Status of Air Quality and State-of-art Control Measures in Dhaka, Bangladesh

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ABSTRACT

Environmental problems in all major cities of Bangladesh occur due to the lack of environmental facilities, such as infrastructure, coupled with the rapid rise in transportation demand. It is also caused by the huge number of non-motorized vehicles on roads, lack of application of adequate and proper traffic management schemes, improper land use planning, industrial growth, construction activities, resuspension of dusts, and open burning. Ever increasing traffic congestion in the streets, use of low leaded gasoline without catalytic converters, increasing number of two stroke engine vehicles and high content of sulfur in diesel enhance sufferings of the inhabitants of Dhaka from vehicle emissions.

A study has been performed under the direction of Japan Bank for International Cooperation (JBIC) during February 2000 on improvement of transportation and environment in Dhaka. This paper is based on JBIC supported study results. The paper has reviewed existing transportation problems and databases on traffic pollution to have insight into the state of traffic pollution in Dhaka. It also evaluated existing transportation and environmental related projects of the Government of Bangladesh and identified the sectors where development partners, especially Japanese Government can consider exploring their assistance in improving air quality in urban areas of Bangladesh. This study has also assessed the feasibility of introducing CNG to automobiles in the short and long term.

Key Words: Bangladesh, Urban Air Quality Management, Development Projects, Alternative Transportation.

STATE OF AIR QUALITY IN DHAKA

Air pollution from transportation systems in Dhaka occurs due to the use of low lead gasoline without proper catalytic converters, high sulfur in diesel, large number of high polluting vehicles, impure fuel, inefficient land use, and overall poor traffic management. The heterogeneous flows of traffic and the two stroke engine vehicles, which emit greater proportion of black smoke, are the major issues of concern. In addition, the increasing numbers of two-stroke engines (auto-rickshaw, auto-tempo, and motorcycle) are also a dominating factor for Dhaka's air pollution. This increase is most remarkable as the proportion of such two stroke engine vehicles in the total vehicle population rose from 2.2% in 1982-83, to 18% in 1990-91, and as high as 23% in 1996-97. It is not out of subject to mention here that the two stroke engine vehicles (auto-rickshaw) moving in Dhaka City are simple modified forms of an Italian model of the 1960's. It is estimated that an auto-rickshaw emits 30 times more pollutants than a normal car. Moreover, gasoline pilfered from official vehicles find its way into the informal...
market for sale to the auto-rickshaw and auto-tempo drivers. Such pilfered gasoline is often mixed with kerosene and when used in two stroke engines becomes a potential agent for pollutant emission.³

Figure 1: Ambient Concentration of selected Pollutants in Dhaka.

The pollutant species most often of concern in developing countries with respect to transportation systems are carbon monoxide (CO), hydrocarbons (HC), photochemical oxidants e.g., ozone (O₃), nitrogen oxides (NOₓ), suspended particulate matter (SPM), sulfur dioxide (SO₂), and lead (Pb). Air quality monitoring data is limited in Dhaka, however, periodic surveys by the Department of Environment (DOE), indicate that the ambient levels of SPM, SO₂ and airborne lead are higher than the Bangladesh air quality guidelines.⁴ The pollutants emitting from automobiles are obvious contributor to the pollution problem in Dhaka; however, no emissions inventory detailing sources of pollution in national level is currently available. Figure 1 presents measured ambient concentrations of SPM, NOₓ, and SO₂. DOE collected this data in 1998 at Farmgate area, which is located in a higher traffic zone in the north central portion of the city and classified as commercial/mixed use area. It is clear from Figure 1 that the ambient levels of SPM exceed Bangladesh air quality standard (Table 1) in commercial and mixed areas along all the months of the year, while the SO₂ levels exceed the standard during the dry winter season. The NOₓ levels appear to be under acceptable limit of the air quality standard. However, Bangladesh standard is not directly comparable with the international air quality standard because of differences in averaging time, but in general SPM and SO₂ exceed international standard of ambient air quality during the whole year in Dhaka.
Lead content in ambient air was measured by Bangladesh Atomic Energy Commission during November 1995 to January 1996 and detected 4.63 $\mu$g/m$^3$ of lead in ambient air over Dhaka$^5$, whereas, WHO standard for lead in air is 0.51 $\mu$g/m$^3$. Besides ambient monitoring of lead, a survey performed in 1997 by the Health Economics unit of the Ministry of Health and Family Welfare of the Government of Bangladesh (GOB) indicated that the concentration of lead in blood samples of 39 people in Dhaka were all above the maximum tolerable limit of 10 $\mu$g/dl recommended by WHO. The concentration levels ranged from a minimum of 13 $\mu$g/dl to a maximum of 132 $\mu$g/dl.$^7$ A World Bank study has estimated that a 1 $\mu$g/m$^3$ increase in airborne ambient lead concentrations caused about 70 thousand hypertension in one million males aged 20 and 70 years, 340 non-fatal heart attacks, and about 350 deaths per one million males aged 40-59. Studies have also indicated effects of lead on male productivity of children.$^8$

