A STUDY ON APPLICATION OF NATM METHOD FOR CONSTRUCTION OF METRO SYSTEM IN DHAKA CITY

BY

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MASTER OF SCIENCE IN CIVIL ENGINEERING

(TRANSPORTATION)

DEPARTMENT OF CIVIL ENGINEERING

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The thesis titled "**A study on application of NATM method for construction of Metro system in Dhaka city**" submitted by **Mohammad Farzad Farazandeh, Roll: 04084426(F), Session April 2008,** has been accepted as satisfactory in partial fulfillment of requirement of the degree of Master of Science in Civil Engineering (Transportation).

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February 2010 **MOHAMMAD FARZAD FARAZANDEH**

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ABSTRACT

A study on the application of various methods of construction of underground metro for Dhaka city is undertaken in this thesis. A tunnel route alignment along the existing road surface starting from Pallabi to Sayedabad is chosen for this study. Infrastructure nearby the route that may affect the total tunnel construction or that may get affected by underground tunneling is identified in order to propose the best possible metro construction system for the route. A high density of the buildings nearby the selected route is found to be located between Bijoy Sarani and Bangla motor intersection. Also some rare and large structures are located in the Pallabi area. Based on the nature of the methods discussed in this study none of the existing structures in the route create a big problem.

Identification of challenges to be encountered on the route of the Metro construction is undertaken in this study. Availability of unmanaged and unarranged network of utility lines lying beneath the road surface in the selected route makes the management of the city utility networks in case of tunnel construction a bit difficult as cut and cover method of construction is concerned. Also present situation of the network of utility line which means dislocation and relocation for construction of metro is a great cost in this aspect. Another challenge to be faced in this route is application of future development programs in the Dhaka city. In two points of the route there are very large conflicts among the three projects meeting which they need synchronization today in order to construct all the projects in future for specified point. Application of any proposed project without synchronizing with other two makes the application of other project very difficult or even impossible. The third challenge identified is the presence of large buildings nearby which they will affect the earth retention systems design.

In this study an analysis regarding the metro route, the stations and the proper construction method is presented. Proposed 15.21 km of the route, 12 stations and tunnel section as well as the section suitable for the New Austrian Tunneling Method (NATM) proposed. The construction method details about the steps required in New Austrian Tunneling Method (NATM) is included in this study as well.

A cost analysis is undertaken in order to assess the total costs needed for any considered method of tunnel construction. This analysis is restricted to the cost of tunneling only. The detailed costs like construction of station utilities etc are not considered in this study. Also in this thesis NATM and Cut and Cover costs are compared. Based on findings and calculations, NATM method shows to be 25.12 % cheaper than Cut and Cover method by the total cost of Tk7, 507.2 million for NATM and Tk 9,392.99 million of Cut and Cover. Due to large capital cost for Tunnel Boring Method (TBM) as compare to NATM and Cut and Cover, this TBM method was not considered in this analysis.

Selected route is subjected to large utility networks of WASA Titas Gas, Electricity and BTCL located all along the route with their specific behavior to the tunneling process. Some of these utility lines need to be relocated, displaced, and replaced during the construction. Also proposed projects by DCC, STP 2004 and Bangladesh Bridge Authority (BBA) are to be constructed along the route, which synchronizations of the present at meeting points due to conflicts should be considered. As the conflicts, challenges and flexibility of the construction method is concerned, NATM shows more practicality as compare to Cut and Cover. The NATM has no conflict with Utility networks, and there is no limit in deep excavations to eliminate the effect of surrounding elements which the Cut and Cover shows a lot of difficulties in this aspect.

This study revealed that despite all of the present challenges in the route, application of Metro tunnel construction is feasible for Dhaka city. Based on this study the best method of contraction is NATM in aspects of cost, technology, ease of application and independency of science. Also due to less amount of conflict between NATM and the surrounding elements and due to ease of synchronization by environment, application of NATM method for Dhaka city underground metro construction is suggested.

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LIST OF ABBREVIATIONS

BBA	: Bangladesh Bridge Authority
BRT	: Bus Rapid Transit
BRTA	: Bangladesh Road Transport Authority
BTCL	: Bangladesh Telecommunication Company Limited
BTRC	: Bangladesh Telecommunication Regulatory Commission
BUET	: Bangladesh University of Engineering and Technology
DCC	: Dhaka City Corporation
DESCO	: Dhaka Electric Supply Company Limited
DMDP	: Dhaka Metropolitan Development Plan
DPDC	: Dhaka Power Distribution Company limited
FHWA	: Federal High Way Administration
GDP	: Gross Domestic Product
LRT	: Light Rail Transit
MRT	: Mass Rapid Transit
NATM	: New Austrian Tunneling Method
PWD	: Public Work Departments
RMR	: Rock Mass Ratio
RQD	: Rock Quality Designation
SEM	: Sequential Excavation Method
STP	: Strategic Transportation Plan
TBM	: Tunnel Boring Machine
WASA	: Water and Sewerage Authority

1.1. General

By development of human societies and technology, there is always a great constrain regarding the space, utilization because of constant spaces and positive growth rate for population and technology. Despite of scientists‟ effort regarding population control and utilization, space limitation is a great concern in such a way that even the theory of living in mars is approaching to the reality in recent years regardless of impossibilities and difficulties faced even in theory in last decades. That s why astrologists are looking for mars for accommodation, farming scientists are looking for seas and undersea facilities for agriculture and transportation engineers are looking for spatial and underground structures.

As in any developed society with complex transportation infrastructure, congestion has always been a start for alternatives and solutions of transportation issues which so many of them have been solved by unique transportation solution such as traffic flow improvements techniques (at grade improvements) , spatial traffic flow improvements (grade separated) and underground structures which as the last always gives a great opportunity for a vast variety of capabilities underground, as there is always not much constrains in number as compare to at grade and grade separated facilities.

Traffic jam is showing to be the major problem in Dhaka city for the last decade. As there is no growth for the transportation infrastructure as compare to geometric growth rate of population, road and the networks are not capable of accommodating the demand. Despite of land surveys regarding making of more road links, more interchanges, and more flyover, Dhaka traffic problem does not show any improvements due to limitations. As it has been the same problem in the developed cities such as Network, Tokyo, New Delhi, London, etc, subway systems are used successfully. Metro system is believed to be one of the most superior with respect to volume of mass transport, uninterrupted operation, safety, noise, pollution and preservation of city space.

Any tunnel in Dhaka can be constructed by any of three main modes of construction, as Tunnel Boring Machine (TBM), New Austrian Tunneling Method (NATM) and Cut and Cover. Cut and Cover and NATM are known as the more economic as well as less technology demanding and TBM is known as the most expensive and most automated form of excavation. Also cut and cover demands a large excavation and fill back as compare to other methods. Also it may disturb the surrounding structures nearby. Peck (1969) Goldberg et al (1976) Mana (1978) Clough and O‟ Rourke (1990) and Long (2001) have identified the factors influencing the ground deformation due to excavation, stress around tunnel and stability after excavation are described in Matsumoto and Nishioka (1991) .

1.2. Reasons for Underground

Underground spaces is a position which may be used as the setting for the activities or the infrastructures that are difficult, spatially impossible or not beneficial, or environmentally undesirable and offers a natural stoppages of undesired factors. The containment created by the structure protects The Surface environments from their risks/disturbance inherent in certain types of activities. Underground space also provides temperature control, noise isolation and environmentally acceptable location for unwanted but necessary facilities. The use of underground space has recently gained popularity in the developed countries for civil, industrial, residential and even recreational facilities. In densely populated cities like Dhaka, the contrast between available spaces and spaces for different functions is enormous. Highways congestion and increased daily travel time appeared to pose a threat on daily life. The growing number of vehicles generates daily traffic jams, pollutes air and creates conflicts with the pedestrians the traffic become a real nightmare, aggravated by ineffective transportation system at the surface. Underground subway system is the only alternative that can solve the problem. Subway system also provides a balanced coordinated well-managed and efficient support system, which is a precondition for the sustainable developments and economic growth of Bangladesh.

Another case which Dhaka is suffering from is the limitation for at-grade improvements, which is mainly defined as the space limitation which does not allow any further link construction or traffic flow improvement by improvement techniques. Also in case of Grade separated structures, Interchanges are not applicable due to lack of space in providing Direct and Indirect access of the ramps to different levels of interchanges.

Meanwhile application of Flyovers is no longer an option in Dhaka city due to consuming the best lanes of the road and diverting the buses and heavy trucks under the flyover which is a great jam at-grade level and due to attraction of small vehicles to flyover, congestion at landing of flyover. Also in future BRT systems, as the BRTs should be located at the middle of the street to have a good operation, future application of BRTs is concerned to be conflicted by functionality of the flyover.

1.3. Metro Rail Proposition for Dhaka City

In this thesis analysis and cost estimation of a metro line for Dhaka is concerned. Although selection of route is considered to be a very vast study demanding, based on factors such as road traffic pattern and corridors, volume, soil strata condition, land use strategies in present and future, sustainable development and economic benefits , etc.

Based on different proposed metro lines by STP 2004, there are three metro lines of which one is selected as the topic of this thesis. Due to concentrated traffic and population in main corridor of north south of Dhaka, and as compare lesser traffic in east west alignment or around the city in circular metro pattern, proposed metro line of Line No.6 of STP2004 (MRT6) is selected. Although this line is subjected to various at-grade intersections and congestion, there is not much right of way left open in construction purpose. So selection of a construction method is a concern which leads toward a non disturbing method of construction which does not interfere with the environment. Figure 1.1 shows a view of existing route from developing areas at west of cantonment area up to Saidabad Tongi bridge to Kamalpur station. There are some reasons for selection of proposed route in the following alignment such as:

1. Presence of congested roads and traffic and intersections at-grade in selected route.
2. Future development of Phase three of Uttura satellite city in makes a lot of migration attraction to North West of Dhaka which due to proper metro route management will be organized in a good matter of transportation.
3. Based on STP 2004, as there is a strategy regarding the development of routes four and five, there can be a critical connection between route 6 (present one) and route 4 in north (Tongi) and in center of the city which leads in to a large loop system carrying commuters in north south direction in MRT network. Following in Figure 1.1 a typical map indicating the future Development of MRT4, MRT5 and MRT6.

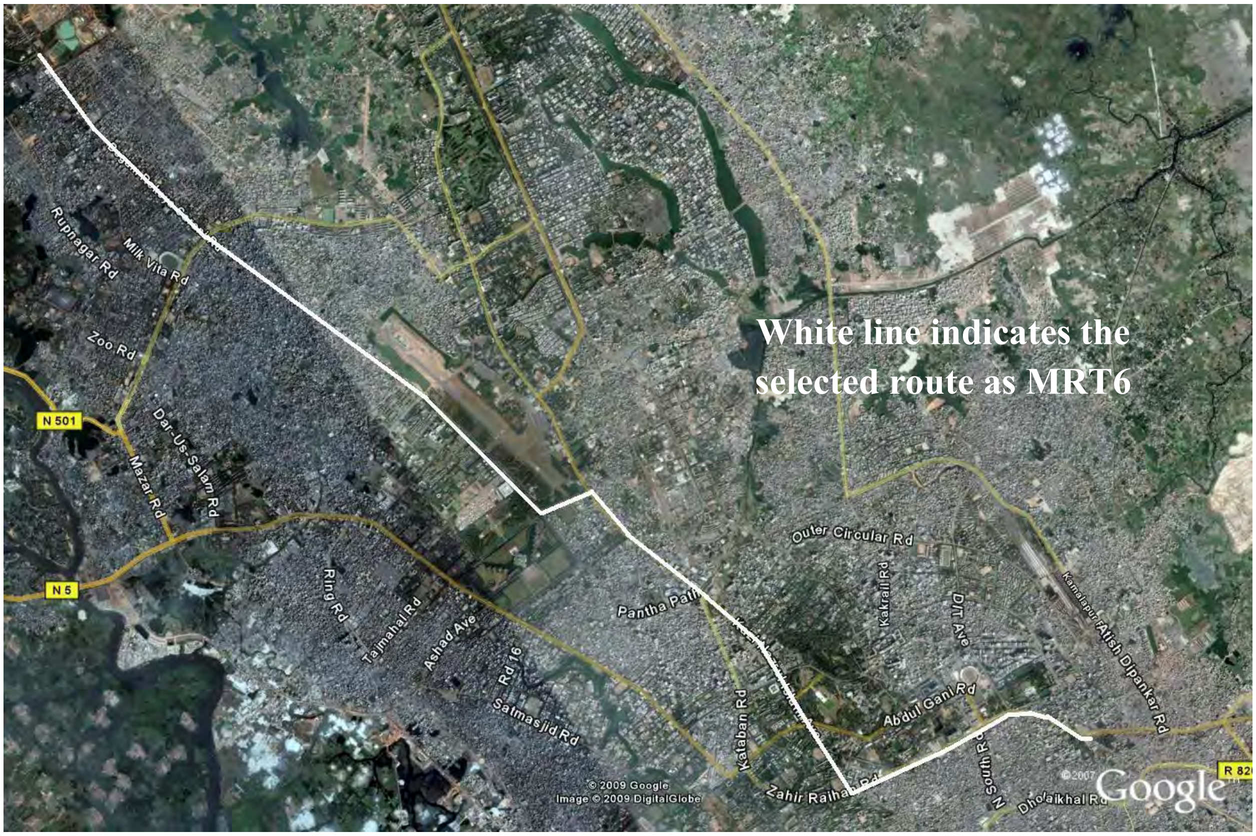


Figure 1.1: MRT6 as proposed by STP 2004

1.4. Route Characteristics

As shown in the Figure 1.1 the route is selected and proposed by STP 2004 based on the surveys and studies of 2001. Route starts from Pallabi at north of Dhaka from Section 12 Bus station in Begum Rokeya Sarani road reaching to parliament directly passing from section 10, Taltola and Agargaon then takes a sharp bend to east and then to south which reaches to Farmgate in the Airport Road continues in Kazi Nazrul Islam avenue up to TSC square, goes to south in Shahid Minar road up to Zahir Minar road. Then it takes a sharp bend to east in Zahir Reihan Road passing from reaching to Kaptaan Bazaar and ends in Sayedabad bus station. Figure 1.2 shows the MRT4, MRT5 and MRT6 and their respective locations.

Total length of the route is 15.21 km and is passing from the north to south of Dhaka. As proposed by STP 2004, connected in future in stations of Section 10 and Farmgate to MRT5, and connects to MRT4 in stations of Sayedabad bus station in south and to Uttura in north creating a loop of commuters in underground MRT network. MRT6 is passing from different roads beneath which they are surrounded by different land use as well as different loadings. Due to type of the land use in the route, width of the road is a great concern in order to determine the set back demand of the method of the construction. Table 1.1 shows the list of the roads that MRT6 is passing from them and their relative width and length.

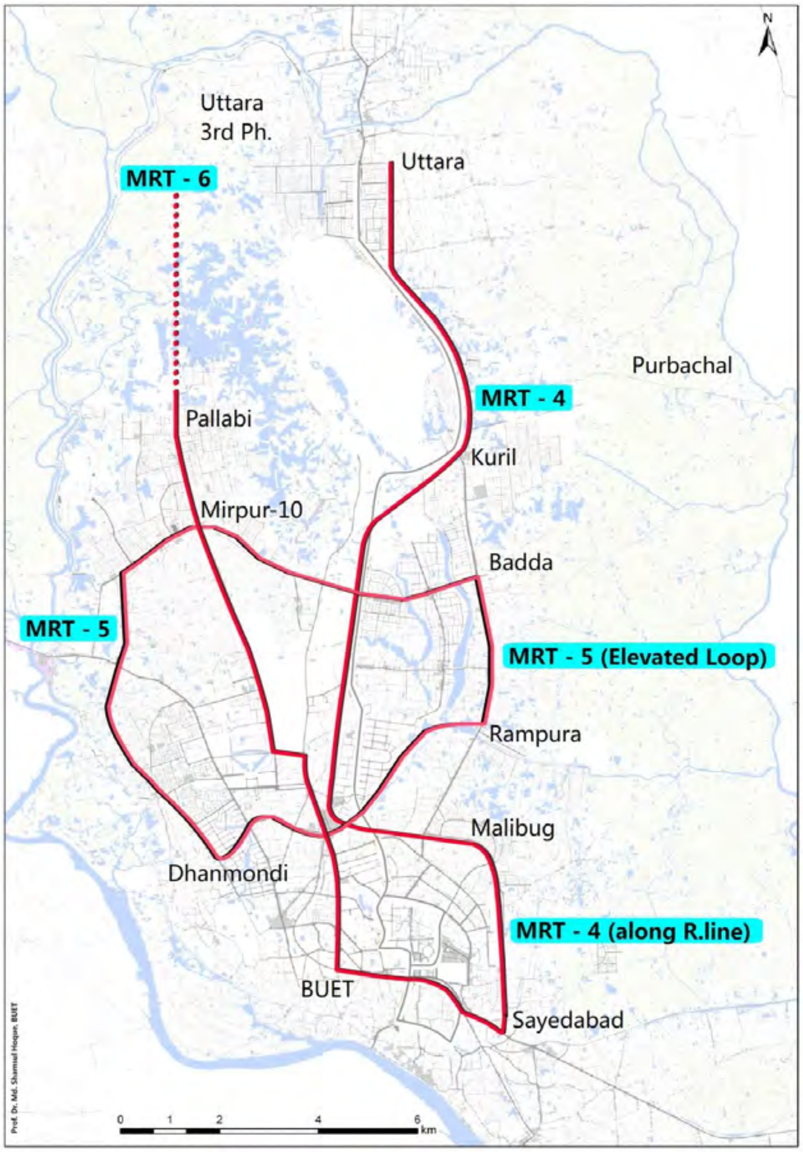


Figure 1.2: Schematic Diagram of MRT4, MRT5, and MRT6 in Dhaka City

Table 1.1: Route Characteristics and Dimension of MRT6

Road name	From	To	Width (m)	Length (m)
Begum Rokeya Sarani	Pallabi	Mirpur road	32	2357
Begum Rokeya Sarani	Mirpur road	Bijoy Sarani	32	4874
Bijoy Sarani	B.R. Sarani	Airport Road	35	550
Airport Road	Bijoy Sarani	Saarc Square	28	1666
Kazi. Nazrul Islam	Saarc Square	TSC Square	28	1954
Shahid Minar Road	K.N. Islam	Zahir Reihan Road	16	896
Zahir Reihan Road	Shahid Minar Road	S.K Sarani	25	502
S.K. Sarani	Zahir Reihan Road	Dhaka Chittagong Highway	25	1453
Dhaka Chittagong Highway	Zahir Reihan Road	Sayedabad bus station	26	958

Source: Google Earth

The at-grade road is having the variation of 16 meter in 896 meter of the route and 6533 meter of 25 to 30 meter, 7781 meter of 30 to 35 meter. Total route is subjected to 84 T junctions, 14 cross junction and three roundabouts.

