	34588	59814	119219	440620	35131	932776
2007	148425	67031	12277	34645	34970	62335	129749	525751	38865	1054048

Source : Bangladesh Road Transport Authority (www.brta.gov.bd)

Table 3: Trend in modal split in Bangladesh.

Year	Passenger				Freight			
	Total Pass-km (billion)	Mode Shares (%)			Total Ton-km (billion)	Mode Shares (%)		
		Road	Rail	IWT		Road	Rail	IWT
1975	17	54	30	16	2.6	35	28	37
1985	35	65	20	15	4.8	48	17	35
1989	57	68	17	15	6.3	59	11	30
1993	66	75	12	13	9	61	7	32
1997	72	73	13	14	10	63	7	30
2002	152	70	12	18	19	72	8	20

Source: Bangladesh Integrated Transport Sector Study 1997, Planning Commission

been approved to construct elevated expressway and flyovers without commensurate consideration for mass transit, railways and waterways.

Figure 1 shows modal share of different surface transport, i.e., road vs. rail over a period from 1973 to 2007. Passenger-km and tonne-km data for railways are obtained directly from the Bangladesh Railway website (http://www.railway.gov.bd/) and road transport performance is reported based on Table 3 and some other published documents from the central statistical organization (Bangladesh Bureau of Statistics) and governmental reports. It has been depicted from the figure that more than 90 percent of passenger and freight from the surface transport sector are presently carried by the road mode and the share for rail transportation is following decreasing trend.

There has not been enough investment in railway infrastructure to encourage growth. For example, the growth of total route kilometers has been very low during the last two decades, and the rate has been much lower in the last decade compared to the seventies. This implies that further growth of railway performance cannot be achieved by capacity utilisation alone without significant investment in infrastructure.

For Bangladesh, land use planning seems very important as statistics show that around 50 percent of the country's vehicle ply on the capital Dhaka city. This is mainly due to centralized governmental system and people from all parts of the country concentrate to Dhaka city as the country has not evenly developed. There is another point that old and worse vehicle ply more in rural areas. In order to improve air quality of Dhaka, the government has adopted a policy to ban two stroke 3-wheelers (locally called baby taxi) and buses and trucks older than 20 years from Dhaka city and allow to operate in the countryside. This means that this policy option did not have any positive impact on countryside emission. For the estimation of GHG emission and finding options to reduce it, urban and rural transportation policies should be addressed separately. Within the limited scope of the study, the energy consumed by transport data have been found as national aggregate level and it would not be possible to segregate it to urban and rural transport easily. Besides to set a visionary target for emission reduction it is imperative to consider the issue from macroscopic view first and then more precise analysis is needed. In this paper national transport has been pointed focusing combined strategies to reduce GHG emission from transport sector.

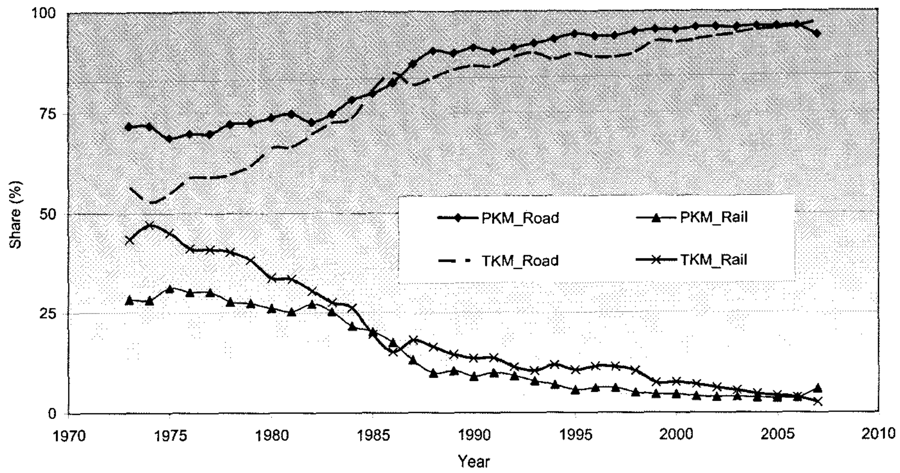

Figure 1: Rail mode showing decreasing share comparing with road transport.