Table 1: Bangladesh national ambient air quality standards.

<table>
<thead>
<tr>
<th>Landuse Category</th>
<th>8-hour average concentration in $\mu$g/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO</td>
</tr>
<tr>
<td>Industrial/mixed use</td>
<td>5,000</td>
</tr>
<tr>
<td>Commercial/mixed use</td>
<td>5,000</td>
</tr>
<tr>
<td>Residential and Rural use</td>
<td>2,000</td>
</tr>
<tr>
<td>Sensitive use*</td>
<td>1,000</td>
</tr>
</tbody>
</table>

*Sensitive areas include national monuments, health resorts, hospitals, archeological spots, and educational institutions. Source: DOE, 1997.

Table 2: Ambient pollutants level in Dhaka and their standards

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging Time</th>
<th>Ambient Concentration in Dhaka$^{**}$</th>
<th>Bangladesh Standard$^9$</th>
<th>WHO Standard</th>
<th>US Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>Annual</td>
<td>N/A</td>
<td>N/A</td>
<td>500-7000$\mu$g/m$^3$</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>8 hour</td>
<td>N/A</td>
<td>1000-5000 $\mu$g/m$^3$</td>
<td>10 mg/m$^3$</td>
<td>9 ppm 10 mg/m$^3$</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>11 ppm (instantaneous average)</td>
<td>N/A</td>
<td>30 mg/m$^3$</td>
<td>35 ppm 40 mg/m$^3$</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>24 hour</td>
<td>0.126 ppm 252 $\mu$g/m$^3$</td>
<td>N/A</td>
<td>0.075 ppm 150 $\mu$g/m$^3$</td>
<td>N/A</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>24 hour</td>
<td>244.8 $\mu$g/m$^3$</td>
<td>N/A</td>
<td>150-230 $\mu$g/m$^3$</td>
<td>150 $\mu$g/m$^3$</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>24 hour</td>
<td>445.2 $\mu$g/m$^3$</td>
<td>N/A</td>
<td>N/A</td>
<td>65 $\mu$g/m$^3$</td>
</tr>
<tr>
<td>VOCs</td>
<td>24 hour</td>
<td>1,131 $\mu$g/m$^3$ (instantaneous average)</td>
<td>N/A</td>
<td>N/A</td>
<td>193 $\mu$g/m$^3$</td>
</tr>
</tbody>
</table>

* PM$_{2.5}$ and PM$_{10}$ measured at different locations and days.

The Government of Bangladesh took an initiative during August 1999 in marketing low lead gasoline from Singapore, instead of refining the imported raw petroleum products in the eastern refinery of
Bangladesh. In addition, the enforcement mechanism of low-lead gasoline in the market was not bind to the mandatory use of catalytic converters for all gasoline powered vehicles. Therefore, the purpose of importing cleaner fuel (low-lead gasoline) failed because the implementation was not planned and executed properly. Therefore, strict government measures on use of catalytic converters with low lead fuel are necessary to reduce the level of air pollution in Dhaka.

Besides government information, there are several independent researcher’s data available on instantaneous CO monitoring at Farmgate, daily average NO$_2$ concentration in selected urban intersections of Dhaka, PM$_{10}$ and PM$_{2.5}$ measurements at Farmgate police box, DOE Agargaon office and rooftop of World Bank office, and volatile organic compounds (VOCs) measurements at four locations. These data are listed in Table 2 and compared with local and international ambient air quality standards. All measured data exceed Bangladeshi and/or international standards.