1.5. Objective and Scope:

This thesis is organized in such a way to review and study the tunneling construction method in order to make the metro line for Dhaka city and to study the different applicability of the metro in Dhaka situation regarding the land use as well as traffic and soil conditions. Specific objectives and outcomes of this study is listed below:

1. To propose the most appropriate route for Dhaka city underground metro alignment
2. To propose the stations and their locations
3. To find out the most appropriate tunnel construction method for Dhaka city
4. To discover the challenges that tunnels in Dhaka will face during construction

1.6. Organization of the Thesis

Based on the type of the thesis this study is divided into following chapters. Chapter one includes the background of the study, objective and scope. Also some general information about the route is included. Chapter two is the literature review which provides the vehicle and travel characteristics in Dhaka, modal choice of transport in Dhaka, transport authorities in Dhaka, Transportation problems in Dhaka, Features and comparison of different Mass rapid Transit Options. Also different tunneling construction methods are included in this chapter about, TBM, Cut and Cover, and NATM method. Chapter three is including methodology of the study. Chapter four includes data collection which comprises the both primary and secondary data collection and analysis and implementation of the metro system. Chapter five includes Proposed Metro for Dhaka city with respective site surveys and suggestion. This is a proposal for underground metro construction for Dhaka city. Chapter six includes cost estimation for the total metro implementation. Chapter seven includes conclusion and recommendation.

2.1. General

Dhaka city as one of the most congested cities of the world with population of about 7 million estimated 2008 by Bangladesh Bureau of Statistics, Statistical Pocket Book, 2008 Population Estimate (Accessed on 2009-08-05) and congestion of 45,461 population/Km is one of the least transportation managed cities of the world. The growth rate is 8% and it gets the total of 33% urban population (STP 2004). Today the only mass transit option in Dhaka city is bus and the service provided is insufficient in all aspects of safety, capacity, comfort and convenience. It is obvious that an efficient mass transit system with rapid movement is essential to overcome the transportation crisis in Dhaka City. This chapter is furnished by different studies regarding the implementation Underground Metro System for Dhaka city.

2.2. Vehicle and Travel Characteristics

The vehicular pattern in Dhaka city is a mixed type combining both motorized and non motorized vehicles. The motorized vehicles comprises of single Decker bus, double Decker bus, minibus, microbus, car, jeep, auto-rickshaw, tempo, maxi-hauler, motorcycle. The non motorized vehicles are rickshaw, rickshaw van, bicycle, push cart etc. It is evident that non motorized transport system dominates Dhaka"s urban transport system. Among all the vehicles the huge number of rickshaw is a very significant travel choice for the people. The number of rickshaws plying in Dhaka city is almost 250000. About 80 % of the total passenger trips are shared by the non-motorized modes. Motorized transport modes constitute only 19.87 % of all passenger trips of Dhaka city. However, among the motorized modes the bus occupies the most significant position with up to 9.46 % share of all passenger trips. The significance of bus transport becomes clearer when only the motorized modes are considered excluding the walk mode. The Figures 2.1 and 2.2 show the pictorial view of the proportional view of the registered vehicles in Dhaka and their respective growth in recent years. Among all the vehicle types, it is seen that the number of motorcycles are the most in numbers (173637) and after that, the number of motor car is the second highest (115880).

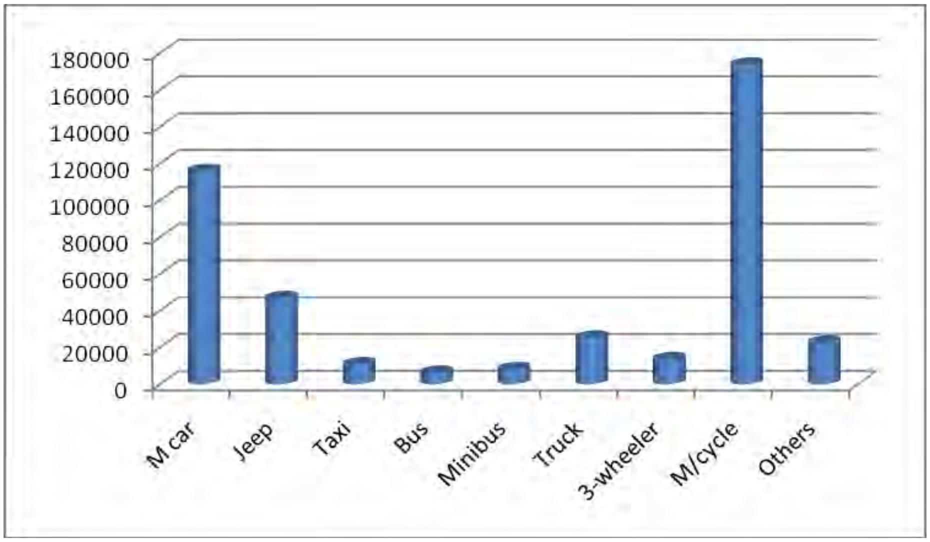


Figure 2.1: Total Number of Registered Vehicle in Dhaka (BRTA, 2007)

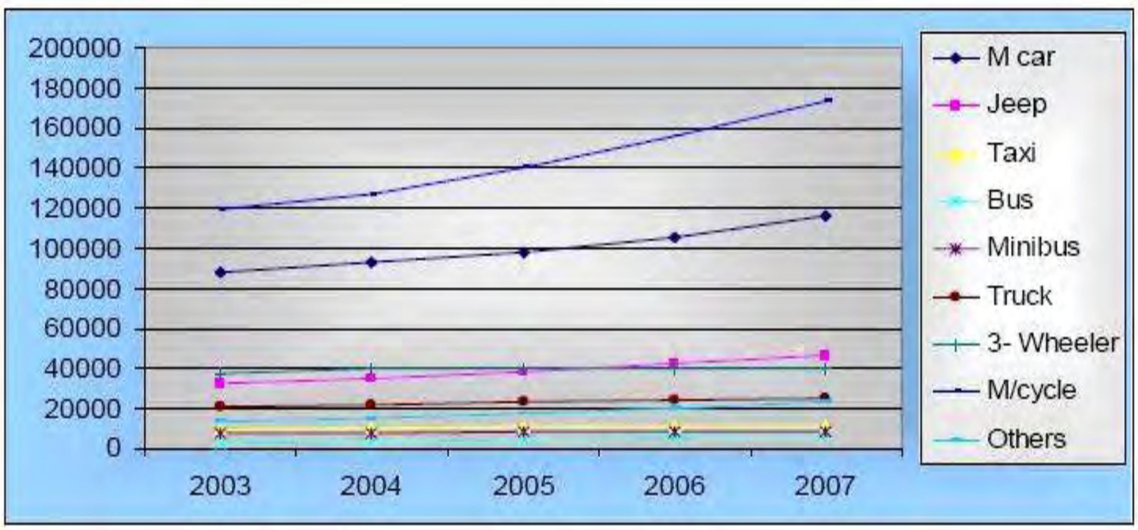


Figure 2.2: Number of Registered Vehicles in Dhaka in Recent Years (BRTA, 2008)

The Figure 2.2 shows that the number of motorcycle increased significantly in the recent years and the number of motor car is also increasing. Other vehicles such as jeep, minibus, bus, truck show a steady rate over the past few years.

Generally a trip is defined as the movement of from origin to destination and might involve several modes, each mode comprising a trip segment.

2.3. Various Modes and Modal Choices of Transportation

There are various modes of passenger transports available in Dhaka city. These can be broadly categorized in three groups:

- **Transit:** They generally operate on fixed routes. Capacity and service category is relatively high but differs from vehicle to vehicles. Double Decker, bus, mini-bus are examples of those.
- **Para Transit:** Route is flexible in Para transit. Capacity and service category is relatively low. Rickshaw, taxi, CNG, tempo, stuff bus are the examples of Para transit.
- **Private:** This type of system is more flexible and its capacity is low. Pedestrian, bicycle, motorcycle, car are the examples.

The latest surveys of person movement in Dhaka city show that walking is the predominant mode with a share of 62 percent of total person trips. This is followed by rickshaw (13.3%), bus (10.3%), auto-rickshaw (5.8%), and car (4%). The Figure 2.3 gives a pictorial form of the statistics.

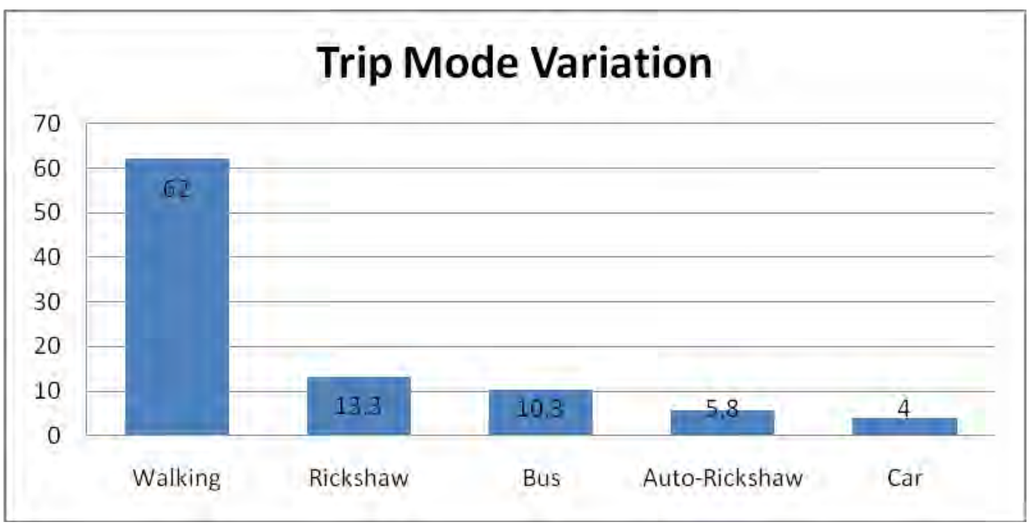


Figure 2.3: Variation of Trip Mode (STP, 2005)

In considerations to person trips by vehicle, rickshaw takes the highest share, accounting for 35 percent followed by bus (21%), auto-rickshaw (15.2%), and car (10.5%). Figure 2.4 shows the graphical form of this data. It has been observed that the rickshaw and walk trips have declined in the form of percentage of person trips in recent years (Hossain, 2002). Rickshaw‟s contribution has reduced 47.8 % (1992) to 35% (1999) of person trips by vehicle. Walk trips have lessened from 64.9% (1992) to 62 percent (1999) of total person trips. But auto rickshaw trips and car trips have increased. In percentage of trips by vehicle, share of auto rickshaw has increased from 3.3 % (1992) to 15.2 % (1999). Bus takes almost the same share of person trips in percentage in between this time period. So trend in change of modal split is toward motorized rickshaw and walking. Absence of efficient mass transit is responsible for high share of passenger trips taken, by auto-rickshaw. It is causing congestion and deterioration of environment. Figure 2.5 shows the variation of trip rate of the people for different purposes. It shows that maximum number of trip rate occurs for home-other purposes (3.1) and the next is home-work (2.5).

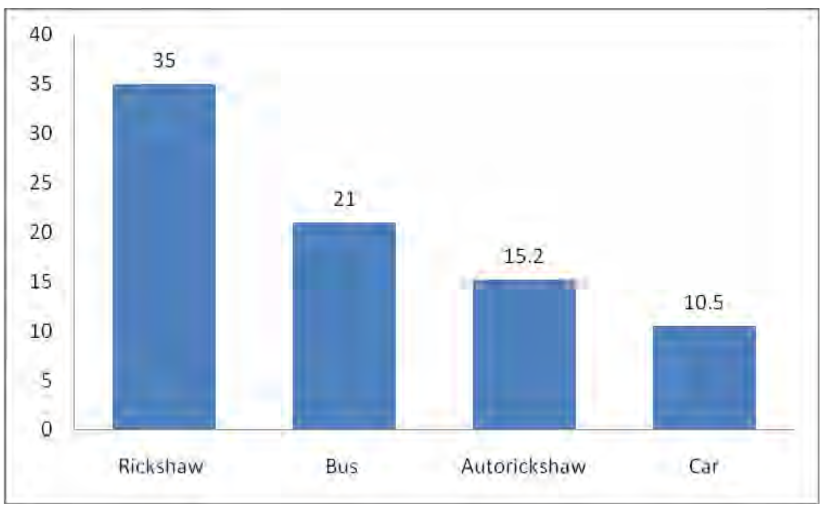


Figure 2.4: Percent Variation of Trip by Different Modes of Transport (STP, 2005)

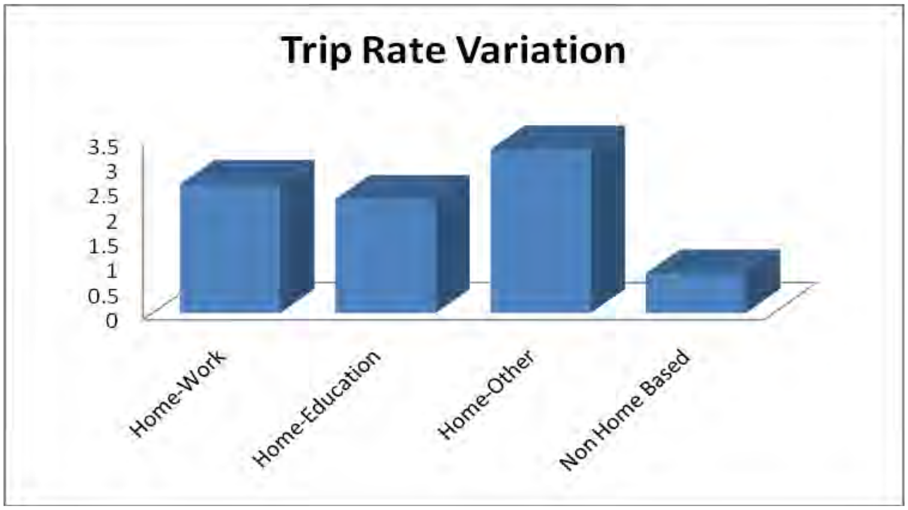


Figure 2.5: Variation of Trip Rate for Different Purposes (STP, 2005)

2.4. Various Transport Authorities

The public transport systems (buses, rickshaws, and baby taxies) are operated by both the government and the private sectors. Public sector involvement through the Bangladesh Road Transport Corporation (BRTC) is quite limited while private sector operators are fragmented and numerous. Consequently, the public transport system is not as developed as in many cities in South Asia. Recently route franchised specialized bus services such as the premium bus service, NIRAPAD (Safe), Dipon Gas Bus Service, City Bus Service, Mega Bus Service have been introduced. Present bus operation in Dhaka is characterized with the existence of 750 individual bus owners who have 2 owners association (BRTA, 2004). BRTA issues licenses for bus routes and operation to operators except BRTC, which has the right to operate buses at its own direction. Bus fares are fixed and regulated by BRTA.

2.5. Transportation Problems in Dhaka

Perhaps the transportation problem is one of the most at stake problems of the Dhaka city as it affects the total of population‟s daily activities which almost all of the activities are Transportation demanded.

Following is a typical list which indicates the different problem causes of Dhaka improper transportation system:

- Congestion
- Services Irregularities
- Poor traffic system management
- Poor conditions of buses in line
- Lack of safety
- Lack of awareness
- Lack of pedestrians facilities
- Disintegrated Transportation system
- Significant population Growth
- Absence of any good and adequate MRT
- Mixing of motorized and non-motorized transportation system
- Absence of facilities of bus or any other MRT system

2.6. Features of Mass Rapid Transit

Mass rapid transit (MRT) is a passenger transportation service, usually locally in scope that is available to any person who pays a prescribed fare. It is generally operated on specific fixed tracts or with separated and exclusive use of potential common tract, according to established schedules along designated routes. The mass rapid transit covers the following basic features:

- All forms of MRT are operated with relatively higher speed and passenger capacities and the basic requirement of MRT in a developing country is that it carries large amount of passengers rapidly.
- MRT systems usually offer a superior level of service compared to unsegregated road based modes such as regular buses, taxies and Para transits. Superior service is evident for example with terminals and interchanges, cleanliness, passenger information, environmental consideration, modal integration and integration with major trip attractors.
- Mass rapid transit system includes excellent integration with other modes of transport such as cars, walking and cycling.
- Mass rapid transit systems can be constructed on, above or beneath the earth surface.