2.2. Energy consumption from transport sector

Transport sector is the second largest consumer of energy in Bangladesh with petroleum consumption growth rate 7.6% per annum. Aggregate energy demand in Bangladesh at present is about 700 Trillion BTU with an average growth rate of 5.2 percent. Of this total energy, 40 percent comes from biomass burning and the rest primarily from fossil fuels, among which natural gas alone constitutes 70 percent (Jobair et/ al., 2008). During 2003-04 transport sector consumed 218.29 Trillion BTU of commercial energy which was around 23.70% of total nationwide consumption (BBS, 2007). As transport sector is dependent on fossil fuel, which is mostly imported, it imposes huge burden on national economy.

In 2005 about 3.5 million ton of petroleum fuel was imported at a cost of US$1.12 billion, which is about 1.94 percent of the country's GDP and 15 percent of current account balance. Since Bangladesh has some gas reserves, there has been an increased reliance on gas and gas usage has been increasing at an average rate more than 10% percent per year for the last five years. It is also expected that coal will play a significant role as an energy source in the future. Since there is serious scarcity of energy source in Bangladesh, careful planning will be needed to strike the balance between demand and supply. Since the independence of Bangladesh in 1971, petroleum sector has been served by the state-owned Bangladesh Petroleum Corporation (BPC). The organization is responsible for importing crude oil and petroleum products and operating the only petroleum refinery plant in the country. The prices of BPC's petroleum products are strictly regulated by the government. Since the price within the country is kept artificially lower than the world market, BPC has been operating under loss in recent years.

The trends in energy consumption and physical performance of rail and road transport in Bangladesh are presented in Table 4. In the initial period, railways have registered negative growth in energy consumption, while registering positive growth in its physical performance. The reason is the shift from the fuel-inefficient coal traction to more efficient diesel traction. But after 1982 railways performance became decreasing both in passengers and goods. Table 4 shows that the growth of energy consumption by road transport (13% per year during 1973-2004) is less than the growth of PKM performance (8.35%) and TKM (10.85%), indicating roughly an increase in energy efficiency. A similar observation can show an increase in energy efficiency in rail transport as well.

Table 4: Physical performance and energy consumption in road and rail transport in Bangladesh.

Year	PKM_{road} (billion)	TKM_{road} (billion)	$Energy_{road}$ (TJ)	PKM_{rail} (billion)	TKM_{rail} (billion)	$Energy_{rail}$ (TJ)
1973	8.42	0.815	2039.069	3.33	0.63	N.A.
1978	12.53	1.227	5493.344	4.83	0.83	5214.96
1983	18.54	2.045	8286.073	6.28	0.78	2318.51
1988	39.54	3.403	13712.43	4.34	0.67	1872.68
1993	52.85	5.479	21219.72	4.57	0.64	1430.02
1998	68.82	7.738	34199.42	3.68	0.90	1594.66
2003	103.42	15.441	39094.02	4.34	0.90	1370.18
2006	118.51	19.652	N.A.	4.58	0.78	1258.01

2.3. Environmental emissions from transport sector

Figure 2 shows the CO_2 emissions from the transport sector of Bangladesh. The data has been taken from the International Energy Agency (IEA) database (source: http://geodata.grid.unep.ch). It has been depicted from the figure that CO_2 emission has been growing from 0.3 million metric ton in 1971 to 3.8 million metric ton in the year 2004 with an average growth rate of 2.8% per year.

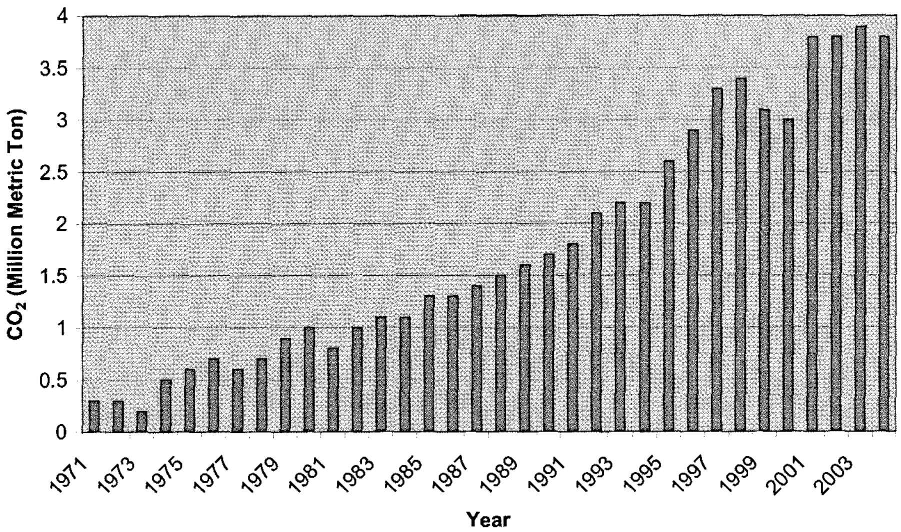

Figure 2: CO_2 Emissions from transport sector of Bangladesh.