**EXISTING AIR QUALITY IMPROVEMENT PROJECTS**

Bangladesh is yet to implement an internationally compatible National Ambient Air Quality Standards and there are lack of a detailed air quality regulations in national level. Air pollution in Dhaka is a high priority concern as it is seriously affecting the quality of life in the city and represents a major public health issue. Various development partners are supporting projects to tackle the deteriorating air quality in Dhaka. However, the assistance involved is discrete and somewhat narrowly focused. The World Bank is supporting Dhaka Urban Transport Project for transportation infrastructure development, which will improve traffic congestion as well as pollution in Dhaka. The World Bank's learning and innovation loan on air quality management will focus on training DOE personnel, providing monitoring equipment, and conducting pilot studies to control pollution of two-stroke engine and diesel vehicles. The World Bank also supported the Consultative Group Meeting on Vehicular Air Pollution Control in Dhaka in April 1998. The UNDP funded sustainable environmental management program, with the World Bank administering US$ 6 million to carry out environmental pollution mapping and develop environmental quality guidelines for the industrial sector is also an initiative to improve air quality. In the development of alternative fuels, Canadian International Development Agency (CIDA) supported Bangladesh Environmental Management Project is strengthening DOE’s capacity in monitoring air quality, evaluating environmental impact of projects, and examining the use of compressed natural gas in industries and automobiles. The United States Agency for International Development is assisting the Government to develop an Energy Action Plan that includes impact of CNG and clean fuels on air quality. The New Zealand Government has provided a grant to install four service stations in Dhaka with CNG facilities. The Dutch Government has given a CNG operated double-decker bus to BRTC for road testing. The following projects funded by the various development partners are either directly or indirectly related to improving air quality of Dhaka.

**FUTURE AIR QUALITY IMPROVEMENT DIRECTIONS**

High number of aged vehicles, absence of catalytic converters with low lead gasoline, impure diesel with high sulfur, inaccurate forecast of air pollution and overall inefficient traffic management are few of the potential reasons of alarming air pollution in Dhaka City. The heterogeneous flow of traffic and
two-stroke engine vehicles are also dominating factors of Dhaka’s air pollution. To have better air pollution inventories and as well as to improve the air quality of Dhaka City, future direction of works could be outlined as:

**Replace Two-stroke Engine by Four-stroke Engine Vehicles**

Two-stroke engine vehicles fulfil a major share of Dhaka’s transportation demand. Emissions from these vehicles are hazardous to Dhaka’s air quality and these could be effectively improved by incorporating better quality engines. The first step in controlling emissions from high polluting (two-stroke) vehicle is eliminating the excessive emissions from two-stroke engines. Modifying the engine incorporating timed fuel injection and crankcase lubrication can do this. This would reduce hydrocarbon and particulate matter emissions by 90%, at a cost of about US$60 per vehicle. But, the lack of understanding about the air pollution, adverse effect on vehicle running capacity, routine work to operate the engine, and lack of government incentives discourage the stakeholders to modify the vehicle even with US$60 only. Additional emission reductions are also possible with improved four-stroke engine design and tuning and through the use of catalytic converters. Catalytic converters are used on two-stroke motorcycles in Taiwan and on mopeds in Austria and Switzerland. Secondly, extra precautions are inevitable during import of two stroke engines, because technology of two-stroke engines is of 1970s. Automobile industry did major improvements in 90’s in terms of tailpipe emission reduction (automobiles produced after 1988 are 90% cleaner than 1970s). Bangladesh government does not allow to import more than 5 years old car; hence no extra precautions are necessary during import of four-stroke new and reconditioned cars. Although, high import tax keeps the stakeholder out of introducing four-stroke engine or advanced engine vehicles into the mass three wheelers. Government initiative and incentive with the private sectors' participation are recommended to introduce better technology, which emit less pollution.

