Going subterranean

Admittedly, Dhaka's traffic system is on the verge of a total collapse. Ever-increasing population has resulted in progressive deterioration of street transport system over the years. The time has come to devise a mass transportation system that encourages people to live in the suburban areas and thereby reduce the growth of population near the business centres, writes Dr. Mir Maqsud Ali as he advocates for construction of subway

We need to find an alternative option to the overburdened traffic system

POPULATION OF DHAKA has grown from only 250,000 in 1950 to about 11 million in 1999. It is predicted that this population will further grow to 20 million in the year 2020 and to 25 million in 2025. A principal reason of this rapid growth in recent times is the fact that Dhaka has assumed the role of a metropolis after the independence of Bangladesh and is the nerve centre of the country. There have been relatively little improvements in other cities, towns, and villages in terms of infrastructure development and attracting people to live and work there. Improved road communication in the country has made it easy for rural people to converge on Dhaka for finding employment. Rivers and flood-prone areas on its south, east and west sides bound the city. It is only on the north and north-west where it is growing. A new phenomenon that has also developed lately is the mushrooming of residential high-rises in a somewhat uncontrolled manner overloading the city's services and creating light and ventilation problems for residents.

Historically speaking, people have a love-hate relationship with large cities. While they are attracted by the liveliness, job opportunities, access to the centres of socio-cultural, governmental and trade activities, and availability of healthcare and other facilities of large cities, they also want to flee from poverty, filth, pollution, traffic jams and crime - the evils of cities. In Dhaka all of these problems warrant immediate attention. When we realise that the city population is drastically growing, and nothing is really happening to change it, we are virtually waiting for a looming disaster on the horizon.

The street scene

STREET TRANSPORTATION SITUATION has progressively deteriorated over the years. Of late, visitors to the city complain of air pollution, choking of traffic-even for emergency vehicles and ambulances-and unusually long time needed to go from one part of the city to another. The polluted air contaminated by the toxic lead emitted by automobile exhausts is going to have serious health hazards for the citizens. When we consider the city's mass environment we have to take into account that there are a lot of people moving on the street in cars, rickshaws, autorickshaws, trucks, buses and other modes of transportation. Presence of thousands of slow rickshaws makes the problem even worse. Citizens from within the city and the suburbia come out and return home almost at the same time, during peak business and office hours, and in the evenings for shopping. The present transportation system is simply inadequate to take the pressure. Although the population and volume of traffic have increased dramatically, the number of streets has not increased in that proportion and is highly inadequate. As a result, even the narrow lanes have become crowded with traffic. Lack of respect for traffic and street regulations by citizens also contributes to the problem. Because of the existing conditions of the city streets, no room for lateral expansion is feasible.

We must learn from the experience of other large cities of the world, which have handled these problems well and resolved them successfully. Our stubbornness or indifference to accept new ideas to solve our urban maladies will get us nowhere. People of Bangladesh in the past did not face these problems that are only getting worse every day. It is time we removed the shackles of our past and look forward to solving these problems with an open mind in an innovative way. Public transportation is clearly one such problem that demands immediate resolution and should be placed at the top of our priority list to make Dhaka a liveable city.

Not only do traffic congestion and air pollution cause environmental and health problems, there is also an economic premium to be paid. The crawling pace of traffic results in wastage of valuable time and reduces productivity of people. Business suffers, people are late to work and other destinations, and edible produces and raw goods rot early on the way. Traffic jams also create social problems like increased number of beggars on the street. The idling automobiles, buses and trucks burn valuable fuel during traffic jams resulting in wastage of our limited energy resources. The total economic loss can be estimated to be millions of dollars per year. By one estimate, this figure is 200 million US dollars annually (*Muktokantha*, *Traffic Jam: Loss of One Thousand Crore Taka Every Year*, October 25, 1999). Chaotic traffic of Dhaka reflects the national psyche and creates an unfavourable impression on tourists and other foreign entrepreneurs who may consider making financial investment in this country where labour cost is cheap.