2.7. Different Types of Mass Rapid Transit

A variety of approaches are commonly used to distinguish between the different modes and features of various mass rapid transit systems. Apart from defining features such as cost, capacity and technology, other features used to describe the MRT systems might include distance between stops, right-of-way requirements, operational regimes and guidance systems. For the purpose of this section four categories of mass rapid transit (MRT) are used and identified as:

a. Light Rail Transit (LRT)
b. Commuter Rail
c. Bus Rapid Transit (BRT)
d. Heavy Rail Systems (Metro)

2.7.1. Light Rail Transit

Light rail transit is a class of medium capacity urban public transport which uses electrically powered cars in single and multiple car units using an overhead power pick up. Light rail vehicles may be operated on exclusive guide-ways or integrated with street traffic, depending upon the characteristics and opportunities that exist within the areas being served. LRT cars are usually designed for rapid acceleration and braking and articulated for tight turning radii. LRT can be used below grade, at-grade and on elevated guide -ways.

LRT systems generally have a high degree of flexibility to serve a wide range of applications. Most light rail systems are associated with line capacities in the range of 5000- 20000 passengers per hour per direction (pphpd). However, modern systems using current technology have the potential for line haul capacities up to 40000 pphpd. Achievement of the higher levels of capacity is based upon a totally grade separated system, long train set and short headways. These involve consequently higher costs and have the same features that characterize high capacity metro systems.

With a less restrictive right-of-way requirement, there are opportunities to save significant capital costs as compared with high capacity metro systems. At-grade operations, not requiring expensive grade separation structures or tunnels and able to use smaller stations, have been shown to result in substantial cost savings. However, there is a corresponding reduction in line haul capacity for at-grade operations due to influence and interference of vehicular and pedestrian traffic. Figure 2.6 and 2.7 show an example of a LRT in Malaysia.

Figure 2.6: kuala Lumpur Light Rail Transit

LRT is only operational in a few developing cities – notably Tunis, Shanghai, Kuala Lumpur, Putra, Manila, Istanbul and Mexico City. Recent examples of LRT systems in developing cities include the elevated Putra and monorail systems in Kuala Lumpur, Tren de la Costa of Buenos Aires and Shanghai‟s Pearl Line. Malaysia‟s Putra LRT is one of the busiest and most popular in the world. Among all the light rail transits, Dallas and Putra LRTs are two of the most widely used and busiest LRTs. Dallas‟s LRT ridership is now approaching the 50,000 per day mark, while Putra is serving the busiest areas of Malaysia.

Figure 2.7: Putra LRT

2.7.2. Commuter Rail

Suburban or commuter rail tends to be part of a larger rail network that carries passengers within urban areas or between urban areas and their suburbs, often at grade but separated from road traffic, and differs from Metros and LRT in that the passenger cars generally are heavier, the average trip lengths are usually longer, and the operations are carried out over tracks that are part of the railroad system in the area. Existing railway needs to be strengthened to introduce a new commuter rail as it often integrates with the existing systems. These systems have to operate within the context of the wider network demands, and are characterized by higher headways and longer station spacing as compared with both Metros and LRT. Suburban railways in developing cities are usually radially oriented into the city center. Although even in relatively well-served cities like Mumbai, Rio de Janeiro, Moscow, Buenos Aires and Johannesburg, they carry less than 10% of trips, they can be important in supporting a transit-friendly city form and maintaining a strong city center. The main advantage of this type of system is the low cost implementation attributable to the fact that it is using existing right-of-way and infrastructure that was developed for other purposes. When such infrastructure is old and outdated and requires major upgrading or replacement, the cost advantage can quickly diminish. In addition, the ability of commuter rail systems to serve passenger demand is somewhat restricted by the fact that service is limited to the existing railway network alignment. Often this neither does not serve the areas of highest passenger demand efficiently, nor does is serving the longer spacing between stations. Often 2 to 3 kilometers, compared with 1 kilometer or less for an urban metro system. Figure 2.8 and 2.9 are two examples of commuter rails.

Figure 2.8: London Commuter Rail

Figure 2.9: Toronto Commuter Rail

2.7.3. Bus Rapid Transit (BRT)

Bus Rapid Transit (BRT) is a relatively new concept that provides a similar type of high-quality, fast, dependable, comfortable urban transport service normally attributable to rail type systems, but at a more affordable cost for both the provider and the user. The goal of BRT development is to enhance service levels and quality. A BRT system combines the technology of intelligent transportation systems, traffic signal priority, cleaner and quieter vehicles, rapid and convenient fare collection, and integration with land use policy. Essentially a BRT system is a Metro/LRT type system that uses buses, instead of electrically powered rail cars. Some key features of BRT system are as follows:

- Physical separation of the bus lane from mixed traffic lanes (to give buses a congestion free right-of-way)
- Bus station platforms are level with the bus floor (to speed and ease bus boarding)
- Bus way alignment in the center of the carriageway (to avoid conflicts with turning traffic, unloading trucks, bicycles, pedestrians, and stopping taxis.)
- Payment occurs when entering a physically enclosed bus station rather than on board the bus. (to speed bus boarding and alighting and to give passengers greater security)
- A clear identity for the system (for marketing purposes)
- Trunk and feeder routing system with free transfer terminals (to avoid bus congestion and make the system more profitable)
- Large, articulated buses with multiple wide doors (to increase the capacity of the bus way and the speed of boarding).
- Quality control of bus operation, cleanliness, maintenance and service
- Traffic signal priority (typical only in Europe at low bus volumes)
- Information technologies to provide real-time information to passengers
- Clean bus technologies to reduce emissions

Figure 2.10 shows an example of BRT system in Tehran, Iran.

Figure 2.10: Tehran BRT System

2.7.4. Heavy Rail System (Metro)

High capacity, heavy rail systems are often referred to different ways (Mass Rapid Transit, Rail Rapid Transit, Heavy Rail Transit, Subways, Undergrounds or Metros) at various locations around the world. A metro is fully segregated, usually elevated or underground, is often referred to as an underground railway (Subway), but can, in fact, be any grade-separated urban railway. The track and electric vehicles are similar to suburban railways though with closer station spacing. Trains may have 6-8 carsor even more, with a total capacity of up to 3000 passengers, in some cases trains are operated over an extensive network. It has high capacity at an extremely high cost. Metros in developing cities carried about 11 billion journeys in 2000, more than twice the ridership of commuter rail and more than four times the ridership of LRT systems (GTZ, 2005). Figure 2.11 shows a typical metro view in Tehran. Metro systems are being developed or expanded in several developing cities, such as Bangkok, Santiago de Chile, Kuala Lumpur, Delhi, Mumbai, Kolkata, Sao Paulo, Buenos Aires, Mexico City, Cairo, Dubai, Ankara, Manila, Beijing, Shanghai, Taipei, Hong Kong and many other parts of the world. There is extensive metro activity and substantial future activity is under planning or underway in many cities. Increase in Metro systems in different countries of the world is reflected in the Figure 2.12 which shows the growth of metro systems all over the world.

Figure 2.11: Tehran Metro Imam Hussein Square. 2009

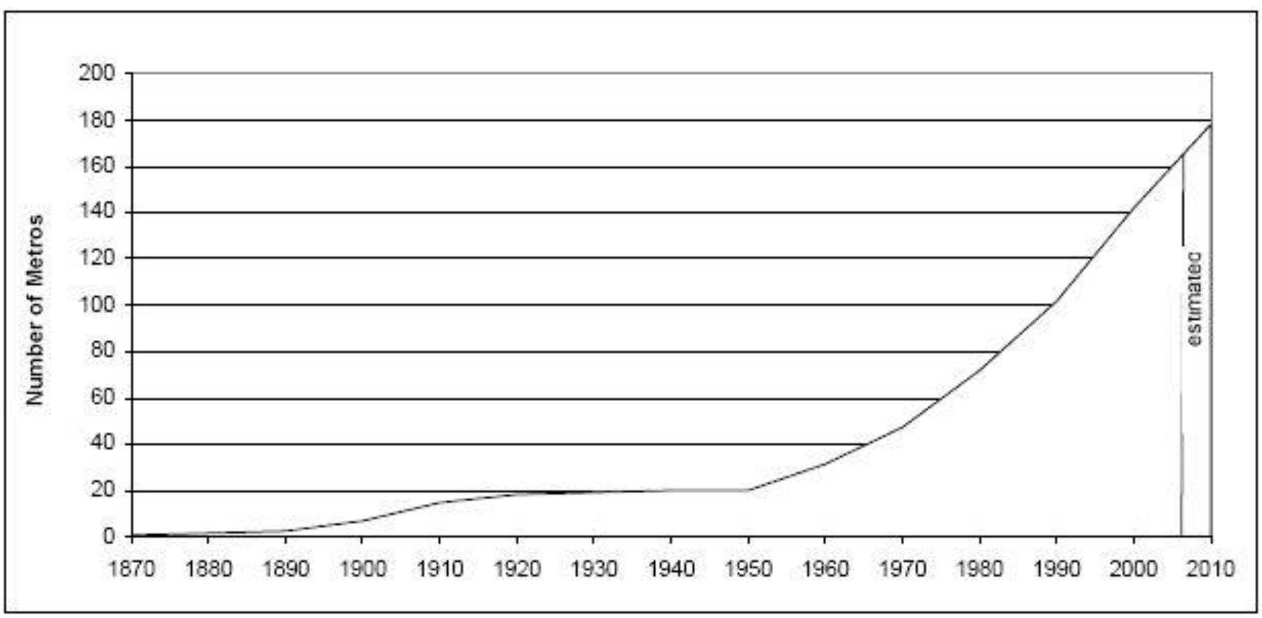


Figure 2.12: Incremental Growth of Metro All Over the World, Source: Metro Bits, 2008

One of the greatest aspects to measure the scale of a metro is number of the passengers served on yearly bases. Following is the name and respective yearly carriage capacity of the top metros of the world with their respective year of measure (source: Wikipedia):

1. Tokyo Subway (Tokyo Metro and Toei Subway only) 3.174 billion (2008)
2. Moscow Metro 2.573 billion (2008)
3. Seoul Subway (Seoul Metro and SMRT)) 2.047 billion (2008)
4. New York City Subway 1.624 billion (2008)
5. Mexico City Metro 1.460 billion (2008)
6. Paris Métro 1.388 billion (2007)
7. Beijing Subway 1.372 billion
8. Hong Kong MTR 1.309 billion (2008)
9. Shanghai Metro 1.3 billion (2009)
10. London Underground 1.197 billion (2007)
11. Osaka Municipal Subway 877.8 million (2007)
12. Saint Petersburg Metro 829.8 million (2007)
13. Cairo Metro 700 million (2002)
14. Madrid Metro 690 million (2007)
15. São Paulo Metro 684 million (2008)
16. Guangzhou Metro 675 million (2009)
17. Santiago Metro 642 million (2008)
18. Kiev Metro 642 million (2007)
19. Buenos Aires Metro 620.5 million (2008)
20. Prague Metro 597 million (2008)
21. Singapore Mass Rapid Transit 571 million (FY 07/08)
22. Caracas Metro 510.2 million (2008)
23. Vienna U-Bahn 498.1 million (2008)
24. Berlin U-Bahn 473.1 million (2008)
25. Taipei Metro 462.472 million (2009)
26. Nagoya Municipal Subway 427 million (2008)
27. Barcelona Metro 422 million (2008)
28. Tehran Metro 416 million (2007)

Based on the surveys conducted in Tehran, Iran, 2008 by each trip 0.7 lit of petrol and 30 minutes of the time saved which leads into a 291,200,000 lit of petrol and 208 million hours yearly is saved which shows the total efficiency of the metro to the nation. Tehran metro is standing as the 28^{th} metro system in the world. Tehran has a population of 8,429,000 and population density of 10,330 per square km as compare to Dhaka with population of 7,000,000 and population density of 23,029 per km square (source of population info Wikipedia, estimate 2008).

2.8. Comparisons Among Various Mass Rapid Transit Options

2.8.1. Comparisons Among Key Features

Among the four forms of mass rapid transits, choosing the most appropriate form depends on the key features of all the options. The key features of them help to determine whether it is structurally and economically feasible or not. Table 2.2 shows some important features of MRT systems.

From the above Table 2.2 it is seen that heavy rail system or metro has some advantages over the other forms of MRT systems in the form of traffic congestion, land use interaction, traffic accident, capacity, space requirement and segregation which are very much useful in the heavily built up cities. It is seen that the implementation time is higher in the cases of metro system from the all other MRT systems.

Table 2.2: Key Features of MRT Systems

Characteristics	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Metro	Commuter Rail
Current Application	Mostly in Latin America and some developing cities	Most European and North American cities	Most developed cities and few large developing cities	Most European and North American cities
Segregation	At grade	At grade	Mostly elevated or underground	At grade
Space Requirement	2-4 lanes from existing roads	2-3 lanes from existing roads	Little impact on existing roads if elevated or underground	_
Impact on Traffic	Depends on policy and design	Depends on policy and design	Reduces congestion	Depends on frequency
Implementation time	Short	Medium	Long	_
Interaction with Land Development	Good	Very Good	Excellent	Variable
Air pollution and Noise	Considerable	Low	Low	Low
Speed(km/hr)	17-20	20-50	30-80	40-45+
Capacity	10000-35000	12000-30000	30000-60000	30000
Traffic Accident	Minor	Minor	No	Minor (at level crossing)

Source: GTZ 2005; World Bank, 2001 and 2002

2.8.1.1. Construction and Operating Costs

Infrastructure cost is an important decision making factor for a proposed transit system in developing countries. The infrastructure cost per kilometer of system in conjunction with the likely financing capacity for the system will determine the overall size of the eventual transit network. According to SUTP (2008), the infrastructure cost for urban heavy rail (metro) varies from approximately US$15-30 million/kilometer for at-graded system, US$30-75 million/kilometer for elevated system, and US$60-180 million/kilometer for underground system. The infrastructure investment for LRT falls between US$13 and 50 million/kilometer, depending on the system whether it will be at graded, elevated or underground. In case of BRT, the initial investment cost is much lower and varies from US$ 0.5-15 million/ kilometer, depending on the elements added to the system. Although the BRT systems apparently show promises in terms of cost effectiveness, especially in terms of initial investment cost, more importantly, the Table 2.3 shows that BRT is a poor long term investment; whereas True (heavy-rail) Rapid Transit is the best long term investment.

Table 2.3: Comparison of Long Term MRT Infrastructure Costs

Items	Metro	LRT	BRT
Average roadbed cost per mile (million US $)	80	30	17
Refurbish cost per 50 years (million US $)	0	40	68
Cost per mile over 50 years (million US $)	80	70	85
Cost per mile over 100 years (million US $)	80	120	170

Source: CRTAWP, 2002

Heavy Rail-based transit"s infrastructure lasts 50 to100 years because it runs on an exclusive right-of-way that is separated from all streets, highways and railroads. It is never affected by traffic accidents nor slowed by heavy traffic. LRT infrastructure lasts 40 to 50 years because it runs on a combination of exclusive rights-of way and surface streets, but its track on surface streets typically needs to be refurbished every ten years also it can be delayed by accidents and heavy traffic during the operation. BRT infrastructure lasts 10 years because it runs on surface streets and dedicated HOV highway lanes. BRT can be delayed by accidents and heavy traffic. True Rapid Transit cars cost US$1.2 million each and last 50 years. LRT cars cost US$1 million each and can last 45 years. BRT buses cost US$700,000 each and last 10 years. Thus they need to be replaced 5 times in 50 years for a total cost of US$3.5 million. On the other hand, the long-term financial sustainability of a public transport project is highly dependent upon the on-going operating costs of the system. These costs can include vehicle amortization, labor, fuel, maintenance, and spare parts. Figure 2.13 compares costs per passenger-mile of various modes. Rail transit costs are usually less than combined road, vehicle and parking costs, particularly in large cities (Litman, 2006).

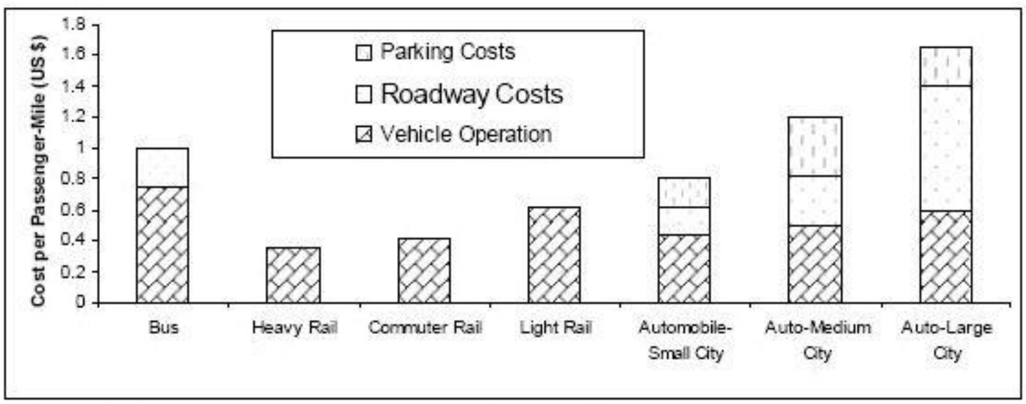


Figure 2.13: Average Operating Costs by Transit Modes (Litman 2006)

Moreover, the physical structure of a city is very important to introduce a new transit system. As mentioned earlier, BRT is not feasible where available road space is limited. Besides, it is an interim solution for limited traffic; and if traffic demand is high, like Dhaka City, BRT is not a solution. Recently (in April 2008), BRT trial run failed miserably in Delhi. The dedicated bus lanes invited mixed reaction from the public; with the car users complaining about having to spend more time on the road now than before and the bus riders being annoyed with the bus-stands being displaced to the middle of the road. Poor design and lack of coordination between different stakeholders further worsened the situation. Whereas, the success of Delhi Metro has triggered of a rush with many other cities, including Mumbai, Bangalore and Hyderabad clamoring for similar heavy rail-based mass rapid transit systems.