Although in terms of environmental emissions, the national level situation is not so worse (Bangladesh ranked 61 among 184 countries for total CO_2 emission during 2005) the situation of Dhaka, the capital of Bangladesh, is completely different. Uneven development throughout the country has led Dhaka to possess around 10 percent of total population and 44 percent of total motor vehicles although its land area is only around 1 percent of the total land area of Bangladesh. According to the Department of Environment Dhaka's air pollution poses a serious health hazard to the city's residents with rising respiratory illnesses causing more than 15,000 deaths a year (Daily Star June 9, 2009).

3. Empirical analysis of energy use and emissions

3.1. Methodology

Various econometric and statistical models have been employed in this study to predict future transportation demand, energy consumption and consequently estimating environmental emission from land (road and rail) transport of Bangladesh. At first a cointegrating econometric model has been developed to predict the future transportation demand in terms of Passenger Kilometer (PKM) and Freight Transport (TKM) using log of Gross Domestic Product (GDP), Consumer Price Index (CPI), Index of Industrial Production (IIP) and Population data as dependent variable.

Secondly, the predicted indicators of PKM and TKM have been utilized along with energy data to estimate future energy consumption for road and rail mode separately using Data Envelopment Analysis (DEA) efficiency model. Input oriented assuming constant return to scale DEA model has been employed in this connection and associated equations are given below:

$$\max \frac{\sum_{j=1}^{J} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}} \qquad (1)$$

Subject to

$$0 \le \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}} \le 1; \quad n = 1, 2, \ldots, N \qquad (2)$$

$$v_{jm}, u_{im} \ge \varepsilon; i = 1,2,\ldots,I; j = 1,2,\ldots,J \qquad (3)$$

Where the subscript i stands for inputs, j stands for outputs and n stands for the DMUs. The variables v_{jm} and u_{im} are the weights to be determined by the above mathematical program. Note that by setting the denominator of the ratio equal to unity, one can obtain the following output maximization linear programming problem as denoted (Eq. 4) below:

$$\max \sum_{j=1}^{J} v_{jm} y_{jm} \qquad (4)$$

Subject to

$$\begin{aligned} &\sum_{i=1}^{I} u_{im} x_{im} = 1; \\ &\sum_{j=1}^{J} v_{jm} y_{jn} - \sum u_{im} x_{in} \le 0; \mathrm{n} = 1,2,\ldots,N \\ &v_{jm}, u_{im} \ge \varepsilon; \ \mathrm{i} = 1,2,\ldots,I; \mathrm{j} = 1,2,\ldots,J \end{aligned} \qquad (5)$$

In this study, the applicability of DEA is further extended to estimate energy consumption of rail and/or road transport that would result in a pre-specified DEA efficiency. In order to estimate the energy requirements, if road transport has to perform according to the data in Table 4 for 2010, road in 2010 is introduced as a new DMU (in addition to those listed in Table 4) in the DEA analysis. In this DEA model, PKM and TKM have been used as output data and energy consumed has been considered as input variable. The PKM and TKM performance of road in 2010 has been obtained from Figure 4 (forecasting section). The procedure of using DEA to estimate energy requirements for road in 2010 is sketched in the flow chart shown in Figure 3. Both the bounds are based on the assumption that the energy efficiency of road in 2010 will be equal to that in 2004, but as shown by past trends, energy efficiency is generally expected to increase over the years. Hence, the first and second bounds on energy consumption estimated using DEA should be considered larger than the values that would be actually registered. The second bound of energy consumption is always smaller than the first bound. Hence, only the second bound values on energy consumption are considered in this analysis. In the similar fashion projections for the year 2025 has been made.