Rapid transit options

A WELL-PLANNED mass transportation system is immediately needed to solve the problem of Dhaka's street transportation. Such a system will encourage people to live in the suburbs and consequently the density of population in the city near the business centres will not grow any more at its present rate. There are two possible options for Dhaka: a. an overhead bridge system, and b. an underground tunnel system.

An overhead or elevated system (flyovers) for street traffic is feasible in limited areas where the congestion is the maximum. A large-scale overhead system, however, means an extensive network of "bridges" throughout the city. This is not only cost-intensive but also impractical. To build the piers of these bridges, many existing facilities and structures have to be demolished and many inhabitants in this densely populated city have to be displaced. With the rise in city population, the bridge lanes with street traffic will again be clogged. Similarly, cost of elevated heavy rail for mass transportation is simply prohibitive. Many of the existing open and broad streets of the city will lurk in the shadows these second-story bridges. They will obstruct light, air and privacy and create nuisance from constant noise and drippings from the structure in rainy weather. Public safety at the lower level will be jeopardised by falling objects. Air pollution will increase even further at two levels, or at least will not decrease. In short, the consequences will be less than happy. New railway tracks to allow for surface trains will be difficult to build in the built up areas and will be constantly encumbered by the street traffic. Other desirable measures like improving traffic flow pattern and creating one-way streets or new diversion roads will temporarily improve the situation but will eventually creep into familiar problems until a long-term measure is adopted. This is precisely the reason why most cities of the world have judiciously decided to implement an underground transportation system.

Asian cities like Tokyo, Hong Kong, Singapore, Manila, Taipei, Calcutta, Cairo and Bangkok are good examples of underground rail. Most recently, Bangkok has taken this step in favour of a subway to solve its traffic congestion problem, even though the city has already built an elevated rail system (*New York Times*, *Bangkok Opens Skytrain, but Will it Ease Car Traffic?* December 6, 1999). Calcutta, our closest neighbour, has always been notorious for its traffic woes. Recent visitors there have reported a marked reduction in street transportation crowding.

Subway construction

WORLDWIDE GROWTH OF population and urbanisation and the accompanying problems of congestion, environmental disruption and pollution point to the need for and the importance of using underground space. Increased costs of land and surface structures and improved underground excavation and tunnelling methods make use of underground space more attractive.

Several factors influence the decision for adopting an underground subway system. The principal factors are technical feasibility, soil conditions, interference with existing buried infrastructure and other structures, flood protection, and cost of construction and maintenance.

Technical Feasibility: Tunnel-building is an ancient phenomenon. The technology of present-day tunnels is about two centuries old. Marc Brunel's tunnel under the Thames River in London was started in 1821 and completed in 1843. Some other notable underwater tunnels exist beneath the St. Lawrence River in Montreal; Detroit River between Detroit and Windsor, Ontario; and Hudson River in New York. The famous Holland Tunnel was opened to traffic in 1927 followed by the Lincoln Tunnel in 1937. Both these tunnels run under the Hudson River and connect New Jersey to New York.

The first railway tunnel in the USA was the Allegheny Portage Railroad in Pennsylvania built in 1833. Scores of other tunnels criss-cross the country. The first underwater tunnel of the USA is the Washington Street Tunnel beneath the Chicago River built in 1870 for horse-drawn vehicles. Construction of New York City's subway systems started in March 1900, and the first train operated on a nine-mile track on October 27, 1904. It is worth noting that by the year 1900 many of the world's major cities—including London, Paris, Boston, and even Glasgow and Budapest—had fully operational subway transit systems. Even the city of Amsterdam, having an elevation below sea level, has underground tunnels.

A station in the New York subway system

One of the outstanding construction achievements of recent years is the Channel Tunnel linking England and France traversing under the English Channel. This tunnel was designed by a British consultancy, Mott MacDonald, aided by many other consultants. The builders were Transmanche, a consortium of ten leading French and British contractors.