2.8.1.2. Capacity and Speed

The capability and speed of a system to attract ridership is a prime decision-making determinant in selecting a mass transit technology. The ability to move large numbers of passengers is a basic requirement for mass rapid transit systems particularly in developing cities and in this context rail based metro systems show unparallel performance. Urban heavy rail transit system can serve up to 81,000 passengers/hour/direction (Hong Kong Subway) with maximum operational speed of 80 km/hour (Delhi Metro). With its own right-of-way, LRT carries up to 30,000 passengers/hour/direction (Kuala Lumpur). However, when compared with heavy rail transit systems, the BRT system typically has slower operational speed and less passenger capacity, varying from 10,000 (Ottawa Busway) to 35,000 (Bogota TransMilenio) passengers/hour/direction. However, these capacities and speeds of the MRT systems greatly vary based on systems designed and technology used. Figure 2.14 shows the far higher rates of transit ridership and transit commute mode split in "Large Rail" cities compared to „Bus Only‟ cities (the dashed line at 100% indicates "Bus Only" city values).

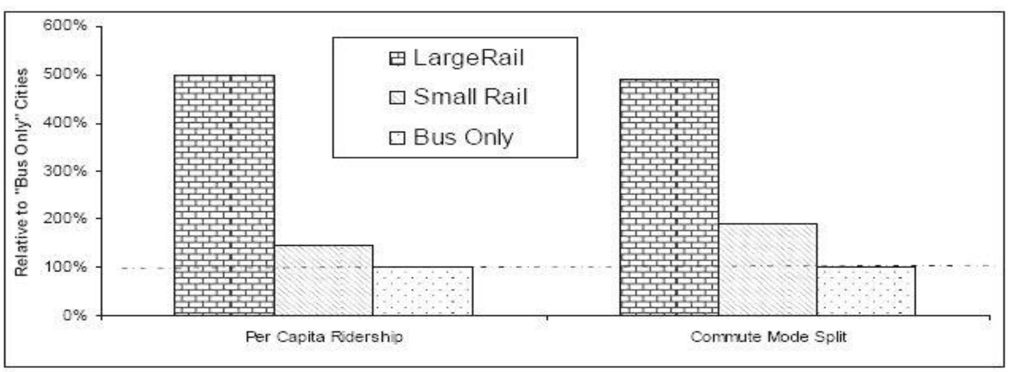


Figure 2.14: Transit Ridership and Commute Mode Split Comparison of Rail and Bus

(Source: Litman, 2007)

While implementation of a mass rapid transit system, considerations of a lot of parameters are needed. Capacity and cost are two of the most important of them. The design of a mass rapid transit system needs a projected capacity for which it should be implemented and an estimation of cost is also needed to justify whether it is economically feasible or not. A comparative study has been made between world leading BRT and Metros in Table 2.4.

Table 2.4: BRT and Metro Systems Cost and Capacity Comparisons

Line	**Capital cost/km. (million dollars)**	**Actual Capacity (passengers/hour/direction)**
Metro System		
Hong Kong Metro	220	81,000
Bangkok Sky train	74	25000-50000
Caracas Metro	90	21600-32000
Mexico City Metro	41	19500-39300
BRT System		
Bogotá TransMilenio	8	35000-45000
Sao Paulo Busways	3	27000-35000
Porto Alegre Busway	2	28000
Curitiba Busway	2	15000
Quito Bus Rapid Transit	2	9000-15000
Trans Jakarta	2	8000

Source: Pre-Feasibility for Bus Rapid Transit Hyderabad, Andhra Pradesh

2.8.1.3. Comparative Benefits: Rail Vs. Bus Transit

A comprehensive evaluation of rail transit benefits over bus services conducted by Victoria Transport Policy Institute (Litman, 2006) shows that Large Rail cities are found to have significantly better transport system performance (Figure 2.15). The study investigates that compared with Bus Only cities, Large Rail cities have: 400% higher per capita transit ridership (589 versus 118 annual passenger-miles); 887% higher transit commute mode split (13.4% versus 2.7%); 36% lower per capita traffic fatalities (7.5 versus 11.7 annual deaths per 100,000 residents); 14% lower per capita consumer transportation expenditures ($448 average annual savings); 19% smaller portion of household budgets devoted to transportation (12.0% versus 14.9%); 21% lower per capita motor vehicle mileage (1,958 fewer annual miles); 33% lower transit operating costs per passenger-mile (42¢ versus 63¢); and 58% higher transit service cost recovery (38% versus 24%).

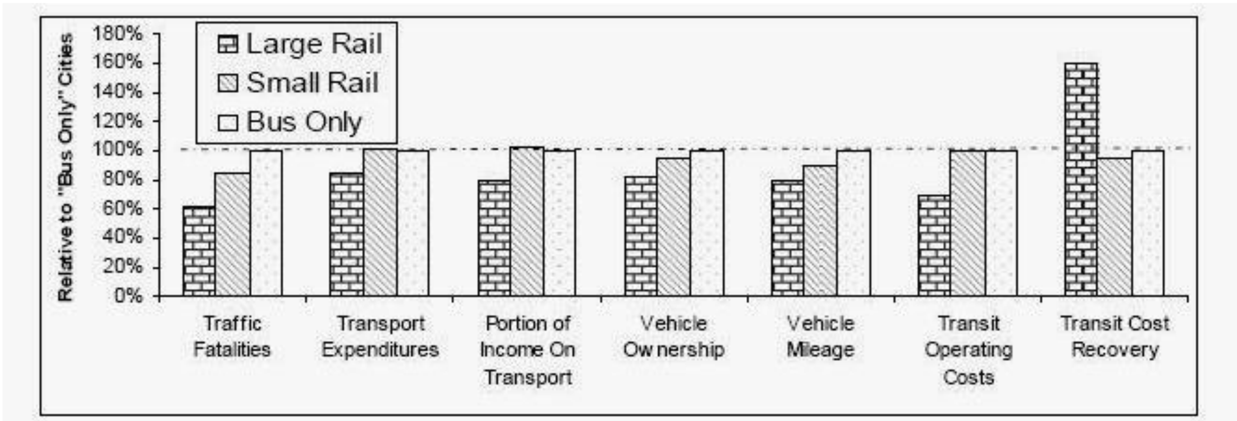


Figure 2.15: Transportation Performance Comparison of Rail and Bus Mode (Source: Litman, 2006)

Moreover, rail transit can provide substantial energy conservation and emission reduction benefits (Figure- 2.16) Rail travel consumes about a fifth and a fourth of the energy per passenger-mile as automobiles and buses travel, due to its high mechanical efficiency and load factors. Electric powered rail produces minimal air and noise emissions. International comparisons indicate that per capita energy consumption declines with increased heavy rail transit use.

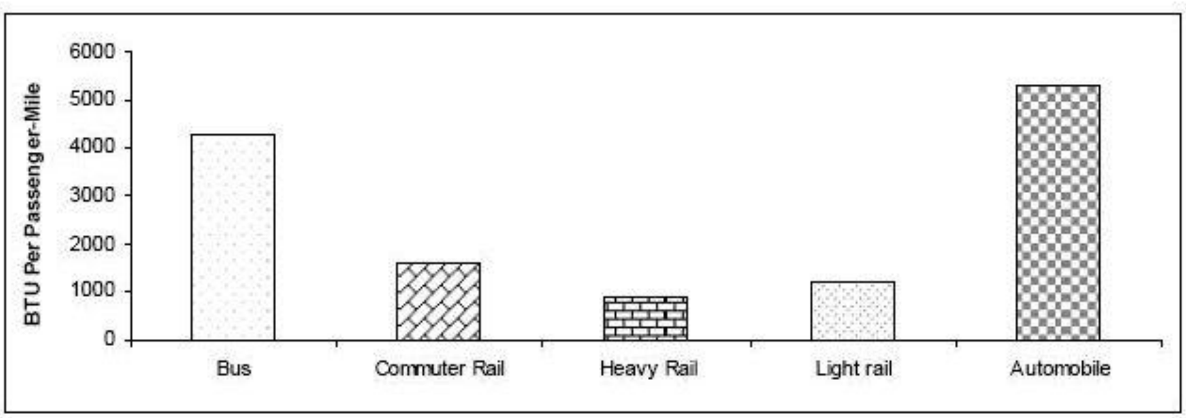


Figure 2.16: Transit Energy Consumption of Various Modes

(Source: Litman, 2006)

From the Figure 2.26, it is seen that transit energy consumption is maximum in the case of automobile while, the energy consumption is minimum for the heavy rails. It means, implementation of heavy rail in the transportation system not only saves energy, but also it helps save the environment and financial condition of a country. Table 2.5 gives a comparative view of London Bus way and Sao Paulo Metro in terms of operational parameters like arrival time, time for opening doors, time for boarding and alighting of passengers, time for closing doors etc. From Table 2.5 it is seen that for Sao Paulo metro time spent by the Metro in the station is 52 seconds which means that this service is faster than the bus service.

Table 2.5: Capacity and Dwell-Time Details on a London Bus way Compared to the Sao Paulo Metro

Items	Unit	Bus London	Metro Sao Paulo
Arrive	Seconds	5	10
Open Doors	Seconds	2	2
Boarding and Alighting	Seconds	48	25
Close Doors	Seconds	2	5
Exit Stations	Seconds	2	10
Total Time	Seconds	59	52
Frequency	Seconds	24	33
Passenger/vehicle	Seconds	70	1700
Capacity	People	1708	56100

Source: Pre-Feasibility for Bus Rapid Transit Hyderabad, Andhra Pradesh

2.9. Review of Tunnel Construction Method

2.9.1. TBM Method

Tunnel Boring Machine (TBM) is known as the most automated method of tunnel excavation and construction with large initial investments. TBMs are used for large and lengthy tunnels excavation with capability of excavation varying from the softest clay soil to hardest rocks and anything in between. Efficiency of TBM method is decreasing as the length of the project decreases and it is very difficult and lengthy process to assemble the machine underground, as in case of the tunnels they will be never disassembled in such a way that they will be left in one piece underground in order to continue the extension for the future development of underground network.

TBMs do not disturb the at grade network, as they have no need of at grade surface which is considered as a great positive point for Dhaka city also they do not need to move and relocate the underground facilities as it was a difficulty faced in Cut and Cover.

TBMs are used usually for circular sections only. In MRT designing, change of section to any other form, makes it very expensive to change the excavation section shape. The biggest TBM today has been made for Kuala Lumpur‟s 13.2 m diameter dual purpose SMART tunnel project.

The main toots of the TBM shall be designed and selected based on the water table and soil characteristics, which the change of the toots in future due to difficulties in changing is a tough and expensive task to be handled.

Although all of the TBMs have got their own advantages and disadvantages there is a great concern about the assembly and handling of the machine which needs its own professional team for excavation purpose only. Tunnel boring machines are used as an alternative to drilling and blasting (D&B) methods in rock and conventional 'hand mining' in soil. A TBM has the advantages of limiting the disturbance to the surrounding ground and producing a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes them suitable to use in heavily urbanized areas. The major disadvantage is the upfront cost. TBMs are expensive to construct, difficult to transport and require significant infrastructure (Wikipedia). TBMs are used mainly for the areas that there cannot be accessed from the top, so that the entire excavation evacuation job shall be done through ramps and shaft as it was the case for the India.

2.9.1.1. Method of Construction

TBMs are mainly consist of two parts, cutter head (TBM), and Backup Terrain. Cutter head is the main part of excavation which makes the boring process and Backup terrain is the structure following the boring head and provides needed material. For construction f a tunnel by a TBM, there will be shaft constructed and pieces of TBM machine is moved underground and assembled. Then the excavation process starts. As the TBM goes in desired alignment, stations are made in specific points in order to reach the boring alignment of the TBM machine, before, at the same time, or after the passage of the TBM machine. Due to expensive and complex operation of TBM machines, there is only one cutting machine known as Cutting Head in the total process which leads into a great consideration that if there is any problem by cutting head, and it stops, all of the excavation process is affected as well. As it is not the case for Cut and Cover or NATM method.

2.9.1.2. Tunnel Boring Machine (TBM)

Consist of a circular cutter which is pressed to the excavation surface supported from Gripper which gives the pressure to the sides and produces a lateral support to the TBM cutter head and after the pressure is applied, and excavation is made, there is a change in position of gripper by help of the hydraulic jacks which leads to a 1 to 2 meter forward move to provide a new supporting point for the cutter.

Cutter head (Figure 2.17) is consist of several and multidirectional drills and cutters which are assembled in place part by part which chips the rocks away, and broken rocks due to gravity fold into lower level of excavation where the collectors collect them into the bucket wheels are and then transferred to a conveyer belt behind the cutting head.

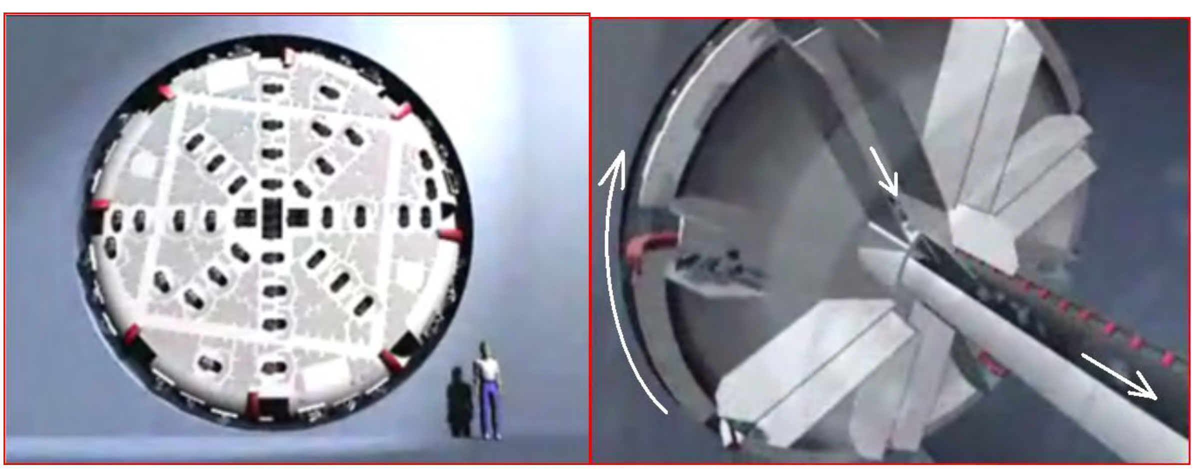


Figure 2.17: TBM machine Cutting Head

While the boring is going on, securing machine is working and placing the proper steel mesh needed for future concrete shots right behind the cutting head which leads in to surface support in order to eliminate the weathering and future rocks fall (Figure 2.18). Application of these parts is only based on presence of faults and geological studies. Securing machine may be used in order to make mesh, steel bars support, arches or steel arch segments.

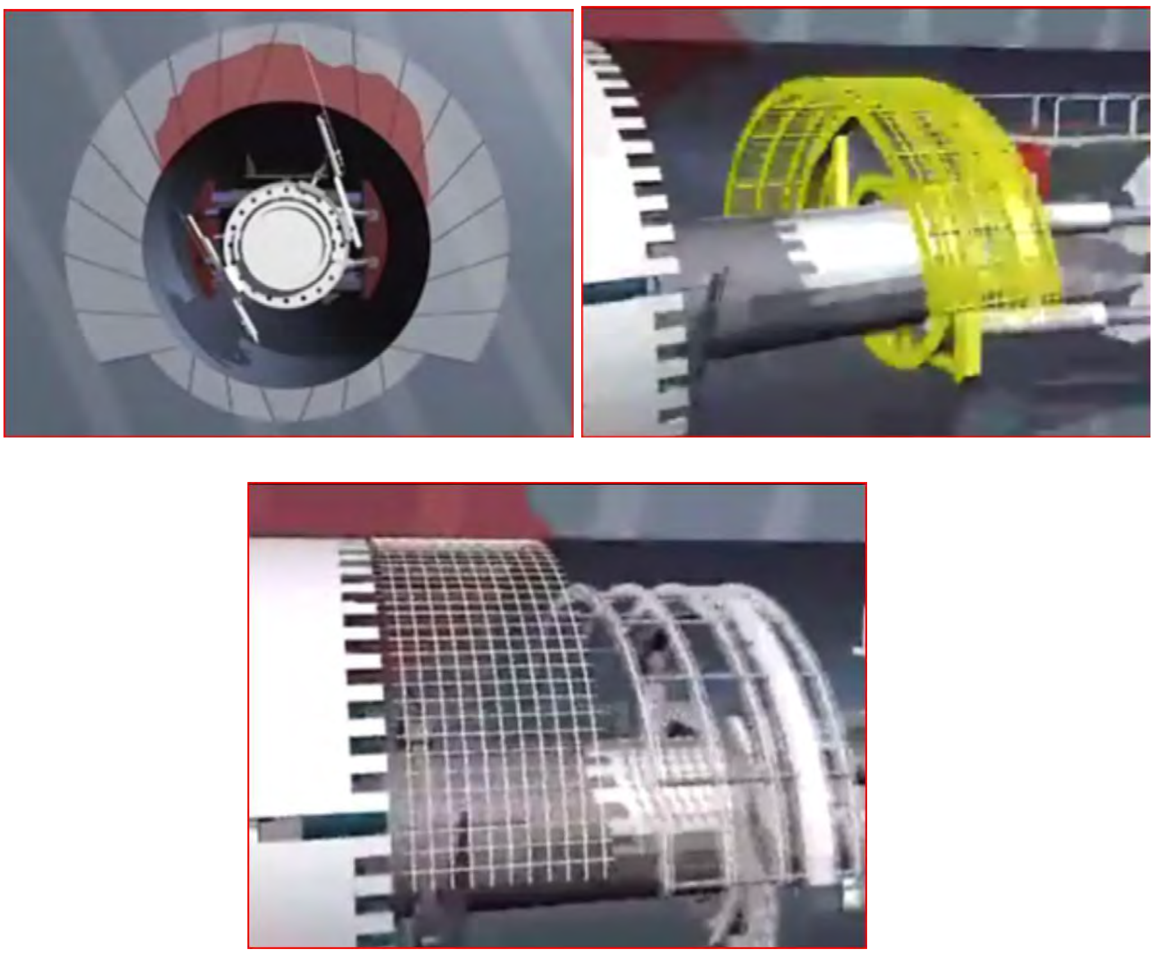


Figure 2.18: TBM Safety Mesh Machine

The main concern about all this process is a part called Gripper (Figure2.19) which supports the TBM on its sides, which each strike of the gripper moves the TBM for a few meters forward and moves forward with the boring machine itself in the same time.