Table 3: Comparison between auto-rickshaw & light duty four-stroke engine vehicles.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Auto Rickshaw</th>
<th>Light Duty Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Capacity</td>
<td>cc</td>
<td>150 ~ 200</td>
<td>&lt;660</td>
</tr>
<tr>
<td>Size (L x W x H)</td>
<td>m</td>
<td>2.34x1.1x1.53</td>
<td>3.29 x 1.95 x 1.44</td>
</tr>
<tr>
<td>Speed limit</td>
<td>km/h</td>
<td>~80</td>
<td>~140</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>km/l</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Passenger Capacity</td>
<td>Person</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Interior facility</td>
<td>N/A</td>
<td>Stereo, AC, extra load</td>
<td></td>
</tr>
<tr>
<td>CO emission</td>
<td>g/km/v</td>
<td>17.11</td>
<td>2.58</td>
</tr>
<tr>
<td>HC emission</td>
<td>g/km/v</td>
<td>12.24</td>
<td>0.27</td>
</tr>
<tr>
<td>PM emission</td>
<td>g/km/v</td>
<td>0.025</td>
<td>0.00</td>
</tr>
<tr>
<td>NOx emission</td>
<td>g/km/v</td>
<td>0.47</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Two-stroke engine vehicles can be phased out and replaced by Japanese light duty vehicles of less engine capacity with cleaner fuel option. Japanese vehicles of less engine capacity are not known to the people of Bangladesh, government with the assistance from Japanese Government can take this opportunity to introduce them which will be much beneficial in cleaning the urban air instead of rehabilitating the two-stroke engine vehicles. These vehicles will be chosen taking care of Dhaka's
road geometry, financial constraints, and environmental condition. Light duty four-stroke engine vehicles are in the market in Japan with engine capacity less than 660 cc. Table 3 provides a comparison between these vehicles with locally running two-stroke engine vehicles (auto-rickshaw). In short, to avoid chaos from political, business, and auto-rickshaw owners and drivers association the recommendation is to arrange a replacement in the existing two-stroke engine vehicles’ industry sector by:

- allowing importers of two-stroke engine vehicles to import new four-stroke engine vehicles,
- allowing importers of two-stroke engine parts to import new four-stroke engine parts, and
- providing permissions of driving new four-stroke light duty cars to those who have been driving two-stroke engine vehicles.

This is one of the recommended ways to achieve a comfortable solution. The only bottleneck is Ministry of Communication, GOB's policy oriented directives to replace the whole industry. The technology for these cars cost almost equivalent to those of auto-rickshaws if government allows tax exemption like the taxi cab services. There is a lot of enthusiasm in private sectors and they are ready to take up projects if government develops policies and arranges foreign financial assistance for them. Raising the awareness among mass people on clean environment by promoting individual responsibility to take measures against pollution and developing convenient system for financial assistance to the people could significantly improve the overall impact of various air quality initiatives.

**Utilization of CNG in Transportation Sector**

The use of locally available compressed natural gas (CNG) to power automobiles is an economically viable option. There are more than 1200 CNG powered private cars and one BRTC double-decker running in Dhaka with the existing 5 CNG refueling stations. This study proposes a pilot initiative of medium/big sized CNG powered buses which will be introduced to one/two routes with one CNG refueling station. These routes partially identified by the World Bank supported DUTP for the year 2003. This pilot initiative will enhance impact on Dhaka’s transportation system as an environmentally friendly mode.

Environment friendly act must start by the government initiative, which will attract private sectors. CNG conversion of a petrol driven car costs only BDT 25,000 (US$50). The current initiative of CNG conversion of government vehicles taken by the PETROBANGLA has not worked well, as drivers do not cooperate to fuel the vehicles with CNG. Most of the drivers are involved in fuel pilferage with the help of labor union and this can not be done when vehicles are powered by CNG. Investment packages to convert public and government vehicles to CNG were announced by the GOB. However, such bottleneck might delay or even scrap the short-term plan. Strong policy support from the government is essential, which requires long time frame in Bangladesh. In addition, conversions to CNG-powered vehicles need an integrated CNG refueling facilities. PETROBANGLA recently identified 50 such CNG refueling stations with high demand, which will be constructed in whole Bangladesh. The total estimated cost for 50 CNG refueling stations is BDT 1.062 billion (US$21.2 million). Strong commitment of the policy makers and efficient management of the concerned agencies are necessary to execute the project.
Reduce Lead in Petrol

Exposure to lead is one of the most significant yet preventable threats to human health. Government initiative in importing low lead gasoline is a timely decision for Bangladesh however it leads high cost of gasoline and for long time the cost must be subsidized by the government. There is an opportunity for the government to renovate eastern refinery of Bangladesh for refining the imported raw petroleum products. Therefore, government can take measures on refining petroleum products for low lead gasoline and to improve the facilities and storage the fuel to enhance its use in private and public vehicles.