Thirdly, Aggregated Multinomial Logit Model is also employed to predict the future mode share behavior of road and rail using accessibility, fare and investment (Annual Development Plan, ADP) data (Economic Review of Bangladesh, 2005). Similar model has also been applied to obtain future share of different types of vehicle e.g., bus, truck, car, auto rickshaw, motor cycle etc. Then the estimated energy (which is obtained from procedure shown in Figure 3) has been subdivided into three groups namely gasoline, diesel and CNG (compressed natural gas) using the vehicle population ratio, vehicle usage ratio and vehicle efficiency ratio. Finally multiplying corresponding emission factor with the total grouped energy (diesel, gasoline and CNG) estimation has been made for Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) emission from the transport sector which are three main Green House Gases (GHG) as suggested by IPCC guideline (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html) for national greenhouse gas inventories.

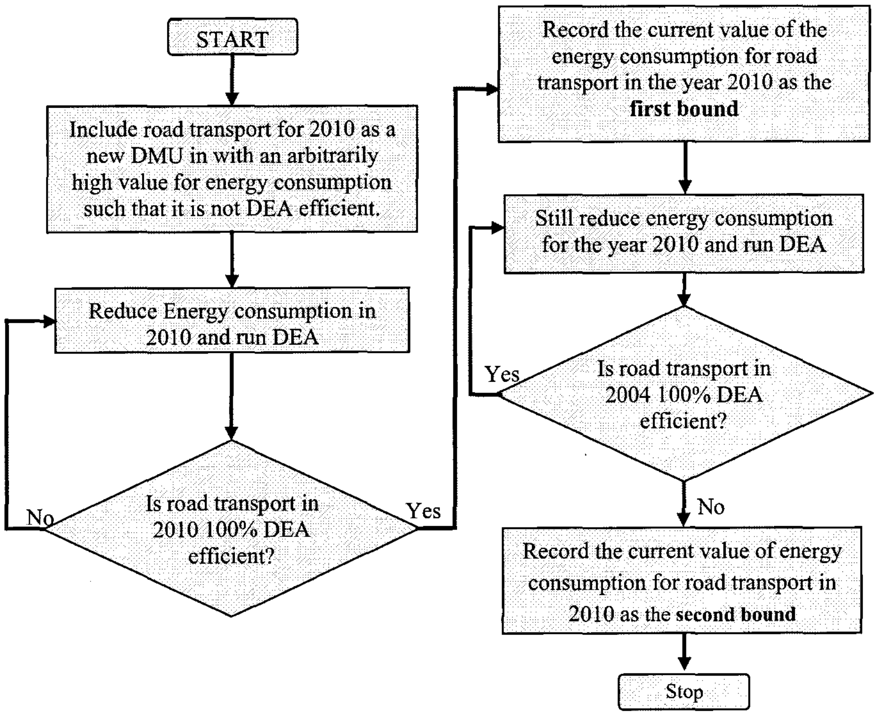

Figure 3: Flow chart showing the use of DEA for estimating future energy consumption.
Source: Ramanathan, 2005.

3.2. Data and tools

The data used in this study include GDP, population, consumer price index (CPI), index of industrial production (IIP), energy consumption in road and rail mode, fare of passenger and goods transport, annual development budget for road and railway and total length of roadway and railway (accessibility index) etc. Though most of the vehicles are concentrated in urban areas of Bangladesh, total population may be considered as an important parameter for freight transport. Hence total population instead of urban population has been used in this study. Oil price index or similar type of index may be most relevant for transport study, but due to lack of available data, consumer price index has been used here. In fact consumer price index also derived from many elements including fuel prices. Nation level time series data from 1973 to 2007 were obtained from secondary sources from several official documents published by the government of Bangladesh. Data sources include Statistical Year Book of Bangladesh (1973-2007) published by Bangladesh Bureau of Statistics, Economic Review of Bangladesh 2008 by Planning Commission of Bangladesh and official web sites of various ministries and department of Bangladesh Government. Energy data for road transport have been taken from the official website of International Energy Association (http://geodata.grid.unep.ch). Emission factors were selected from the IPCC 2006 guideline. Railway energy data have been obtained from the official web site of Bangladesh Railway (http://www.railway.gov.bd/). Cointegrating and other regression analyses are done by the Microfit 4.0 for windows econometric software package and DEA analysis in this study has been performed using the DEAP (Data Envelopment Analysis Program) software package.