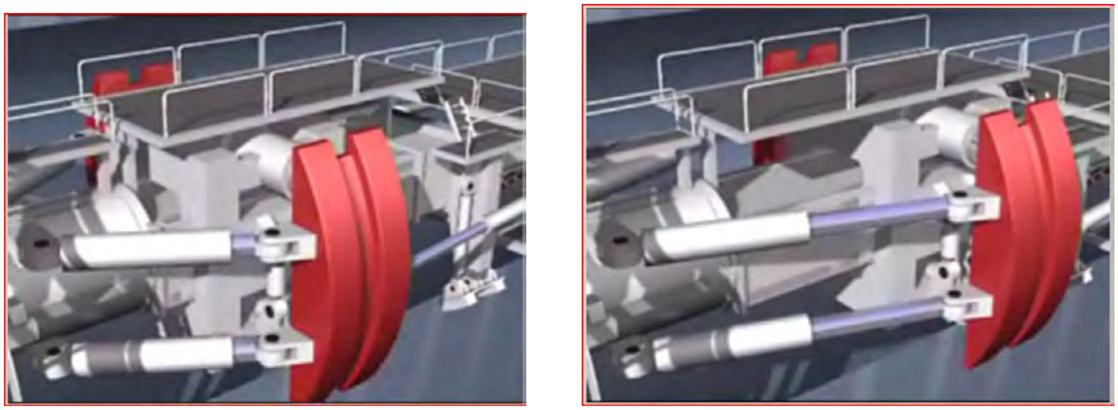


Figure 2.19: TBM Gripper

Also the hydraulic is responsible for changing the direction of cutter‟s movement in horizontal and vertical alignment which allows the TBM driver to steer the alignment in all time (Figure 2.20). Based on different soil conditions and geological situations and properties of TBM machine, TBMs may cut 40 meters a day.

Figure 2.20: TBM Steering

2.9.1.3. Backup Terrain

Backup Terrain is a set of machinery consist of all other utility and construction demands of tunnel construction materials starting from shotcrete up to rail and utility installations. Because of vast and large quantity of tasks to be carried out after the boring head, Backup terrain is a set of moving factory which is attached in the end of the boring head in order to satisfy all the demands as they are expected. All of the materials, all of the installation grids, tunneling material demand and evacuation of excavated rock are done by the backup terrain.

Size and length and functionality of the Backup terrain are function of tasks and may vary on large scales as there are many factors in need of tunnel. It may reach more than 400 meters. As shown in the Figure 2.21. TBM process is consisting of 4 main sections followed by each other.

Section 1 the cutting head

Section 2 security machine (shotcrete and steel mesh installer)

Section 3 TBM backup Terrain (cutting head material supporter

Section 4 tunnel utilities and fixture installation Terrain (out of picture and reaching up to more than 300 based on demand job quantity).

1 2 3 4

Figure 2.21: TBM Machine Sections

2.9.1.4. Total Excavation Sequence

As the TBM is considered as a great cost in capital investment, and as a machine cost variably up to several million US dollars there is not usually more than one TBM machine in one project.

Total sequence of the job is always a function completely related to progress of the TBM machine. By progress of machine in the desired alignment, there will be progress in support construction, concrete casting, and waterproofing and proper pavement construction in the same time. It excavates and builds meanwhile of progress.

2.9.2. Cut and Cover Method

Cut-and-cover is a simple method of construction for shallow tunnels where a trench is excavated and roofed over. A strong overhead support system is required to carry the load of the covering material, roads, streets or other transportation systems. Cut and cover is known as the cheapest method of construction but a huge quantity of cutting, filling and covering is needed as compared to NATM and TBMs which needs a larger time as well in total progress. Figure 2.22 shows the typical steps in Cut and Cover method also Figure 2.23, Figure 2.24 and Figure 2.25 show the Cut and Cover method in different steps.

Another difficulty which usually Cut and Cover is facing is about the reaching from the top, which is embroiling the at-grade traffic as well as the dislocation and relocation of any underground utilities which should be considered in total cost estimation of the process.

2.9.2.1. Construction Method

Two basic forms of cut-and-cover tunneling are:

1. Bottom-up method: A trench is excavated, with ground support as necessary, and the tunnel is constructed within. The tunnel may be of in situ concrete, precast concrete, precast arches, corrugated steel arches and such, with brickwork used in early days. The trench is then backfilled, with precautions regarding balancing compaction of the backfill material, and the surface is reinstated.
2. Top-down method: In this method, side support walls and capping beams are constructed from ground level, using slurry walling, contiguous bored piles, or some other method. A shallow excavation is then made to allow the tunnel roof to be constructed using precast beams or in situ concrete. The surface is then reinstated except for access openings. This allows early reinstatement of roadways, services and other surface features. Excavation machinery is then lowered into the access openings, and the main excavation is carried out under the permanent tunnel roof, followed by constructing the base slab.

Shallow tunnels are often of the cut-and-cover type (if under water, of the immersed-tube type), while deep tunnels are excavated, often using a tunneling shield. For intermediate levels, both methods are possible.

Large cut-and-cover boxes are often used for underground metro stations, such as Canary Wharf tube station in London. This construction form generally has two levels, which allows economical arrangements for ticket hall, station platforms, passenger access and emergency egress, ventilation and smoke control, staff rooms, and equipment rooms. The interior of Canary Wharf station has been likened to an underground cathedral, owing to the sheer size of the excavation. This contrasts with most traditional stations on London Underground, where bored tunnels were used for stations and passenger access.

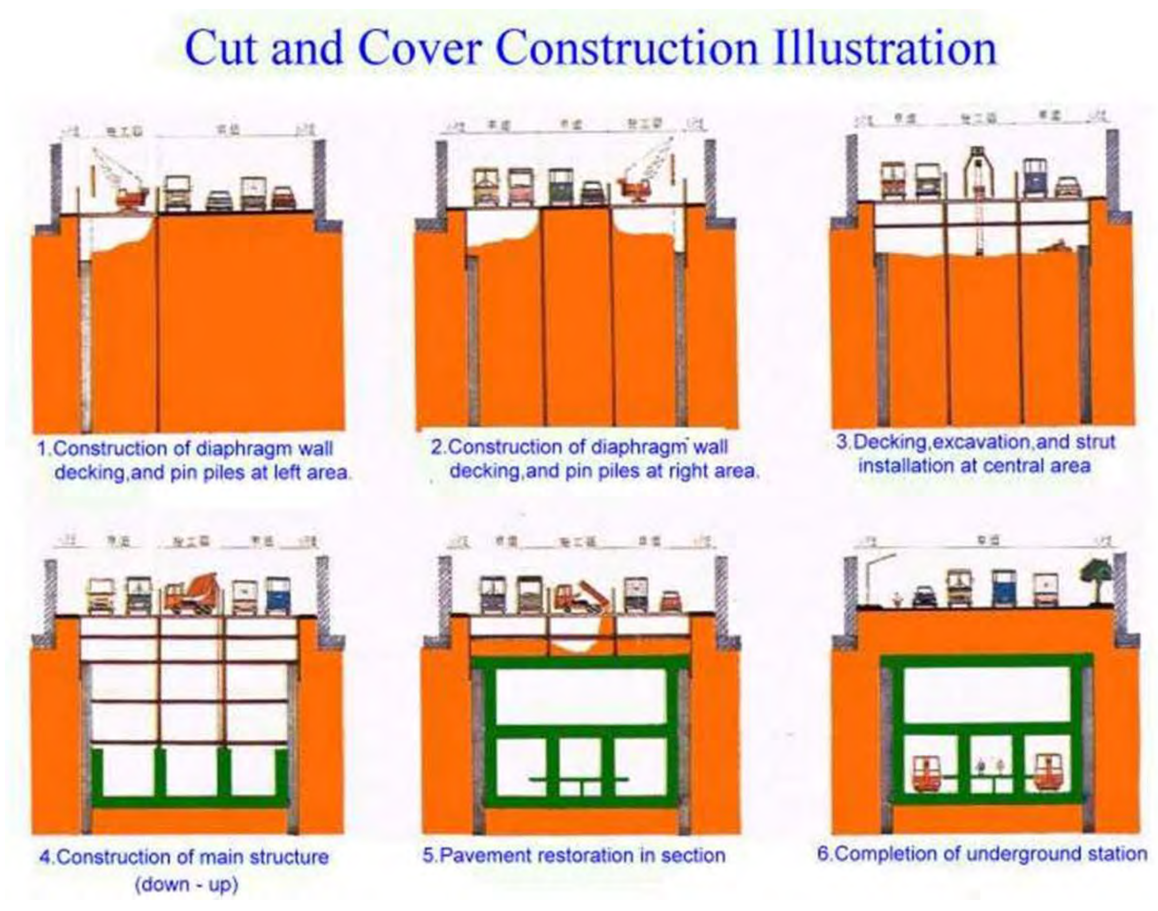


Figure 2.22: Cut and Cover Steps

Figure 2.23: Cut and Cover at Open Step

Figure 2.24: Cut and Cover Earth Retention System Support

Figure 2.25: Cut and Cover application and earth Retention System

2.9.3. NATM Method

As defined by the Austrian Society of Engineers and Architects, the NATM "…constitutes a method where the surrounding rock or soil formations of a tunnel are integrated into an overall ring like support structure. Thus the supporting formations will themselves be part of this supporting structure." In world-wide practice, however, when shotcrete is proposed for initial ground support of an open-face tunnel, it is often referred to as NATM. The term NATM with reference to soft ground, however, can be misleading (as noted in a very thoughtful article by Emit Brown1), NATM can refer to both a *design philosophy* and a *construction method* (NATM in soft grounds by world tunneling, 2002)

The "New Austrian Tunneling method (NATM)" was developed between 1957 and 1965 in Austria. It was given its name in Salzburg in 1962 to distinguish it from old Austrian tunneling approach. The main contributors to the development of NATM were Ladislaus von Rabcewicz, Leopold Müller and Franz Pacher (Wikipedia). The main idea is to use the geological stress of the surrounding rock mass to stabilize the tunnel itself.

This method has been developed basically in Austria so its name make use of providing flexible primary lining in shape of shotcrete , wire mesh, rock bolts ,lattice girder. In case of weaker rock mass the use of pipe forepole/pipe roofing is also resorted for crown support which in turn lead to less over break as well as ensure safety during the execution. The main aspect of the approach is dynamic design based on rock mass classification as well as the in s itu deformation observed. Hence more economical use of the tunnel support system along with the rational approach of execution (use of NATM in Tunneling by Rakesh SabharwalDy CE/Doub/Jammu).

2.9.3.1. Broad Principles of NATM

NATM broadly based on the following principles:

- Mobilization of the strength of rock mass - The method relies on the inherent strength of the rock mass being conserved as the main component of tunnel support. Primary support is directed to enable the rock to support itself.
- Shotcrete protection - Loosening and excessive rock mass deformation should be minimized by applying a layer 25-50mm of sealing shotcrete immediately after opening of the face.
- Measurements - Every deformation of the excavation must be measured. NATM requires installation of sophisticated measurement instrumentation. It is embedded in lining, ground such as load cells, extensometers and reflectors.
- Primary Lining - The primary lining is thin. It is active support and the tunnel is strengthened not by a thicker concrete lining but by a flexible combination of rock bolts, wire mesh and Lattice girders.
- Closing of invert – Early as far as possible closing the invert so as to complete the arch action and creating a load-bearing ring is important. It is crucial in soft ground tunnels.
- Rock mass classification - The participation of expert geologist is very important as the primary support as well as the further designing of supports during the excavation of rock requires the classification of the rock mass.
- Dynamic Design – The deigning is dynamic during the tunnel construction. Every face opening classification of rock is done and the supports are selected accordingly. Also the design is further reinforced based on the deformation as noticed during the monitoring.

2.9.3.2. NATM Process of Construction

In the NATM method, each desired alignment is started by the excavation of the shaft and as the shaft reaches to its maximum depth of the tunnel, construction of the profile in both of the directions starts. As the profile excavation is continued, meanwhile structure of the tunnel is constructed as well by a distance of a few meters.

2.9.3.3. Classification of Rock Mass Type

Rock mass encountered during excavation cannot be said to be favorable or unfavorable only on the basis of the type of the rock. Several other factors also play part in the rock mass behavior. The excavation in the rock is dependent on the rock class based on several factors such as compressive strength of rock, water condition, number of cleavages, condition of cleavages, dip and strike of the rock etc. There are various approaches of classification of the rock mass and most predominantly are RQD, RMR and Q factor of the rock mass.

2.9.3.4. Rock Quality Designation index (RQD)

The Rock Quality Designation index (RQD) was developed by Deere (Deere et al 1967) to provide a quantitative estimate of rock mass quality from drill core logs. RQD is defined as the percentage of intact core pieces longer than 100 mm (4 inches) in the total length of core. The core should be at least NW size (54.7 mm or 2.15 inches in diameter) and should be drilled with a double-tube core barrel.

2.9.3.5. RMR Value:

RMR value depends upon the following factors:

- Uniaxial compressive strength of rock material.
- Rock Quality Designation (RQD).
- Spacing of discontinuities.
- Condition of discontinuities.
- Groundwater conditions.
- Orientation of discontinuities.

Based on this the rock mass classification as per RMR Table 2.6 shows different RMR values:

Table 2.6: RMR Value

RMR Value	100-81	80-61	60-41	41-20<20	<20
Rock class	I	II	III	IV	V
Description	Very good	Good	Fair	Poor	Very Poor

2.9.3.6. Q Factor

It depends on the following:

- Block size
- Inter block shear
- Active stress
- Reduction for joint water flow
- Presence of weakness zones

Q factor varies from 0.01 to 1000 i.e. from exceptionally poor rock to very good rock.

2.9.3.7. Components and Sequence of Execution in NATM

1. Sealing Shotcrete – Shotcrete 25-50mm generally (Figure 2.26)
2. Fixing of Lattice Girder – lattice girder is 3 Bars of steel reinforcement placed at three corners of triangle with 8mm steel bar for connection. Easy to handle comparison of steel ribs.
3. Fixing of wire mesh – generally used 6mm thick wires
4. Primary Lining with Shotcrete – In layers each not thicker than 150mm
5. Rock Bolting
6. Pipe Fore poling – Used for crown support for next Excavation cycle (for Rock Class after III only)

Figure 2.26: NATM in Action, Shotcrete at the end of section

2.9.3.8. NATM for Soft Grounds

In soft-ground tunneling, safety dictates that the ground support be placed immediately after excavation. As long as the ground is properly supported, NATM construction methods are appropriate for soft-ground conditions. However, there are cases where soft-ground conditions do not favor an open face with a short length of uncompleted lining immediately next to it, such as in flowing ground or round with short stand-up time (i.e., failure to develop a ground arch). Unless such unstable conditions can be modified by dewatering, spilling, grouting, or other methods of ground improvement, then NATM may be inappropriate. In these cases, close-face shield tunneling methods may be more appropriate for safe tunnel construction as shown in Figure 2.27 (NATM in soft grounds by world tunneling, 2002).

The excavation can progress in full face when the rock mass class is excellent, very good, good and then depending upon the inferior rock mass class the excavation can be resorted to heading , benching. For further poorer and very poor class of rocks the excavation can further be divided into the sub-segments. Based on the studies Rabcewicz (1965) proposed that the excavation face may be divided into small cells that will help the ground stand until completion of the lining. It is proposed that the excavation is carried out in six or more steps depending on the size and the geometry of the tunnel. Figure 2.27 illustrates a typical main cross-sectional geometry for a NATM tunnel as proposed by Rabcewicz. The Roman numbers indicate the excavation order and sequence of excavation for working in soft ground. The first step is the excavation of the top heading (I), leaving the central part to support tunnel face. Primary lining (shotcrete) II is formed and followed by removing the top central portion (III) subsequently excavation of left and right walls (IV) and then step V & VI so on(use of NATM in Tunneling by Rakesh SabharwalDy CE/Doub/Jammu).