When lead is not added to petrol, the octane boost formerly provided by lead must be recovered. There are several choices available today in a modern petroleum refinery for replacing octane, which includes:

- Blend oxygenates such as MTBE (methyl tertiary butyl ether) into the petrol pool. MTBE has exceptionally high octane rating (115 RON) and other desirable blending properties. The current octane number in Bangladesh is 96. MTBE can be produced by combining methanol and iso-butene produced by the fluid catalytic cracking (FCC) unit of a refinery. If MTBE cannot be produced locally, a world trade of MTBE exists.
- Increase refinery production of high-octane blend stocks, such as FCC petrol, alkylate, isomerate, etc. by increasing utilization and, if necessary, expanding or revamping existing process units.
- Increase the octane of reformat by increasing the utilization of reformer severity. Reformats generally have high aromatics and benzene. Benzene is a known human carcinogen and exposure to it, among other things, increases the risk of leukemia. Therefore, increasing refinery severity to an extreme is not generally recommended.

Determining the best options from the choices calls for a detailed technical and economic analysis for the refinery. Worldwide experience and estimates indicate that annual investment expenditures plus operating cost associated with the removal of lead from gasoline are typically in the range of US$ 0.01-0.02 per liter of gasoline.

Reduce Sulfur in Diesel

The sulfur content of diesel in Bangladesh is abnormally high. It is currently 0.5% (max) although state owned Bangladesh Petroleum Corporation (BPC) imports diesel containing 0.2% sulfur, compared to 0.05% in the US, Europe, and Japan. Somewhere in the process the sulfur content increases up to a maximum level of 0.5% in Bangladesh.

Sulfur is removed from fuel through hydro-desulfurization (HDS) process. Hydro-desulfurization is a process by which heavier petroleum feedstocks are upgraded in preparation for refining. Catalysts effect the removal of sulfur from the feedstocks by breaking carbon-sulfur bonds and converting the sulfur to hydrogen sulfide (H₂S), which is removed as a gas. Low-pressure HDS plants can remove 65 to 75% of sulfur, reduce aromatic levels by 5 to 10%, and increase octane number by 1 to 2. Newer HDS plants operating at medium to high pressures can remove more than 95% of sulfur and 20 to 30% of aromatics. The costs of reducing the sulfur content of diesel to 0.05% by newer HDS method are considered moderate-less than 1 US cent (<BDT0.49 ) per liter and the estimated cost-effectiveness is attractive compared with other diesel control measures. A 1989 study concluded that the costs of reducing sulfur content in diesel fuel to 0.05% in Europe would be between 0.9 and
1.4 US cents per liter, equivalent to US$6,000 - $9,000 per ton of sulfur removed.\textsuperscript{15} The fixed cost of rehabilitating refineries with HDS facility to produce low sulfur diesel is quite large, requiring substantial up-front investment. For example, hardware modifications for HDS to an Asian refinery to reduce the sulfur content of diesel from 0.5 to 0.2% were estimated to raise the production cost of diesel by 1.6 to 1.9 US cents (BDT 0.78 to 0.93) per liter.\textsuperscript{16} The present state of air quality in Dhaka demands HDS facilities for the availability of low sulfur diesel.

**Promotion of better Public Transportation Services**

Promotions of better public transportation services like light rail transit and water taxis are essential in Dhaka. On the basis of past transportation study, the programs that have been implemented in Dhaka (over-bridges, fly-overs, under-passes, intersection improvement, one way roads etc) have not prevented congestion worsening. They have not been able to enhance traffic safety or reduce severe environmental problems. This might be due to the increasing growth of population and increasing transportation demand in Dhaka City. The existing transportation infrastructure in Dhaka cannot bear the current traffic loads. The level of services and options of transportation modes are not at all suitable for the passengers and suitable for the environment either. A preliminary investigation and a passenger interview survey in September 1998 led to recommend measures to increase transportation infrastructure in private investments.\textsuperscript{17, 18} This study has already examined the requirements of a light rail transit line in Dhaka from Sadarghat to Uttara and the preliminary investigation results indicate that it can reduce traffic congestion and pollution extensively. The total investment cost for this 20.21-km route is approximately US$210 million. This study has recommended a balancing package of investment to increase the capacity, convenience, and reliability of public mass transport, which is environmentally less damaging. The result of these measures should improve access and a better quality of life both in Dhaka City Corporation and other strategic planning zones of Dhaka metropolitan. Since, rail transit development requires a long term planning initiative and heavy investment, it is better to stress the importance of starting the feasibility studies immediately under the Ministry of Communication. By doing that, after 15-20 years, Dhaka City’s multi-modal transport should be able to satisfy the demand of 16 million people during 2016. Similar measures are also recommended to encourage modal shift to environmentally less damaging modes.