3.3. Prediction analysis of future transport demands

Economic analysis provides valuable tools for identifying the relationship among macro-economic variables, and hence provide the suitable basis for making future projections. So, econometric models were attempted in this study for projecting future PKM and TKM levels. However, a detailed analysis with data has revealed that simple multiple regressions do not provide satisfactory models. Finally, an approach using cointegrating econometric models (Charemza and Deadman, 1992; Engle and Granger, 1987) has been found to be satisfactory. The relevant models are given hereunder.

$$\underset{(-9.39)}{PKM_t = -13.47} + \underset{(0.49)}{0.053GDP_t} + \underset{(0.49)}{3.57POPTOT_t} - \underset{(-0.25)}{0.038CPI_t} + v_{PKM_t} \quad (R^2 = 0.991, RSS = 0.157, DWStatistics = 0.36) \qquad (6)$$

$$\underset{(-24.69)}{TKM_t = -4.53} + \underset{(13.35)}{1.356IIP_t} - \underset{(-1.00)}{0.086CPI_t} + v_{TKM_t} \quad (R^2 = 0.984, RSS = 0.351, DWStatistics = 0.56) \qquad (7)$$

$$\Delta PKM_t = \underset{(0.12)}{0.004} + \underset{(0.12)}{0.01\Delta GDP_t} + \underset{(0.62)}{1.16\Delta POPTOT_t} + \underset{(0.24)}{0.05\Delta CPI_t} - \underset{(-2.27)}{0.24v_{PKM_{t-1}}} + \underset{(3.39)}{0.55\Delta PKM_{t-1}} + u_{PKM_t}$$
$$(R^2 = 0.39, RSS = 0.031, DWStatistics = 2.30) \qquad (8)$$

$$\Delta TKM_t = \underset{(1.01)}{0.04} - \underset{(-0.035)}{0.007\Delta IIP_t} - \underset{(-0.206)}{0.042\Delta CPI_t} - \underset{(-2.06)}{0.17v_{TKM_{t-1}}} + \underset{(2.13)}{0.372\Delta TKM_{t-1}} + \underset{(1.24)}{0.213\Delta TKM_{t-2}} + u_{TKM_t}$$
$$(R^2 = 0.26, RSS = 0.043, DWStatistics = 1.75) \qquad (9)$$

Where the notations PKM, TKM, GDP, POPTOT, CPI and IIP stand for passenger kilometres, tonne-kilometres, gross domestic product, total population, consumer price index and index of industrial production respectively. Natural logarithm of all variables were used for regression analysis. Time series data from 1973 to 2007 were employed to determine the coefficients of the above equations. Models 6 and 8 are normal economic models for PKM and TKM respectively. They could not be used as such for making projections as they suffered from severe autocorrelation (as DW statistics are quiet low). On the basis of usual tests (unit root / ADF test) for cointegration, the cointegrating relationships given in Models 6 and 7 have been established. First, the stationarity of the variables have been checked and all of them have been found to be nonstationary with order 1. Then, the residuals v_{PKM} and v_{TKM} of models 6 and 8 were used to verify the existence of cointegration. The t-statistics of residual in the unit root test for v_{PKM} and v_{TKM} are found -3.64 and -3.37 which are acceptable in 10% and 5% significance level (critical values are taken from Charemza and Deadman (1992), Table 2 in pp.321-323, m=3 for PKM and m=2 for TKM). Hence the cointegrating relationships of models 6 and 7 have been verified. Models 7 and 9 are called the Error Correction Models (ECM) for models 6 and 8 respectively. Note that the residuals v_{PKM} and v_{TKM} of models 6 and 8 were used in the error correction models with a unit lag.

The values of coefficients in Models 6 and 8 give the long-run elasticities for PKM and TKM respectively. The long-run income and price elasticities of PKM are 0.053 and -0.038 respectively. Further its elasticity with respect to the total population is quite large, at 3.57. The long-run price elasticity of TKM in India is quite low, at -0.86, while its elasticity with respect to industrial output is 1.356. The short-run elasticities for PKM and TKM were obtained as the values of the coefficients in Models 7 and 9 respectively. They are generally much smaller, indicating a relative inelasticity in the short run. This is not unusual in the case of large systems, whose long-term responses are more perceptible than the short-term responses. Transportation sector requires huge capital input and long gestation periods, which make short-run adjustments quite difficult. The smaller short-run elasticity can also be explained by the slow adjustment pattern of use of automobiles by the consumers, especially the households. The coefficients of the residuals $v_{PKM(t-1)}$ and $v_{TKM(t-1)}$ in Models 7 and 9 respectively show the speed of adjustment towards the long-run equilibrium. The results show that both PKM and TKM adjust to their respective longrun equilibrium at a moderate rate, with about 24% of adjustment in PKM and 17% of adjustment in TKM occurring in the first year. Models 6 and 7 were used for forecasting PKM. The exercise involves running series of ordinary least squares regressions using the two models as explained in Engle and Yoo (1987). Using a similar procedure, future TKM levels have been projected using the cointegrating Model 8 and its ECM (Model 9). The forecasts for the year 2025 were estimated. The results are plotted in Figure 4. Passenger growth has been reported from 11.75 billion to 131.75 billion during 1973-2007 periods with