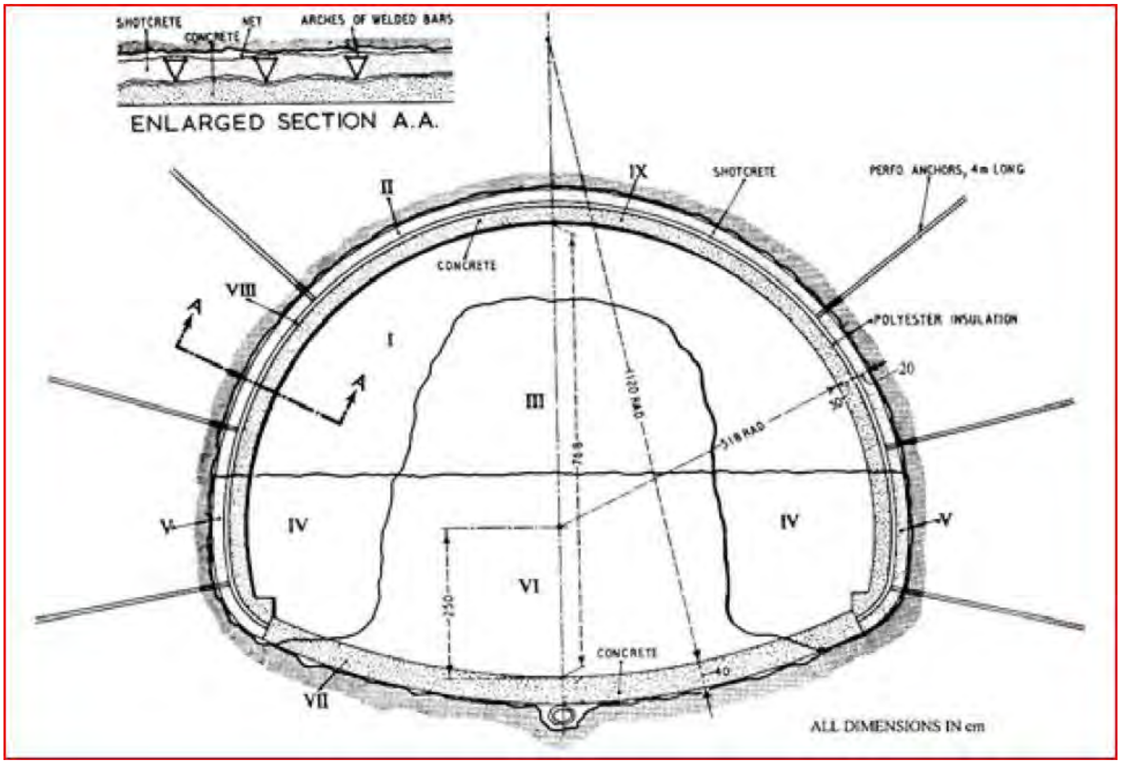


Figure 2.27: NATM Section

2.9.3.9. Protection of Portal Face:

Especially in soft rocks and cracked rocks the face of the tunnel portal should be secured nicely to avoid any fall out and closing the way of the tunnel. The typical face development is shown in Figure 2.28.

Figure 2.28: NATM Portal Face Entrance

2.10. Summary and Comparison of Methods

For any construction method there are some advantages and disadvantages, here is a list of each method whit their correspondent characteristics:

1. CUT & COVER
    a. Low cost
    b. Uncertainty disturbances
    c. Huge excavation quantity
    d. Huge filling back quantity
    e. Soil strata bound loss
    f. At grade routes diversion is needed
    g. Utility lines network dislocation and relocation is needed
    h. Need of access from above
    i. Good for short and shallow projects
    j. No dependency on foreign technology
    k. Full section cutting head
    l. Expensive in deep excavations

2. TBM
    a. High capital cost
    b. Uncertainty disturbances
    c. Lesser excavation quantity and fully automated
    d. No at-grade diversion need
    e. No utility network disturbance
    f. No need for above access
    g. Assembly once forever, no disassembly
    h. Good for long excavations, not short ones
    i. Good for both deep and shallow projects
    j. Fully depending on foreign technology and skilled labor
    k. One cutting head only
3. NATM
    a. Low cost
    b. No Uncertainty disturbances to total schedule
    c. Ease of application
    d. In-place solutions
    e. No need of above access
    f. No at grade diversion
    g. No utility or underground facilities disturbance
    h. No expensive machinery or technology
    i. Good for both long or short, deep or shallow projects
    j. Full independency of foreign technology and labor
    k. Several cutting heads

As in case of Dhaka city, application of a tunnel construction method should be selected on above limits as well as future developments and situation as well as maintenance. As this manner is concerned there should always be a great care regarding the future possible developments and quantity of dependency on foreign technologies.

Also type and numbers of cutting head is a great concern, as if there is any problem in cutting head, total progress is a function of progress of cutting head as in case of TBM there is only one cutting head but for Cut and Cover cutting is full section and for NATM there is multiple cutting heads.

2.11. Overview

Based on different aspects discussed above, Dhaka city is suffering from improper public transport system which is causing all of the jams and disorientations in the city. Although the bus transport system is the most developed in Dhaka as compare to other modes, due to lack of management and improper capacity service, it is not sufficient in order to fulfill the transport demand of Dhaka city.

In case of the routes proposed by STP 2004, due to importance, second route is selected as MRT6 serving from Pallabi to Saidabad as it connects the north south corridor which there is no alternative route to the corridor selected.

Based on different aspects considered above in case of all tunneling methods, application of each Method is a function of type of demand, length of the project, time consumption and budget.

As in case of Dhaka city, application of a tunnel construction method should be selected on above limits as well as future situation and maintenance. As this manner is concerned there should always be a great care regarding the future possible developments and quantity of dependency on foreign technologies.

As any country is subjected to governmental and political variation and changes, independency from foreign technology is of a great importance. In case of TBM there is a huge dependency on foreign technology but for NATM and Cut and Cover dependency is mainly on local technology and labor as well as the knowledge.

3.1. General

Methodology helps to categorize and classify the total sequence of the study in order to have the most efficient result outcome of the thesis.

The current study is an attempt to investigate the overall metro construction consideration of Dhaka and the role of mass transit in the transportation system of Dhaka City and to justify the prospect of Mass Rapid Transit (MRT) as a better mass transit option. The entire study has been performed in a number of stages

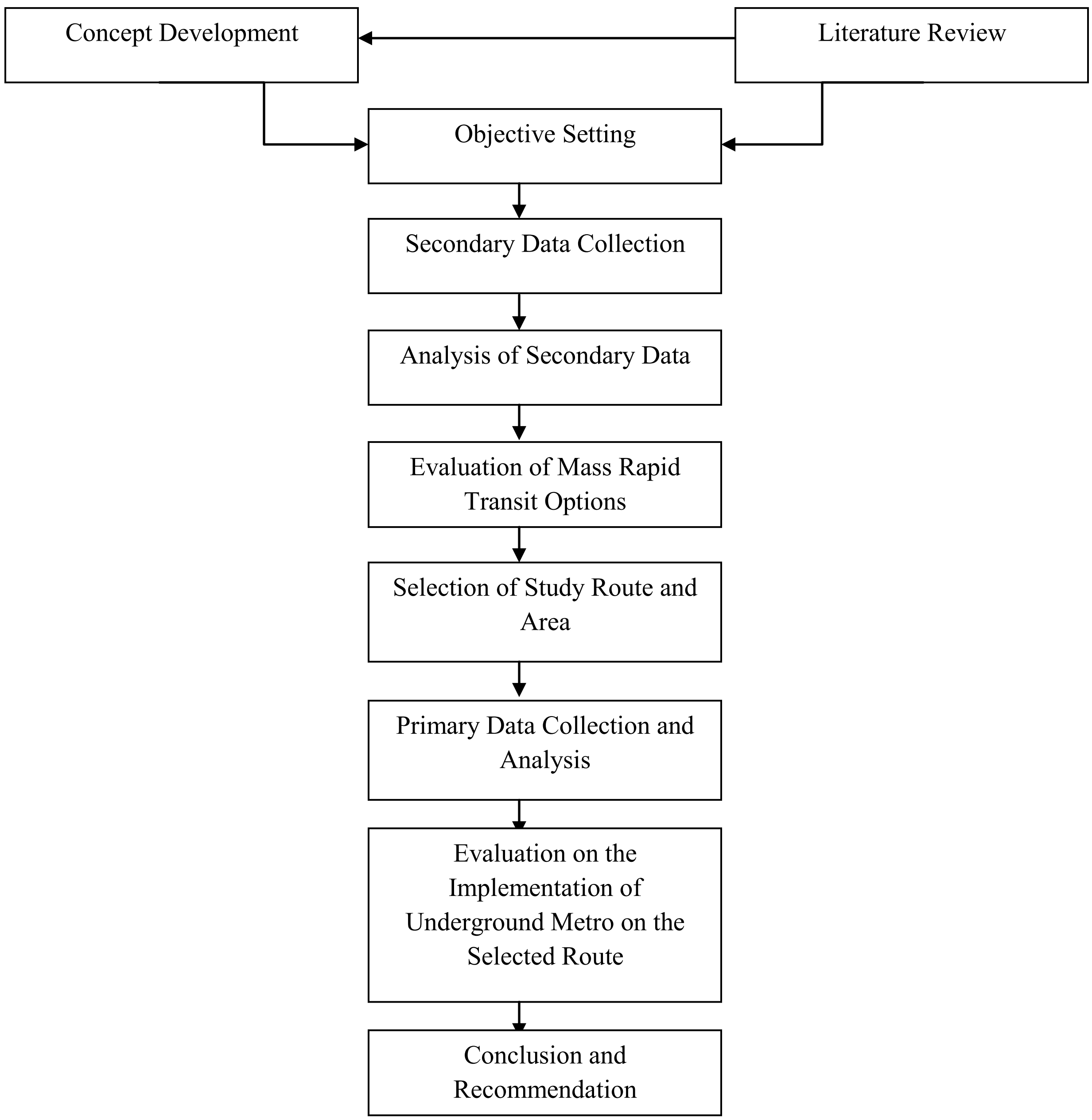
3.2. Methodology of the thesis

In order to achieve the objectives that are set in the introduction chapter, following is the methodology total process which is carried out in this study.

- At first the total objectives of the study were set as without objective formulation there is no progress in the study.
- An extensive literature review was carried out which gives the basic of information and relative topics studies about the thesis including the large number of reports, papers articles, internet sources, etc.
- Analysis of the secondary data was made.
- A study area has been selected to carry out the survey work on the public transport system available for the people.
- As underground metro is a relevantly new concept of transportation, the materials and articles as as well as sites are not available in Bangladesh .internet was used to gather information about the ongoing metro services around the different cities in the world also some abroad trip was conducted in order to see the sites in order to have a clear concept about the total tunneling process as well as the sites characteristics.
- Primary data was collected in order to have a clear concept about the difficulties and limitations as well as challenges in Dhaka city regarding the metro system. The primary data was regarding the challenges was collected from Bangladeshi authorities and abroad information was collected from Iranian authorities.

- Analysis of a metro system has been done for Dhaka based on the information collected on this system.

- Finally, all the facts and information have been congregated to prepare the overall report on the implementation of underground metro in Dhaka city as well as the different challenges and difficulties consideration with necessary recommendations for further study.



3.3. Overview

All the facts and information regarding overall transport situation, problems in mass transit operation and management, etc have been synthesized and compiled together to prepare the report. Moreover, the collection and analysis of data were conducted to justify the prospect of underground metro in selected corridor. The next chapter deals with the data collection and analysis procedure which is required for assessing the need for implementation of underground metro as the mass rapid transit option for Dhaka city.

4.1. General

Despite a very nice, kind and cooperative behavior of following utility service firms and managers to the researcher, collection of data from them was a very tough task to accomplish.

In first aspect of problem presence of old network and improper alignment, as well as absence of separating structures underground, makes the management of network a very difficult job for the operators. Due to impossibility of opening of all trenches in order to update the old, and hand drawn plans into GIS and computer based data, in so many areas and locations, understanding of network by firm is still based on hand drawings and partial maps which some of them are improperly drawn and in low quality as compare to similar computer cases. Also it is here to mention that except WASA which was developing and providing the data in computer format and easy to handle for research, all of other firms are having the old and improper drawings which makes the primary data collection very difficult. That"s why almost all of the drawings provided in this section are drawn by researcher himself and are based on his own understanding of the network present condition based on the information collected from representative utility firm and face to face interview with their managers as well as scattered data collection from them, some of them partially and some of them computer based format.

Second main difficulty faced in this primary data collection should be called "security of open information". Due to commercial possible abuses of the data revealed by the utility services firm they always feel unsafe to provide any information, particularly in DPDC, DESCO, BTRC, BTCL and Titas Gas utility lines. Right now the only authority which is allowed for road excavation in order to provide more services and distributive network is the correspondent organization which they do have the plans and layout information. But by presence of information in the open, there can be access to exact location of the network for anybody who studies this research. So this is a right action by them to not to reveal any information regarding their network layout and characteristics. To overcome this problem researcher has taken a meeting of face to face interview and discussion by high authorities of the utility service providers in order to justify the need of information and convince them about the safety of information used by BUET only in research purpose and no commercial advantages else. Each single utility network information provided in this section is a result of face to face interview of researcher with high authorities of correspondent utility providing services of minimum one hour as well as sightseeing regarding the difficulties faced in each of them. Reports are accompanied by name of authority manager by date which was kind enough to provide the proper and vital information.

As of tunnel construction sites surveyed in this study, collection of information from the construction site as they all have been located abroad, collection of pictures and data is a matter of several days, site seeing and data collection. As the most of information in the field is a matter of experience of the field engineers, collection of data from the field needs a large effort and wide vision. All of data and information provided in this section are the result of sightseeing and field surveys of Iran Tehran underground tunnel construction projects.

4.2. Route selection

Based on the data collected, Dhaka city road is divided in to four main north south corridors as Azimpur road, Airport road, Rokeya Sarani road and Rampura DIT road. Out of three MRT lines suggested, MRT4 is located along the at-grade rail road with a large setback and no difficult challenge also a lot of researches have taken this route as the main topic several times before. MRT5 is standing in circular loop from in east west direction which due to north south development of Dhaka, east west corridors are not main corridors of demand, so it is a second importance as compare to MRT6 travel demands in Dhaka, as far as the MRT6 is concerned it is located on one of the four main north south corridors of Dhaka passing from the most congested Farmgate to Sayedabad section which is having a large travel demand in the routes of Dhaka. Also presence of bus routes along the routes indicates the importance and need of mass rapid transit along the routes. Following is the typical diagram in Figure 4.1 is showing the concentration and demand of transport in the Dhaka city routes.

Based on STP 2004, total of three main corridors is selected as the essential corridors for metro system. Out of those three Uttura to Mottijil is considered as the first priority. That is the most popular corridor in Dhaka city known as MRT4 (called here in after). MRT4 is planned to serve the central corridor and is based on use of the existing railway corridor. It begins at Uttura, serving the International Airport road and could run at-grade possibly as far as the Cantonment Area at the north of New Airport Road. The Metro will then go underground serving Mohakhali, Tejgaon, Moghbazar, Khilgaon and Kamalpur Station terminating at Saidabad Bus Station.

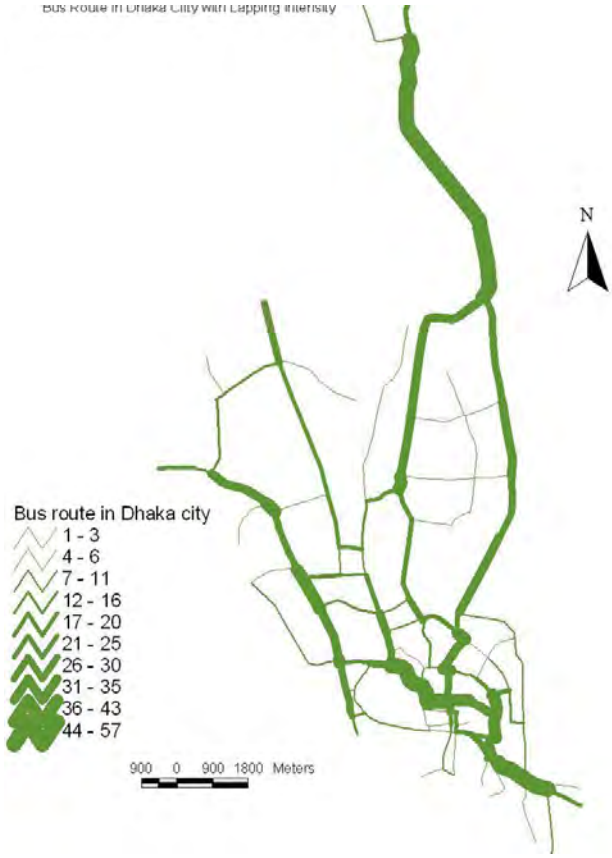


Figure 4.1: Bus Travel Demand in Dhaka Routes.

Due to the levels of passenger traffic demand on this corridor, once the Metro Line 4 is opened, there will not be a need for the BRT Line 3 on the upper sections of Airport Road. This will permit the Airport Road corridor to be released for highway usage where the traffic demand is shown to be high. This central corridor is a prime target for an elevated expressway connecting to the Gulistan Jatrabari flyover. Following is a typical diagram drawn by indicating the presence of BRTs and MRTs suggested by STP2004 in Figure 4.2.