Dhaka is surrounded by four rivers: Buriganga, Balu, Tongi, and Turag. Watertaxis can be planned at the initiative of the Ministry of Communication for low-income commuters as a multi-modal transport facility in Dhaka. This can be done by providing terminals at Aminbazar, Nagarbari linked with Pallabi Mirpur accessed by maxi services, Abdullahpur Tongi, Katasur linked with Lalmatia, Rayerbazar Police ferry, Keraniganj, Sadarghat, Postagola, Kamarghop, Nandipara, Balu Dihitpur, Badda, Gulshan, Purba Harardia, Dakhin Khan, and Ujanpur (Figure 2). Most of the garment industry workers live in the surrounding suburbs and use bus services to have access to their work places. An improvement in watertaxis will alleviate huge load on public transportation especially on buses. This will be a new mode of mass transit for Dhaka City, and will reduce congestion, as well as pollution. The watertaxis will also promote new urban development along the east and western bypasses.
Figure 2: Proposed watertaxi terminals.
Dispersion Modeling Analyses

The World Bank supported air quality management project of DOE has been designed to perform a comprehensive monitoring network in Dhaka, which has less direct and prompt benefit in controlling air pollution. Real time monitoring and sampling provides a way to collect base line data, which is valuable to describe the existing level of air pollution. The monitoring methodology establishes data points applicable only to the location and time of the sampling. No prediction about the ambient level in future or other locations can be made from a single sampling event. In an urban area, such as Dhaka City, the continuous coverage of monitoring at all locations is cost prohibitive and impractical. However, by conducting dispersion modeling using the information gathered about sources and emissions, ambient concentrations of locations where monitoring data is not available can be estimated. Furthermore, the modeling technique will allow predicting future ambient levels from the emissions growth projection. The city planners and growth management agencies will find this information valuable to integrate the predicted future level of air quality in the land use decision making.

The United States Environmental Protection Agency (US EPA) has a model called “MOBILE” which can easily be incorporated to estimate total emissions of CO, PM, and hydrocarbons produced by all the modes of transportation in Dhaka city. The dispersion of emissions at an intersection or roadway can be simulated using a widely used US EPA model named “CAL3QHC.” Besides, there are more sophisticated models available to predict pollutant concentration in urban road microenvironments where roads are located near high-rise buildings. Such a model developed and successfully applied in Japan. This model can also be modified and adjusted to apply in the central business district Motijheel area of Dhaka.

Landuse Planning and Controls

Landuse planning will seek paths to a desirable expansion of the city’s spatial structure, which will sustain urban areas for the long run. The purpose of this planning would be to understand the concept of sustainable urban development and to formulate a spatial structure for turning into a sustainable city. It is found that the current urban structure of Dhaka and other major cities are highly centralized with majority of jobs located in the central parts, whereas the population has been started decentralizing over the time. With this process, more and more traffic flows have been increased towards central city and transferred from public transport to the private car. For achieving a sustainable urban structure, a continual employment and households decentralization process is essential to improve the quality of environment.

Specific landuse planning and controls by decentralization of Bangladesh Secretariat to Shere Banglanagar or Savar with better mass transit facilities, Dhaka Cantonment to existing Savar Cantonment and Dhaka University to Kanchpur (Dhaka-Chittagong Road) area.

AREAS FOR JAPANESE GOVERNMENT'S ATTENTION

Based on the available information this study has identified several areas where Japanese Government can provide technical assistance and financial support in short and long term basis. These are explained in detail in the following section.
Short-term Measures

The first air quality management project (AQMP) of Bangladesh is under preparation. It is expected that demand of new study/sector implementation will arise after completion of AQMP. Based on the objectives of existing projects the following short-term measures require special attention from Japanese Government.

1. Replacement of Two-stroke Engine Vehicle: The government and some development partners already identified that two-stroke engine vehicle is the major contributor of air pollution in Dhaka. World Bank supported air quality management projects in South Asian cities like, New Delhi, India and Kathmandu, Nepal have already recommended to ban this engine. They are already successful in implementing the recommendation and shifting to four-stroke engine vehicles. This study recommends the Ministry of Communication of Bangladesh Government to take a similar initiative with technical assistance from Japanese Government.

2. Introduction of CNG Operated Public Bus: There is an increasing demand of public mass transportation in Dhaka. An environmentally sound option is to introduce CNG operated bus (along one/two routes). This study proposes the experimental introduction of CNG public bus.