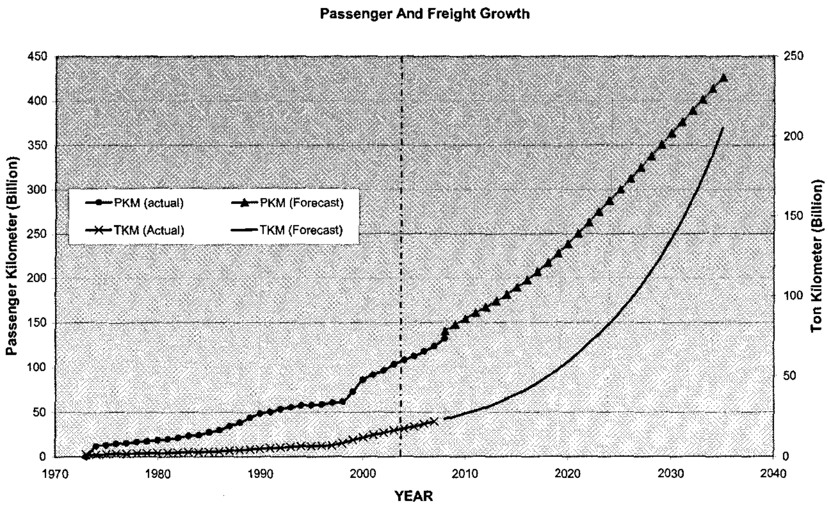

Figure 4: Forecast of passenger and freight growth in Bangladesh.

an average growth rate 7.45% per annum. Freight transport has grown at a faster rate with 8.46 per annum from 1.44 billion to 21.87 billion in the same period. Transportation demand forecasting shows that by 2025 PKM and TKM will go at 300 billon and 90 billion with a growth rate of 7.08% and 17.45% respectfully per annum. With a view to analysing the implications of these forecasts on the sustainability of this sector in Bangladesh, a scenario analysis was performed. The details are presented below.

4. Energy requirements and carbon dioxide emissions up to 2025: A scenario analysis

For policy purposes, it is necessary to identify the implications of alternate courses of action so that the future can be shaped to ensure sustainable development. The impact of the Bangladeshi transportation sector is likely to be felt mainly on two important areas – energy requirements and GHG emissions. Assuming that the PKM and TKM projections made in the previous section will materialise, their likely impacts and the effects of alternate courses of action were analysed using five scenarios. A DEA efficiency model (Ramanathan, 2005) is employed to estimate the future energy requirement. The analysis result shows that the energy consumption in road transport in Bangladesh in the year 2010 is expected to increase by nearly 1.3 times the consumption in 2004. The increase is likely to be more than 2.64 for the year 2025. Thus GHG emission are estimated from the energy demand, vehicle inventory data, fuel efficiency, annual average usage data and emission factor from the IPCC 2006 guideline.

Under Business As Usual (BAU) scenario, existing historical patterns are assumed to continue in future. The trends in the past modal splits have been used to project future modal splits using aggregated multinomial logit model. Figure 5 shows the estimated GHG emission in equivalent CO_2 from surface transport mode for the year 2025. It is revealed from the analysis result that GHG has been increased from 2748,149 ton during 2004 to 3053,850 ton in 2007 and finally will increase to 6918,360 ton by the year 2025 with an increment of around 7% per year under business as usual scenario. Emission for railway is negligible as presently rail mode covers less than 5% of total passenger and freight carried by the surface transport and is about less than 1% of the total GHG emission during 2007. Within the