No one should, therefore, doubt anymore the technical viability of tunnel construction. Man has indeed conquered the inaccessible underground and underwater spaces as he has conquered the sea, air and space. A recently completed project is a pair of tunnels built under adjoining runways at the John F. Kennedy Air Train Project. The tunnels run through an area of high water table but construction drawdown was not an option because of nearby fuel-contaminated soils. This project has been a great challenge and the first of its kind in the USA because the site is crowded and the two runways are adjacent, so construction of each tunnel has to proceed beneath the jet planes. The tunnels were designed by Mueser Rutledge Consulting Engineers of New York and the contractor is E. E. Cruz and Company, Inc. of Holmdel, New Jersey. Tunnel technology is now at such an advanced stage of development and is becoming so sophisticated every year in terms of construction, ventilation and fire safety that it needs no further emphasis.

There are a few methods of tunnel construction. They are cut-and-cover method, shield method, machine-tunnelling method, caisson method and submerged tunnel method. The cut-and-cover and shield methods are most common for open excavation-type construction and underground drilling of soil, respectively. Where there are fewer obstructions, cut-and-cover method is appropriate, whereas in areas with obstructions and encumbrances, the shield method or some other drilling method is appropriate. The shield is a very large "can" with both ends open, pushed through soft ground by thrust jacks. The cutting edge at the front end proceeds while drilling through the soil is carried out. The shield provides safety to the workers and prevents cave-ins. Machine tunnelling generally refers to underground excavation whereby the ground is disintegrated by milling, scarifying or crushing with power-driven tools, and is very popular now. For double train tracks a wide basket-handle type tunnel cross-section is desirable.

Soil Conditions: There is a general misconception that soil conditions may deter the construction of tunnels. Those who are familiar with the history of tunnel construction are aware that although sub-standard soil conditions may pose formidable problems, they are amenable to solutions. All major tunnel projects encounter such problems in one way or another. The ground and soil conditions of Tokyo are no better than Dhaka's, and those of Bangkok are much worse. Most of Bangladesh is underlain by flood-plain deposits from ancient and recent rivers. Dhaka's soil is composed of brown to light brown clay and silty clay belonging to Madhupur Soil Group about nine metres deep with fine dense sand at lower strata below the clay layer and can potentially carry up to 50-storey high-rise buildings. With the use of structural steel or lightweight concrete, in conjunction with a deeply excavated foundation to compensate for the structure's weight, this height may be increased to even 60 stories.

A major challenge of tunnel construction is to prevent caveins. Tunnels are generally supported with braces, ribs, roof bolts or grout during construction. For soft ground, boards are driven around roof and side walls. Caving-in is prevented by liner plates or steel ribs, additional bracing and other similar techniques as tunnelling proceeds. Pressure grouting is another technique to strengthen the soil. A secondary lining usually of reinforced concrete is subsequently installed over the primary lining (installed during construction) to strengthen the tunnel and to keep dirt and water out.

Water is always expected during the tunnelling operation. For a high water table, additional drainage arrangements may be needed. The highest water table in the main areas of Dhaka City (e.g., Lalbagh, Gulshan and BUET Campus), where observation wells are located, is found to be from eight to 12 metres below ground level. During dry seasons the water table is much lower (about 12 to 16 metres below ground level). Water tables in the outskirts of the city are much higher. A number of pre-drainage methods for tunnel de-watering are known to be used by engineers. Improved de-watering equipment and techniques today have made pre-drainage of soils a relatively common occurrence in tunnel operations. Some of the methods adopted to keep water out are: pumping away water, using air compressor or freezing water by installing refrigeration pipes.

Hugh Lacy, partner of Mueser Rutledge Consulting Engineers of New York in charge of tunnelling, summed up his feelings on soil conditions by stating to the author that tunnels can be built anywhere—even in locations with soft or poor soil conditions.