Long-term Measures

Dhaka metropolitan is expected to grow tremendously in terms of population and infrastructure demand. A number of long-term measures are required to fulfil the growing demand in transportation infrastructure and environmental management. Infrastructure development always requires heavy investment and substantial planning for the achievement of a cost-effective solution. The following long-term measures are recommended for Japanese Government attention:

1. Renovation of Eastern Refinery: As explained in the previous sections, high lead content in petrol and sulfur content in diesel are two major sources of pollution. An investment package for the renovation of Eastern Refinery Ltd. (the only refinery in Bangladesh) under Bangladesh Petroleum Corporation is necessary in order to facilitate supply of low cost lead-free petrol and low-sulfur diesel.

2. CNG Conversion of Vehicles and Refueling Station: CNG can be used as a clean fuel alternative for petrol powered government vehicles, which will appreciate private sectors in using natural gas. CNG conversion of vehicles demands more refueling stations. PETROBANGLA's current initiative of 50 refueling stations' development is a viable option for Japanese Government to support. This study proposed the expansion of CNG-fueled buses, conversion of cars to CNG, and the establishment of refueling facility.

3. Transportation Infrastructure Development: In addition to current initiatives of the government on mass transit options, light rail transit and waterways terminals can be developed to promote multi-modal transportation in Dhaka.
CNG AS AN ALTERNATIVE FUEL FOR AUTOMOBILES IN DHAKA

In recognition of the importance of immediate improvement of public transportation services and air quality, an expansion of CNG bus services is considered an effective strategy to simultaneously address the two critical issues of transportation and air pollution. While there is an experiment by Bangladesh Road Transport Corporation to operate a CNG bus based on existing facilities, the JBIC funded study has assessed viability of introducing the CNG more extensively in urban transportation system in Dhaka. Two schemes have been reviewed under the study:

**Short-term CNG Bus Scheme**

**Profile of Short-term Scheme**

The short-term scheme has demonstrated CNG bus service as a system on a pilot route, either on the Motijheel-Kuril circular route (25 kms-round trip) or on the Mirpur-Fulbaria route (29 kms-round trip). Both routes serve as heavy traffic corridors with sufficient potential demand (as CNG bus cost is higher than that of equivalent ordinary bus, its target market is the premium quality services). The short-term scheme was designed in a way that the selected routes are provided with adequate frequent services, which are attractive to potential passengers and competitive with auto-rickshaws and possibly passenger cars. The proposed short-term scheme comprises the following project components: (1) CNG bus - 30 CNG minibuses or 18 CNG big buses which can provide high frequency of 3 minutes or 6 minutes, respectively; (2) CNG station - One station to serve the above buses efficiently.

The cost of the short-term scheme is as follows:

- 30 units of CNG minibuses  TK 186.0 million (US$3.72 million)
- 18 units of CNG big buses  TK 196.2 million (US$3.92 million)
- 1 CNG station (excluding land)  TK 27.7 million (US$0.55 million)

Therefore, the total cost of the short-term scheme is TK 213.7 million (US$4.27 million) or TK 223.9 million (US$4.49 million).

**Evaluation of the Short-term Scheme**

The scheme was evaluated from the operation, financial, economic and environmental viewpoints. The results are as follows:

1. The scheme can provide competitive services with high frequency (headway of 3-6 minutes) and relatively low operating cost (Air-conditioned and all seated, 30 seats for minibus and 52 seats for big bus.) which are attractive to potential passengers. Estimated number of daily passengers is 13,000 to 15,000 for Mirpur-Fulbaria route and 15,000 to 17,000 for Motijheel-Kuril route.

2. If the fare is TK 12 flat per passenger ride, Financial Internal Rate of Return (FIRR) is about 16% for the Motijheel-Kuril route and 12% for Mirpur-Fulbaria route. If the fare is TK 10, then the FIRR will be reduced to 7% and 5%, respectively.

3. Economic evaluation has been made by comparing the cost and the benefit of the scheme. It is assumed in the analysis that the cost is the difference in the costs of CNG bus and equivalent diesel
powered bus, while the benefit include saving in fuel cost and benefit (or saving in vehicle operating cost) due to diversion from auto-rickshaw/taxi/car to CNG bus. Under these assumptions, the minibus can not generate positive Economic Internal Rate of Return (EIRR), while the big bus generate about 0.6%.