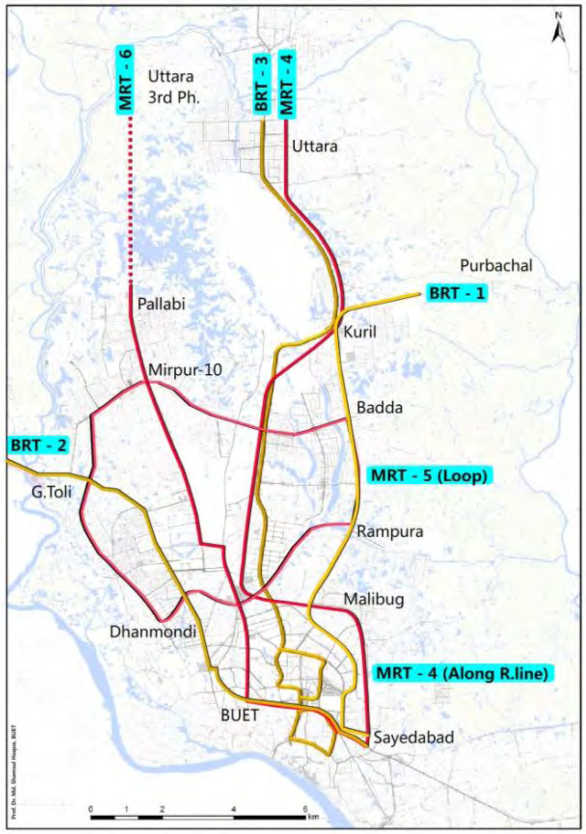


Figure 4.2: MRTs and BRTs Suggested by STP 2004

4.3. Route analysis

The selected route is identified and analyzed based on secondary and primary data collection. Each layout and network is responding to the metro construction differently. Application of methods and type of the method is strongly involved by the elements surrounding the metro system starting from the first excavations up to last operation phases. Each of the steps included in this chapter is analyzed in mainly three categories:

1. What is present situation: what are the layouts? What is the present presence?
2. What is the behavior of the element to the metro system lying near by the element?
3. What is future response of the element to the metro system nearby? If there is no presence today what are the future developments which may conflict or interfere with the metro system.

Any of the above main three questions provides very critical answer and leads to the best possible metro proposition for Dhaka city.

4.3.1. Introduction

Based on the studies undertaken in this thesis, the route 6 proposed by STP 2004 will be facing many challenges and difficulties. Recognition of challenges and finding the proper solutions to any of them in this aspect is an important job in order to identify the total process of the project construction and operation as well as the maintenance.

Different challenges faced in this project can be classified in three main categories:

1. Present utility lines and networks:

As far as the present utility lines are concerned, selection of the method of the tunnel construction as well as all other specifications, such as depth and maintenance is subject to characteristics of the over head utility network. Sensitivity of the network to settlements caused by the tunnel in future and possibility of the future developments in the network should have no conflict with the tunnel, during construction or operation. As the method of construction of tunnel is concerned, by knowing the possibility of dislocation ad relocation of each utility network and difficulties faced in this stage, proper tunnel construction method will be selected.

2. Future developments of other projects.

Dhaka city is subjected to a lot of future transportation improvements which so many of them are in need of making new structures individually. These structures are grade separated or at grade or underground structures. In any of three cases, they all either need foundation or land use, which may conflict in the foundation or in the spatial aspects. In this section studying of the different proposed alternatives in future and possibility of their conflict by the STP 2004 route six metro is considered.

3. Nearby structures:

Presence of large building near by the MRT route makes the engineers to design proper earth retention systems, in order to achieve the best sustainability in the tunnel project.

4.3.2. Utility lines

In order to select the best construction method, there should be a comprehensive study regarding different obstacles faced during the construction. One of the factors playing a vital role in decision making between cut and cover and New Austrian Tunneling Method, Sequential excavation Method (NATM, SEM) method, is the presence of at-grade or underground utility lines which in case of cut and cover method, they should be displaced during excavation and replaced after construction of tunnel and during filling back period. Dislocation and relocation of utility lines is always a difficult job, which is possible or impossible in some cases. Following is a study regarding present utility lines and difficultness and possibilities of displacing and replacing the network.

On the other hand, due to tunnel construction, tunnel‟s arch is causing some minor or major settlements to above utility lines. In this study researcher is considering a possibility and applicability of the network after possible settlement caused by tunnel construction.

As the utility lines are concerned, following is a list of present Dhaka utility networks implanted on selected route.

1. Electricity
2. Water supply and sewerage
3. Gas lines
4. Telephone and Fiber optics

4.3.2.1. Electricity

Electrical utility lines have always been a major arterial to city developments. Due to presence of costumers of electricity in all of streets full length of the route is subjected to underground electric utility lines.

In case of underground distribution network, utility lines have always been excavated , trenched and located long before present widening of the roads, as they were excavated and installed when the roads have all been much narrower as they are today subjected to large widening which leads the research to a very simple but important conclusion in beginning:

Almost all of the electricity distribution lines are located beneath the pavement of the roads and not the sidewalks or footpaths. As in Dhaka they are not usually elevated or spatial.

Here is a schematic before and present situation of the trenches made for electricity distribution network shown in Figure 4.3.

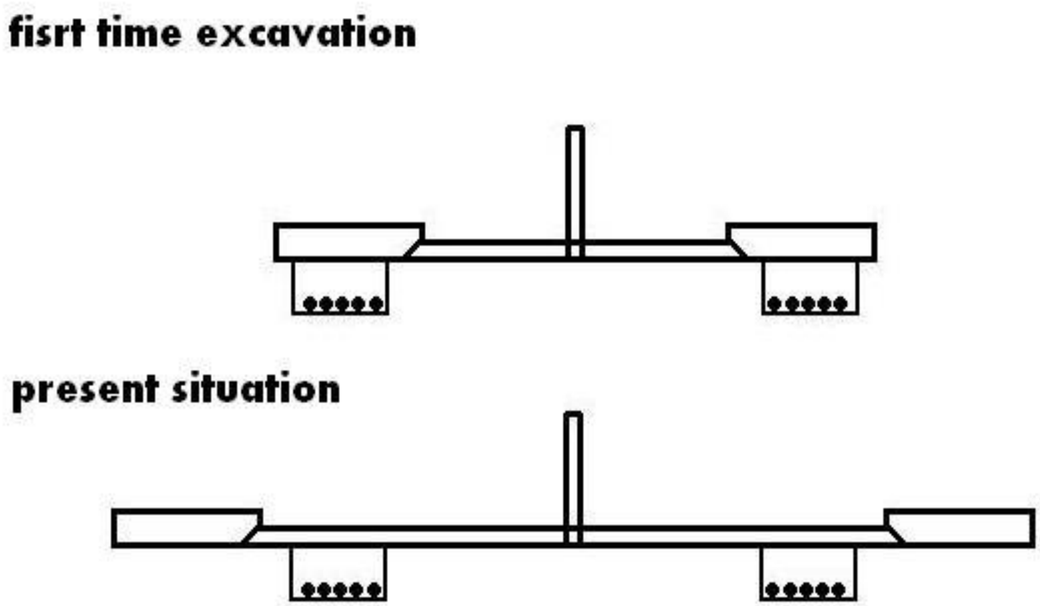


Figure 4.3: Past and Present Layouts Location

DPDC

This section of primary information is based on the interview with Mr. Ataul Hoque D.G.M of DPDC at 10:00 am at 17-NOV-2009.

Dhaka Power Distribution Company Limited (DPDC) is replaced for Dhaka Electric Supply Authority in 19 June 2008 and is supplying the electricity in the routes selected, roads of Fazzli Rabbi Road, Kataban Road, Shahid Minar Road and Kazi Nazrul Islam Avenue and

Airport Road Up to Farmgate, Bijoy Sarani and Parliament which all of them has been located in the route of Metro tunnel construction.

Plans and Layouts of Distribution lines

Based on Questionnaire survey conducted in this thesis, there is variety of different cables diameter depth and layouts which pushes the design of the tunnel construction method over the edge. Presence of all full length of the roads exposed to electricity supply layout is a great concern in dislocation and relocation of this facility. Main cables are;

132 kv U/G Cable which is the main arterial in support of the network, located at the depth of 1.25 to 1.5 meters in all roads and center to center spacing of almost 0.4 meters, beneath the Pavements.

33 kv U/G Cable which is second largest cable located beneath road pavements and provides second arterial located at depth of 1.5 meters included by all base construction.

As the cables change from arterial to more distributive cables, diameters reduces as well as correspondent depths which leads to a shallower cables.

Following is a layout showing a typical plan of Katabon Road indicating all three main cables in one point, near BSMMU medical university in Figure 4.4.

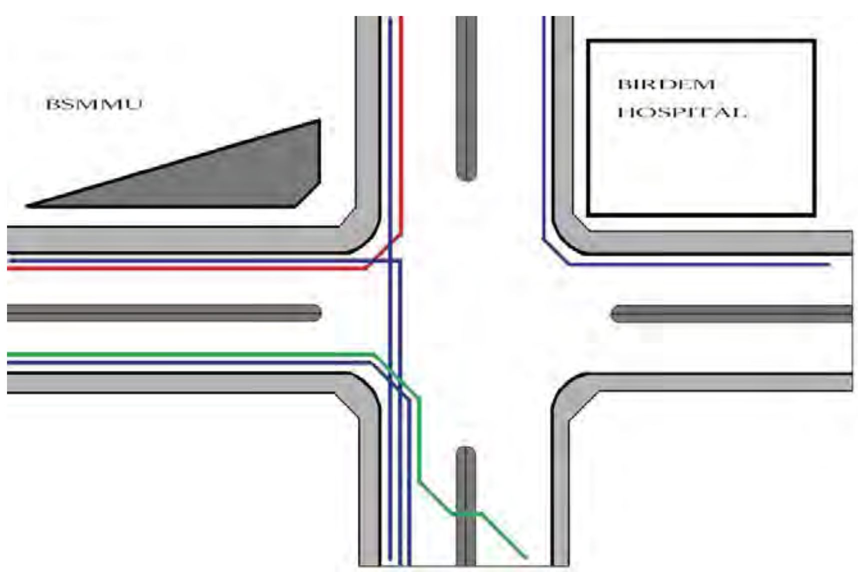


Figure 4.4: Shahbagh Intersection, Typical Location of DPDC Utility Network Location

Where: Red line is 132 kv U/G cable

Green line is 33 kv U/G cable

Blue line is 11 kv U/G cable

Following is a plan which shows the presence of main arterials of DPDC in November 2009 along the selected route for metro system.

DESCO

The DESCO is a replaced firm of DESA in 19-June-2009 which is responsible for distribution and supplying of the electricity of area which is limited from north to Tongi and Turag River, from east to Balu River from south to parliament.

Following in Figure 4.5 the covere area of DESCO November 2009 included by the route alignment for Dhaka metro system.

Figure 4.5: DESCO Area Map

As it was said in introduction due to roads widening there has been a change in position of trenches which causes the lines to be located at the road pavements. Following is a typical plan which shows the current structure of the trenches which are located beneath the road pavement in DESCO section of the route. It is included of 33 and 11 KV U/G Cables extended from Agargaon electric station to Ibrahim station which are covering the route from IDB Babhon building up to Kazipara Zame Mosque which is covered by 2 or 3 of 33 kv U/G Cables.

As it is obvious form the drawings provided by DESCO in appendix, main arterials in the DESCO area is as same capacity as DPDC, as the main cables are of 132, 33 , 11 kv U/G Cables which deepest one is 132 and 33 KV U/G Cable at the depth of 150 cm from ground level. Figure 4.6 indicates the presence of arterials along the selected route.

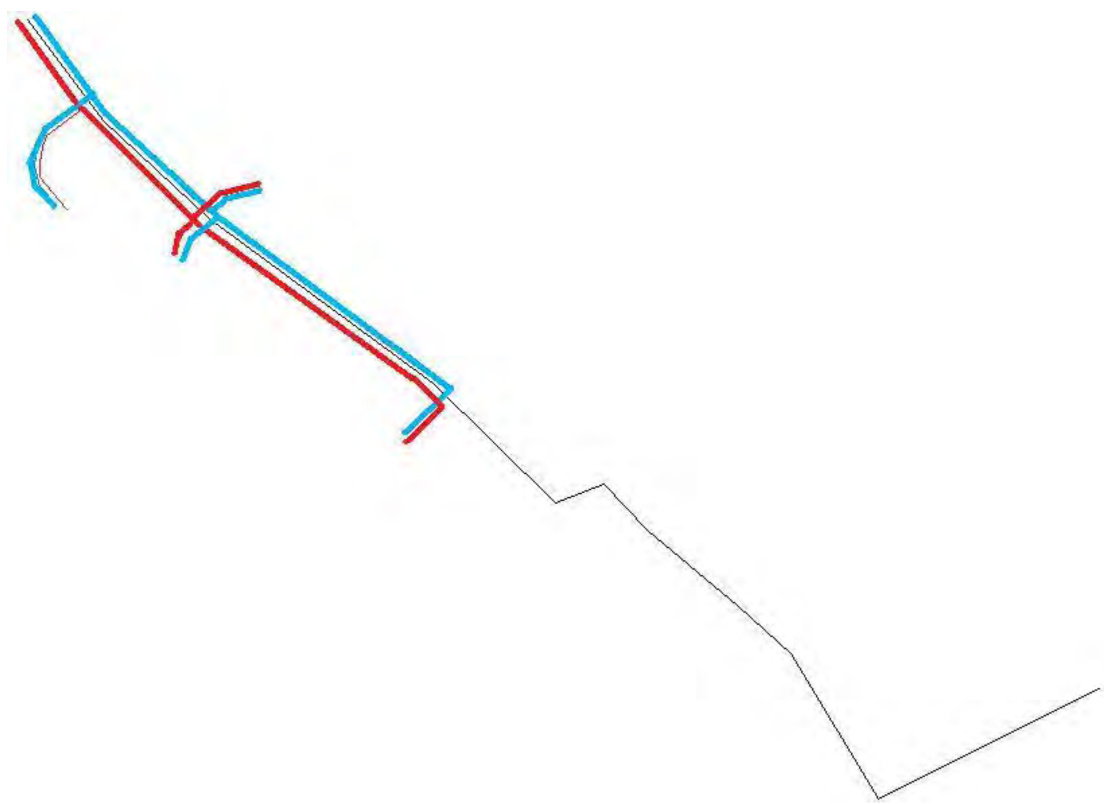


Figure 4.6: DESCO Electric Layout (Source DESCO, Primary)

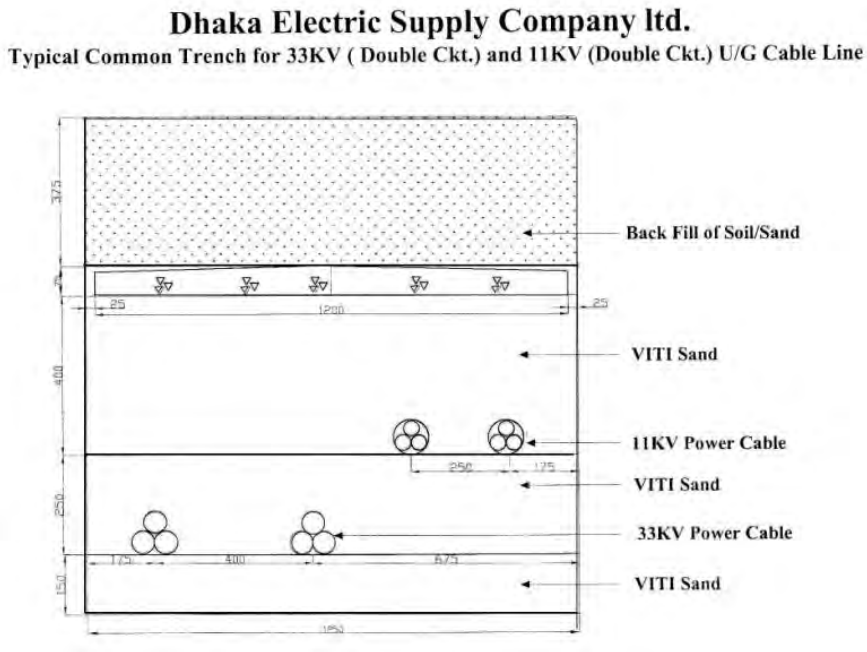


Figure 4.7: Typical Common Trench for 33 and 11 KV Cables

Despite of presence depth of 150 cm in all DESCO and DPDC network, they both have clarified that there is no line deeper than 150 cm which is the limit of the network line depth. Figure 4.7 indicates a typical trench of excavation for DPDC and DESCO utility lines.

Although there are plans and layouts available, but absence of GIS in Dhaka electricity network, is causing a lot of difficulties.

Future Developments

In case of network management almost all of layout lines are subjected to a large contact by environment which poses a lot of uncertainty regarding present network location as well as erosion. Due to lack of arrangement of the network in site, which causes a lot of difficulties in field, both DESCO and DPDC have proposed different layouts and sections which will lead in to a duct of concrete and accommodates all of present and future network arterials as well as distribution network cables. Also the ducts are designed and proposed by enough vacancies in order to accommodate the phone lines, Fiber optics and internet lines underground in the same duct. Figure 4.8 indicates the proposal by DESCO and Figure 4.9 shows DPDC proposal.