According to Mohammed Irshad, Vice President and Director of Infrastructure Engineering of Parsons Corporation, and an expert on tunnel design and construction, Dhaka is much more readily amenable to tunnelling operations than Bangkok where the soil is unstable and initially the idea of tunnelling caused a gridlock in the decision-making process. After building an expensive overhead rail outside the city core area with considerable difficulties with foundations as well as cost overrun and delay, a decision to build a 20-kilometre tunnel was taken. Irshad, who is based in Washington, DC, pointed out that in its design a tunnel boring machine has been assumed for digging underground and sophisticated technology to be employed to stabilise the soil. Initial work has already begun. The overhead rail/highway bridge has been done by the government in its first segment. The recently completed skytrain belongs to this segment. The second segment of overhead rail was started by a financier and is undergoing major problems. The government has now reportedly taken over the subway project as the third segment, which is expected to be, completed within the next three years. It may be noted here that Parsons is a multi-national corporation and its transportation group is an industry leader in tunnel and underground construction. The company has worked on a number of world's largest and most complex tunnelling projects.

In contrast with Bangkok, Dhaka's soil condition is relatively simple to cope with. The roof of the tunnel can be placed in the stable clay layer at about eight metres below ground surface and the tunnel base can be established on fine dense sand at about 15 meters below surface. The sand can be readily dewatered before construction. No expensive rock cutting is involved.

Interference with Buried Structures: Interference of tunnels with sewers and other services can be avoided by laying out the tunnel properly. Deep tunnelling should go underneath these elements. When possible, underground transportation tunnels are optimally laid out with straight lines connecting two points to accomplish the shortest distance. Horizontal layout and vertical elevations can be determined by engineers to minimise any conflicts and for maximum economy. If tunnels have to be routed under buildings, any foundation movement can be prevented by going deeper and by providing additional bracing to maintain soil stability. Tunnels running under buildings with deep foundations should preferably be re-routed. In unavoidable situations, a few piles creating obstruction in the tunnel path may, however, be removed by providing temporary supports or underpinning, and then designing the tunnel to carry the additional loads by transferring these loads from the building's foundation to the tunnel structure. When a tunnel alignment includes complex curves, both horizontally and vertically, in order to avoid obstacles or to change directions, the task of steering the tunnelling machine becomes difficult. Proprietary systems to successfully solve these problems have already been developed. In short, these are common problems faced during tunnelling operations in large cities and have successfully been resolved in the past. For cut-and-cover tunnelling, some buried elements like sewers may have to be relocated. To carry the vertical and lateral loads, tunnel roofs and sidewalls are designed by structural engineers to ensure strength and safety. Arching of the tunnel roof especially increases the strength drastically.

Flood Protection: An important issue that especially applies to tunnels in Dhaka is the flooding that takes place frequently. The 1988 and 1998 floods submerged large areas of the city. A simple approach to handle this problem is to build water-retaining walls high enough above the flood water level around the tunnel entrances. People have to go up this wall before they descend into and enter the subway. The tunnel itself is not affected by flood because it is designed to be watertight. However, the ventilation of the tunnel must be maintained during the flood if the tunnels remain operational.

Another approach is to allow the floodwater in the tunnel and close down the tunnel operation during the flood. In this case the mechanical/electrical equipment and instruments inside the tunnel that are likely to be damaged must have provisions to be sealed. At any rate, flood-protection is a manageable problem.

Cost: Based on the cost of tunnels built recently, it can be estimated that a tunnel costs about 20 to 25 million US dollars per kilometre. The actual cost will depend on site conditions and other factors pertaining to Dhaka. To begin with, a 10-kilometre stretch of subway system will, therefore, cost about 250 million US dollars plus the cost of stations and other related auxiliary items. As mentioned before, Bangladesh already loses 200 US dollars million annually due to its present traffic jams. The tunnel network can always be expanded as the need grows and funds become available. Even though the short-run cost may be slightly higher than that of elevated rail, the long-term rewards are immeasurable. It is the life-cycle cost that is crucial to any benefit/cost analysis. The political leadership of Bangladesh should take steps to secure the funds—preferably through the country's own resources, and if necessary, by borrowing from international agencies or wealthy countries—to realise this project immediately. If a mega-project like the Jamuna River Bridge could be built in Bangladesh spending one billion US dollars, so can a subway system be envisioned and constructed. There is simply no excuse of money for this worthwhile cause. The other alternative is to get a private financier, in which case it demands the government's co-operation. The government's involvement in this case is marginal and mostly regulatory.