(4) It is estimated that lifetime emission benefits of operating a compressed natural gas minibus instead of a diesel minibus is equal to 2.016 tons of NO\textsubscript{x}, 0.345 ton of HC, 0.75 ton of CO, and 1.04 tons of PM. And lifetime emission benefits of a big CNG bus is 7.8 tons of NO\textsubscript{x}, 1 ton of HC, 2.8 tons of CO, and 2.56 tons of PM.

**Long-term CNG Bus Scheme**

**Profile of Scheme**

It is assumed that the future premium bus services (PBS) and a portion of standard bus service (SBS) will be provided by the CNG bus system. Major corridors will be served by big CNG buses and secondary routes by CNG minibuses. It is estimated that a total of 140 big CNG buses and 200 minibuses will be required by 2008, accounting for approximately 12% of the total number of buses in Dhaka. Six CNG refueling stations will be needed to serve these buses. The estimated operating cost of CNG buses (CNG big bus Tk35/km) is higher than that of standard buses (big bus Tk25.5/km), the former should basically be targeted to provide premium services.

**Evaluation of the Long-term CNG Bus Scheme**

The scheme was evaluated from the operation, financial, economic and environmental viewpoints. The results are as follows:

(1) To make the operation financially viable the fare should be at the level of Tk 12 or more. The sensitivity analysis indicates the increase in cost will affect FIRR to a lesser extent than the decrease in revenue. This implies that marketing and promotion efforts are important.

(2) Economic evaluation has been made by comparing the cost and the benefit of the scheme. It is assumed in the analysis that the cost is the difference in the costs of CNG bus and equivalent diesel powered bus, while the benefit include saving in fuel cost and benefit (or saving in vehicle operating cost) due to diversion from auto-rickshaw/taxi/car to CNG bus. Under these assumptions, the minibus can not generate positive EIRR, while the big bus generate about 4%.

(3) Emission Impact of Regular bus and Minibuses: There will be a requirement of 140 regular and 200 medium sized high quality premium bus services along selected routes of Dhaka. It is estimated that about 70% of NO\textsubscript{x}, 60% of HC, 50% of CO, 100% of PM, and 100% of SO\textsubscript{2} reduce due to the introduction of CNG buses.

**Long-term CNG Station for Car Scheme**

**Profile of Scheme**

There is an opportunity to expand CNG stations to serve cars. According to the officials of PETROBANGLA and other transportation agencies in Bangladesh, there is a strong demand for
converting cars (the strong demand is due to the much lower price of CNG compared to gasoline. The cost of conversion is also low) for the use of CNG on condition that efficient CNG stations and conversion are readily available. It is assumed that 30% of the cars/jeeps will use CNG and a CNG station has fuelling capacity of 4,000 m³/day, a total of about 34 CNG stations will be necessary in Dhaka (2008).

**Evaluation of the Long-term CNG Station for Car Scheme**

The scheme was evaluated from the operation, financial, economic and environmental viewpoints. The results are as follows:

1. The financial evaluation of a CNG refueling stations for car, which is composed of a set of CNG cars and CNG stations, was made by comparing the costs and revenue. The costs include acquisition, insurance, licensing, salary, overhead and operating costs and construction, operation and maintenance and fuel costs of a CNG station.

2. The results of the exercise indicate that FIRR and EIRR of the CNG refueling station for car is extremely high, mainly because the benefit of fuel is very high.

4. Emission Impacts of CNG cars: Projected total 90,500 light duty vehicles will run on the street in Dhaka in the year 2008. It is estimated that about 88% of NOₓ, 89% of HC, 92% of CO, 100% of PM, 100% of SO₂, and 100% of Pb reduce due to the conversions of petrol cars to CNG.

**CONCLUSIONS**

This study promotes a green agenda for the citizen of Dhaka and identified that an integrated approach is required to improve environmental quality of Dhaka. Several recommendations are made to improve the air quality of Dhaka, among them:

- Coordination among development partners is necessary to avoid duplication of approaches.
- Replacing two stroke-engine vehicles immediately by four stroke engines.
- Reduce lead and sulfur content from fuel in well planned way.
- Conversions of urban traffic fleets to natural gas. Appreciate transport infrastructure development in private finance.

The challenge for the government of Bangladesh is to understand the transportation as well as the pollution problem which has been deteriorating the urban human life. The real challenge is to take immediate action programs for controlling air pollution in Dhaka.

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