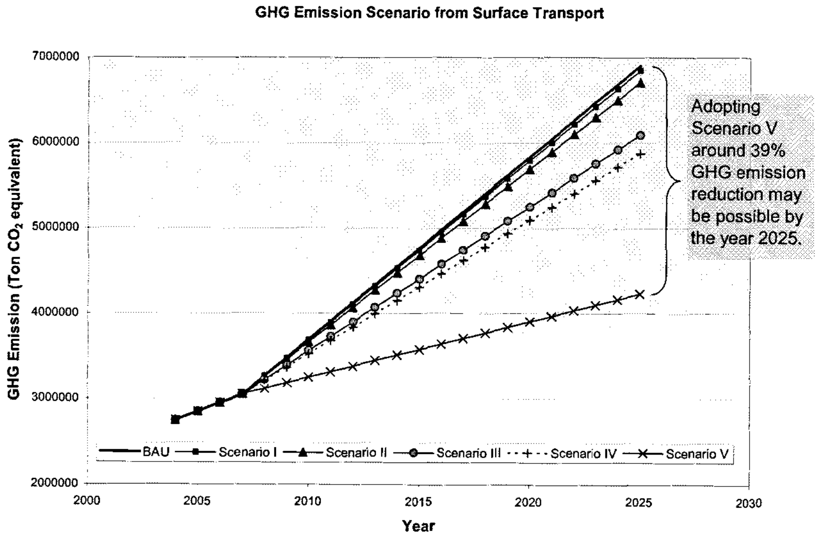

Figure 5: Scenario Analysis to Reduce GHG Emission from Land Transport.

limited scope of this study, five scenarios are analyzed to visualize the possible impacts of alternative policies focusing to reduce vehicular emissions by the year 2025. These scenarios are given below.

Scenario I: 30% modal shift (for both passenger and freight) to rail transport system.
Scenario II: Scenario I plus fuel switching to CNG for 30-60% vehicle.
Scenario III: Scenario II plus 30% energy efficiency and 40% less emission from rail transport.
Scenario IV: 15 % energy efficiency and 40% less emission from road transport.
Scenario V: Scenario III plus Scenario IV.

The estimation results for Scenario I to Scenario V are shown in Figure 5. It is depicted from the figure that adopting scenario I has very little implication in terms of emission reduction. Analysis result shows that if 30% modal shift (for both passenger and freight) can be attained by the year 2025 a total of 16,634 ton of GHG reduction will occur. For the case of option II the savings is about 10 times of Option I and is registered the value as 169,551. In recent years government has been actively promoting the use of Compressed Natural Gas (CNG) as alternative fuel for transport vehicles. In the last couple of years, all the urban three wheeler para-transits have become CNG based and remarkable number of other motorized vehicles, specially car, microbus, jeep etc have been converted to CNG. In this option it has been assumed that by the year 2025, 50% car, microbus, jeep, taxi, 80% of 3-wheeler and 40% of busses will operate by CNG. Presently Bangladesh Railway is running diesel locomotive and they are not much efficient in terms of energy consumption and pollutant emission. The use of modern engine and also switching to much cleaner energy such as electricity, significant amount of improvement may be attainable from the railway. Scenario III refers to this issue and it has been assumed 30% energy efficiency and a 40% emission reduction from railway along with scenario II results about a total reduction of 782,306 ton GHG in CO_2- eq. Scenario IV refers to the tougher target which implies to energy efficiency from the road transport. In the developed world many researches have been going on this issue and recently some very attractive vehicles with ultra low energy consumption and zero emission facilities are coming to the market. Scenario IV assumes that 15% energy efficiency and 40% emission reduction from road vehicle which may be a very difficult task. But since Bangladesh plying very old type of vehicle (sometimes more than 30 years old) with poorly maintained, the target is not so tough. For example, the average fuel efficiency of car in Bangladesh is around 9.8 km/l which is 3 times lower than the Toyota Preus. Given the scenario IV may be achieved, the total GHG emission saved has been calculated to 1521,274 ton CO_2 by the next 15 years. Finally, scenario V which is a combination of scenario III plus scenario IV, estimates about 39% GHG emission reduction from the business as usual condition by the year 2025.

The average fuel economy of cars at present in developing countries in Asia is about 9–10 litre per 100 km. For developed countries the value is about 8. However, new technological improvements have resulted in small cars which have a fuel consumption as low as 5 litre per 100 km. If one assumes that these types of cars will be commercially available in developing countries in about 30 years (Okken, 1991), it amounts to a cumulative efficiency increase of about 2.5% per year. Hence, the assumption of 1% in efficiency increase in road transport (which also includes buses) is not unrealistic. For other transports, the assumption of 1% efficiency improvement per year is quite conservative (in scenario IV 15% energy efficiency is assumed over next 15 years of time). Increasing trend of using ultra low emission (hybrid) vehicles and zero emission (electric) vehicles also complies with the previous assumption of emission reduction from the transport sector.