This proposed rapid-transit tunnel would make travelling and moving easier and quicker. Substantial savings in commuting and travelling time will motivate people to use it. It will reduce street congestion and is not encumbered by surface traffic. It will cut pollution. Air from inside the tunnel can be taken out and put back in the atmosphere by tunnel ventilation systems after scrubbing it clean. It will bring tourist and investment dollars to the economy. It will reduce social problems. The railway tracks in the tunnel need no lighting since the headlights of trains light them up. Only the subway stations need lighting and security measures. Tunnels can even be used as safe facility during wars. During World War II, the subway in London functioned as a safe defence facility against bomb attacks. Finally, tunnels are free from hostile environmental effects and hence structural deterioration is minimal. For this reason, tunnels can last for a long time—hundreds of years—and perhaps even more. The cost of maintenance is insignificant. The long-term benefits of tunnels far outweigh the initial cost. A subway system will result in long-term sustainable growth and socio-economic development of Dhaka. Our future generations will thank us for it.

Flexibility, change

FLEXIBILITY AND CHANGE are part of a society. Building a tunnel in Dhaka is going to be a new experience for the citizens. It will lead to transfer of technology and other beneficial things for Bangladesh. Tunnel construction is a complex engineering project that calls for extensive information gathering, co-ordinated decisions, integrated planning and organised execution and monitoring on a grand scale. It demands strong political will and determination of the country's rulers. Successful completion of the project, and the safety of the workers and of the people who will use the tunnel depend on how carefully the digging and construction are planned. It will warrant the employment of experienced and reputed subway consultants.

A master plan for the tunnel network for Dhaka may be developed following a feasibility study and the construction may be done in phases beginning with perhaps 10 to 15 kilometres. Initially the underground rapid-transit system may be built in the crowded city area starting from the Motijheel Commercial Area to Kowran Bazar, old Dhaka, New Market, etc. It could be extended gradually if financing permits with new tunnel lines to suburbs like Gulshan, Mirpur, Uttara, and other outlying regions—and even to Jinjira by tunnelling beneath the Buriganga River.

Tunnels are so practical and have become so widespread throughout the world that in major cities they are part of everyday life. For example, every day commuters in New York stream beneath the rivers surrounding Manhattan. So do people in Tokyo, London, Singapore, and Hong Kong. People simply forget that the great weight of earth, rock, buildings, and water is held back over their heads by steel, concrete and masonry. Tunnels are the fastest and safest mode of transporting a large number of people by subway trains. City streets throughout the world are getting more and more crowded and going underground is the only option left. For Dhaka, an underground rapid-transit system is inevitable—the question is not whether but how soon. The sooner it is done, the sooner the city dwellers will be relieved of the increasingly unbearable and frustrating transit situation. It is emphasised again that an elevated system will be a giant mistake as many cities, including New York and Bangkok, have found. New York demolished its overhead tracks after building them in the 19th century.

Currently, the Government of Bangladesh is contemplating to build an overhead light rail system with single piers located in the median of some major streets. This will mean that its route has to strictly follow the alignment of existing streets making it inefficient because different areas can otherwise be optimally connected through underground tunnels with flexibility and ease. Of course, tunnelling under streets incurs minimum obstruction and is desirable. Moreover, Dhaka is in a moderate seismic zone. During an earthquake, the top-heavy single columns supporting the tracks will be highly vulnerable. Tunnels in moderate seismic zones are not as vulnerable and, if at all necessary, seismic joints can be provided at regular intervals of their length to permit dissipation of energy. Overhead rail will degrade due to the onslaught of the monsoon season. Lately, Karachi has reportedly dropped the plan of an overhead system for its mass transportation. Although overhead rail may be feasible in some sparsely populated suburban areas, it is certainly not practical for a crowded city like Dhaka. The suburbs of today will turn into congested areas in the future. Also, light rail is inadequate to move a large number of people. A heavy rail is comparable to underground rail and the cost will be much more.

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