Given no other alternative like biodiesel or battery operated vehicle there is very limited scope to switch to other fuel for vehicular use in Bangladesh. In recent years, government has been actively promoting the use of Compressed Natural Gas (CNG) as alternative fuel for transport vehicles. In the last three years, all the urban three wheeler para-transits have become CNG based and about 10 percent of other motorized vehicles have been converted to CNG. Due to CNG conversion policy total imported consumption will reduce. As CNG has been recognized as a cleaner energy source for transportation its promotion may have positive impacts to the environment. Recently more than 100,000 vehicles are operating by CNG and the distribution line has been starting operating in countrywide. Given the available reserve of the natural gas it may be expected that more than 60% cars and some other vehicles will be run by CNG by the next 15 years.

Government has also been trying to extend CNG fueling stations beyond the capital which tends to attract more vehicles in the countryside to use natural gas as fuel. But still the opportunity is limited to big cities only. It is worthy to mention that although consumption of CNG as transport fuel may reduce economic burden in the short term, policy makers should be concerned with its limited availability, international market price and opportunity cost.

Flat terrain, almost square shaped geographical layout and centralized demand pattern of Bangladesh make it highly suitable for rail transport system. Unfortunately it has been severely neglected in the last couple of decades resulting in reduction in its role in national transportation. Recently government has taken initiative to revitalize rail system which is more efficient with respect to energy and environmental considerations. Electrification of rail system will also have a beneficial effect on petroleum imports as natural gas is the principal fuel to generate electricity in the country. Meanwhile, it should be recognized that for materialization of the modal shift improvement in service quality is required which needs commensurate investment. Here it should be mentioned that most of locomotives currently using in the Bangladesh railway fleet are very old and if replaced by new type of energy efficient diesel/electric locomotive then according to the statistics and performance of developed country's railway it may attain the energy efficient and energy reduction target addressed in this study.

5. Summary and conclusions

It this report, the structural changes in transportation scenario of Bangladesh during the past few decades were analysed. It has been shown that both the passenger and freight traffic have witnessed high growth rates (about 7.45% and 8.46% per year, respectively) during the period 1973–2007. Growth in road transport and in the number of road transport vehicles (more than 10% per year) has been identified to be responsible for such a tremendous increase. It has been shown that the growth of the different sectors of transport is beset with several infrastructural bottlenecks, and that removal of the bottlenecks would require considerable financing.

The study has identified population growth as the most important variable for controlling the PKM growth. If the total population increases by 1%, PKM is likely to increase by more than 3.5%. The results of this study show that, IIP for Bangladesh increases by 1% in future, TKM will increase by more than 1%. Forecasting shows that by 2025 energy demand for surface transport of Bangladesh will go to 103,900 TJ from 39,333TJ (about 2.6 times comparing with 2004 level). It is revealed from the analysis result that GHG has been increased from 2748,149 ton during 2004 to 3053,850 ton in 2007 and finally will increase to 6918,360 ton by the year 2025 with an increment of around 7% per year under business as usual scenario.

However, certain alternate policy actions could reduce them considerably. Modal shift only policy towards rail mode was not found to be very good option in terms of emission reduction. Analysis result shows that if 30% modal shift (for both passenger and freight) can be attained by the year 2025 a total of 16,634 ton of GHG reduction will occur. In the same time if it is possible to attain energy saving options (around 30%) and less emission (around 40%) option from the railway, around 40 times reduction may be possible. Estimation result shows that a combined effort of modal shift (towards rail 30%), energy efficiency in transport mode (30% in the rail and 15% in the road), technical improvement of emission reduction (40% from rail and road) and fuel switching (30-60% of different types of vehicle to CNG) can reduce about 39% GHG emission in the surface transport sector from the business as usual condition by the year 2025.

The most significant research can be made by estimating energy efficiency and emission reduction targets suggested in this study for transport sector energy demand assessment and consequent impacts on environment is evaluating alternative planning options for Bangladesh. The study also pointed about the need of country is specific emission factor for Bangladesh and also establishment of reliable data sources. It is also promising to conduct research regarding the applicability of CDM or JI to achieving emission reduction targets discussed in this study. These form directions for future research.

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