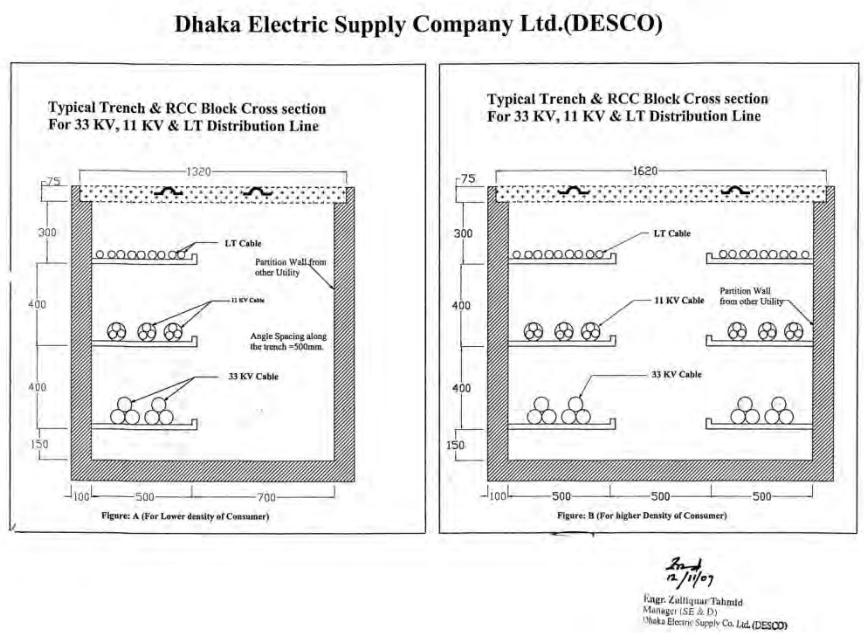


Figure 4.8: Proposed Future Development Trench by DESCO (Source DESCO)

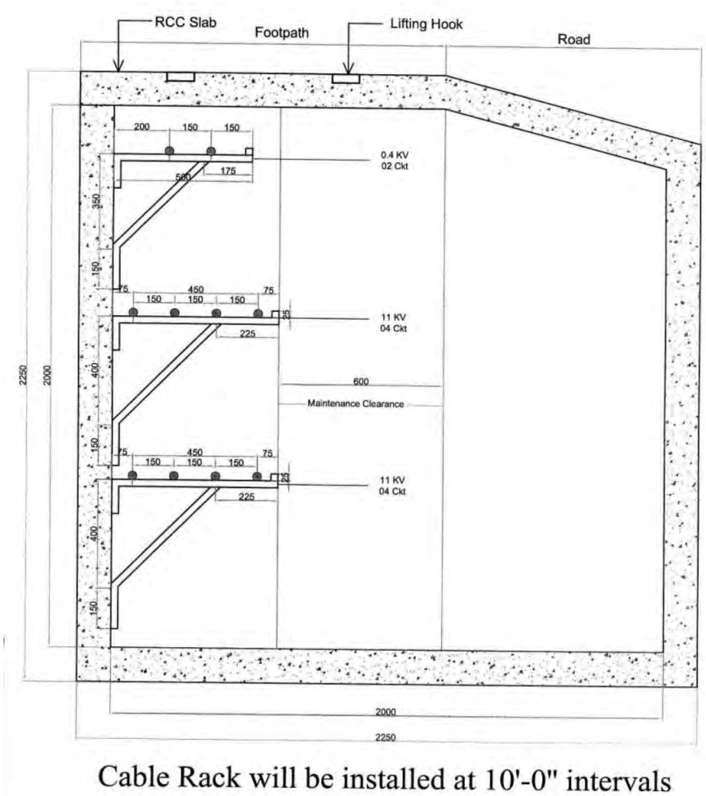


Figure 4.9: Proposed future development trench by DPDC (source DPDC)

Relocation and Settlements

As in case of the Dhaka city, due to large application and demand of electricity, the live lines going on right now are subjected to heavy work currents. Due to flux produced in heavy 33 kv U/G Cables after they are being installed, and loaded, because of inflexibility produced later on in the cables, dislocation and relocation of them is not applicable. On the other hand, in process of removing cable, not enough care can be taken remove the cables safely, and they will damage the cables in such a way that cables are no longer applicable. So after remove of the live cables, during the tunnel construction there should be alternative for live lines in order to provide the electricity to costumers which need a new installment and demolishing and then for the second time, provision of a new live line above constructed tunnel which means a completely new network. For DESCO and DPDC there is no option as remove and relocation, in fact that is defined as demolishing and construction of a new network twice.

As the above tunnel is subjected to possible settlements of a few centimeters, network of DESCO and DPDC are applicable and tolerates the settlements in defined scales.

4.3.2.2. Water and sewerage (WASA)

This section of primary information is based on the interview with Mr. Ataul Hoque D.G.M of DPDC.

Water supply And Sewerage Authority in Dhaka is responsible firm `to provide water supply and sewerage and drain collection service. The network is defined in three classifications; water distribution, sewerage collection and drainage collection. Between all these three, the most complex and variant, as well as extended is water supply as it has to reach each single water consumer in the network. In depth, sewerage and drainage network are the deepest in order to collect and flow under gravity force effect. Some areas are missing in drain and sewerage facility network but water supply system is available almost in all of the road networks of Dhaka city.

Layouts and Characteristics

Considering the alignment selected for metro construction, almost full length of the alignment is subjected to at least one of branches of WASA. Regardless of the fact that they are located at different levels regarding their service and utility, there is no specific structure to support the pipes and conduits which gives clue that the WASA network cannot be subjected to large settlements as they work under the gravity force and there is a great importance to inclination and relative inclinations to other conduits.

Water distribution layout

As it has been the case for DESCO, DPDC, and all other utility lines, they all have been installed long before development and widening of the road, in the sidewalks and by increasing number of costumers, they have been replaced by larger diameter of pipes. Later on by road widening activities and improvements, they have been shifted to the road pavement, usually located at the outer side of the pavement, near by the sidewalk at the offset of 5 to 10 feet. Also today for having the minimum network disturbance due to excavation in order to maintain or repair or renovating of the network new utility lines are placed in the same offset for ease of excavation, information classification and minimum traffic flow disturbances.

Here is a typical plan drawn by the researcher, based on information gathered on questionnaire survey of the site which shows presence of arterials along the selected rout with their respective diameters. This network is the most extended network of WASA as it has to reach to each single costumer on the network. Usually standing on a depth of 4 feet cover plus pipe diameter which reaches to maximum depth of 7.5 feet in the selected route.

Pipes material is Asbestos Steel which today they are recognized as harmful to human health and should be subjected to future replacement. Also as there are no present structure in order to support the pipes installed in network, any future settlement because of tunnels excavation will affect the pipes vertical displacement directly which causes a large defect to the network. Any change in elevation means need of future pumps in order to compensate the pressure drop in the network. Figure 4.10 indicates the presence of arterials along the selected route.

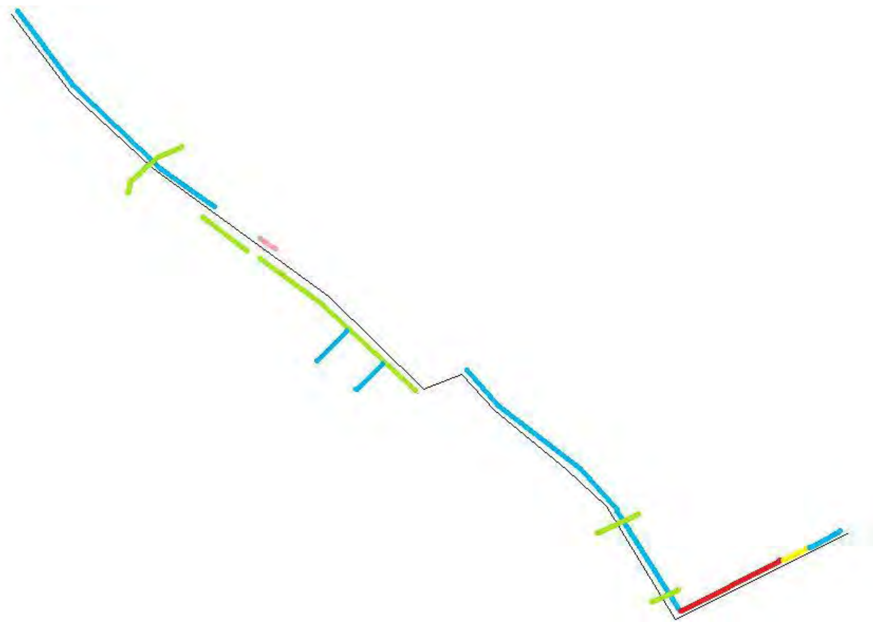


Figure 4.10: WASA Water Distribution Network (Source WASA)

Where:

Blue line: 300 mm diameter

Green line: 400 mm diameter

Red line: 1000 mm diameter

Pink line: 100 mm diameter

Yellow line: 1200 mm diameter

The map drawn above is a typical showing the arterials based on data provided by WASA and based on understandings of the researcher from the network along the selected rout.

In some rare cases water supply utility lines may get lower, due to obstacles like lakes, which in the selected route no point is subjected to such obstacles or limitations.

Sewerage Collection Layout

Sewerage network is the second developed in area as the dimension scope is concerned. Despite the demand for this utility service, due to large availability of open and easy access rivers, in so many areas of Dhaka city, sewerage network is not available, and people are using natural alternatives in order to dispose the sewage water. So due to lack of availability of sewage network, environment is subjected to a large human"s pollution. There are some areas like Uttura which the sewerage network is not developed at all although there are some future plans regarding the network development.

Based on date of installments of the pipes in place, due to change of load and technology there is variety in pipes material. Main materials used as pipes are Clay pipes, DC pipes, PVC pipes and Concrete pipes lying in the soil with no cover pr primary protection or any support in order to keep the inclination fixed. Despite the fact that inclination is having the main role in sewerage network. Minimum depth of 4 feet is applied at start points up to 25 feet with constant inclination.

Figure 4.11 indicatess the typical present sewerage network in Dhaka city covering the route in 7.38 km length.

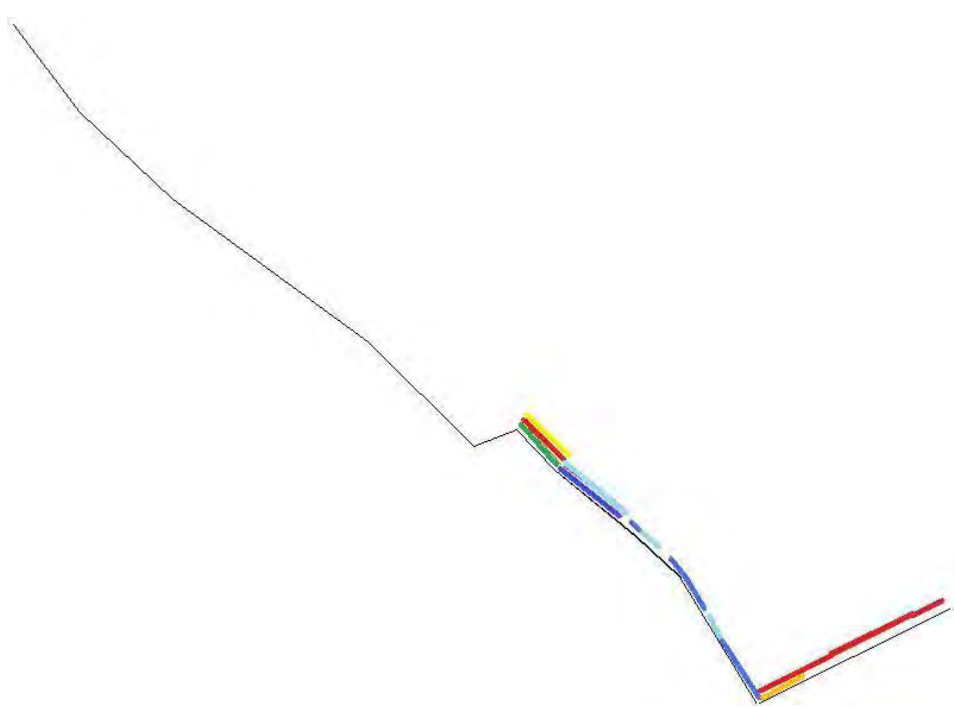


Figure 4.11: WASA Sewerage Collection Layout (Source WASA, Primary)

Where:

Yellow lines: 600 mm diameter pipe

Red lines: 1200 mm diameter pipe

Green lines: 450 mm diameter pipe

Pink lines: blue line should be used in this

Dark Blue lines: 1800 mm diameter pipe

Blue lines: 225 mm diameter pipe

Relocation and Settlements

Sewerage is always flowing under the principles of gravity and should be defined in specific inclination in order to keep the flow constant and in desired velocity, not too fast that water flows and solids remain, not too slow that water flows and solids sediment. That"s why any settlement in network due to tunnel construction will affect the total flow unpredictably as it is no exactly obvious how much to total and relative settlement is. A settlement in sewerage flow is very difficult to tolerate and is almost impossible to carry on.

As long as one sewerage conduit is in duty, it is almost impossible to apply alternatives in order or dislocation and relocation. It is complete remove of existing network and construction of a new conduit although if there is enough space at the site, present pipes may be stored in place and be used later on in future as new network installment to improve the economic aspects of the job. Meanwhile of construction the load of sewerage should be shifted to any other alternative which there should be enough space and capacity to carry on. For that purpose there should be a comprehensive study and analysis of possible alternatives from WASA side which is out of scope of this thesis.

Future Developments

Because of world accepted method of sewerage today, and due to applying the same method in Dhaka, in future there will not be any change in method of sewerage for Dhaka, as the time this research was undertaken. In case of depth the maximum which sewerage network is carrying is 25 feet which in future no further or deeper conduits are considered so far.

Drainage Collection Layout

Drainage is the least developed in case of Dhaka as compare to the other networks of WASA. It is designed and installed in order to collect the storm and rain waters from the city surface, not too much branched but having large diameter arterials in some of the main roads of selected route. Depth can reach up to maximum of 25 feet which is always subjected to inclination and lift pumps in order to keep the storm water flow. Almost all of the characteristics of drainage, regarding the limitations and depth as well as future plans are same as sewerage network of Dhaka city.

Figure 4.12 is a typical plan drawn by the researcher indicating the route subjected to drainage network presence.

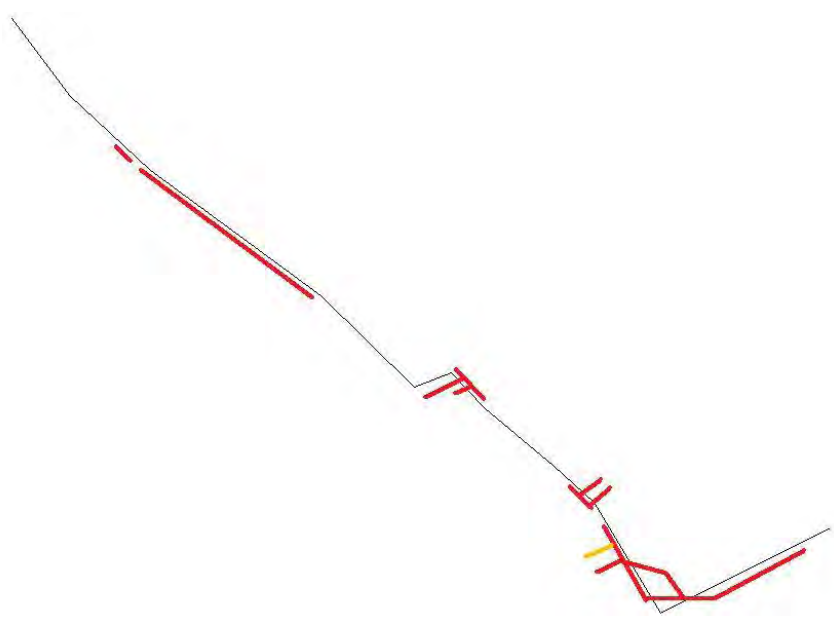


Figure 4.12: WASA Storm Water Collection Layout (Source WASA, Primary)

Where;

Red line; storm sewer line

Yellow line: brick sewer

Future Developments

As the storm water rain water collection system is working under the law of gravity they are always subjected to inclination as it is an accepted method around the world as same as Dhaka. In this case as the Dhaka has already reached to its 25 feet depth, no deeper conduit is considered to be proposed as this thesis is undertaken. No future development is planned in a way that it may interfere with tunnel constructed below.

Relocation and Settlements Issues

Relocation in case of drain is a difficult job to do because of quantity of soil to be removed as well as accommodation of conduits in future. Excavation of 25 feet and removal of the conduits and using them in future is possible, but time consuming and expensive. In case of drainage system, as the number of the conduits in one section is usually one, not much difficulty is faced although it needs time and money.

In case of settlement the scenario is different. As the drainage works under the gravity, change of inclination due to partial settlement of the pipes is not handled easily. As the settlement may be partial and not clear in location and dimension and may cause a change in inclination of the conduit, fixing of the problem is a difficult task due to uncertainties.

4.3.2.3. Gas Utility Network

This section of primary data is based on the interview with Mr. Fuatul Islam, Director Operation of Titas Gas building, 11:30 am 09/NOV/2009.

Titas Gas is the main and only supplier of the gas in Dhaka city covering all of the city and industrial areas consumers as a 42000 capita per Km square.

As same as all other networks gas network is also subjected to road widening and have been located at the footpath at first and later on shifted to road pavements as it was shown in Figure 4.3 located at the offset of 5 to 10 feet from foot path.

Usually the material used for gas pipes are steel and there is a constant defined current in the pipes in order to reduce the possibility of sparks and flame. Pipes are mainly used in a depth 3 feet plus pipe diameter which shows a maximum depth of 5 feet as the largest diameter

Almost in all of the sections, there are different pipes diameter of 16, 12, 8, 4 and 2 inches which are covered in primary paints in order to reduce the possibility of the erosion. All of the pipes are placed in the soil without any supporting structure which means any settlement in the soil due to tunnel construction directly affects the gas network.

Following is Figure 4.13 which shows the diameter and the pipes available and covering the selected route along the way.

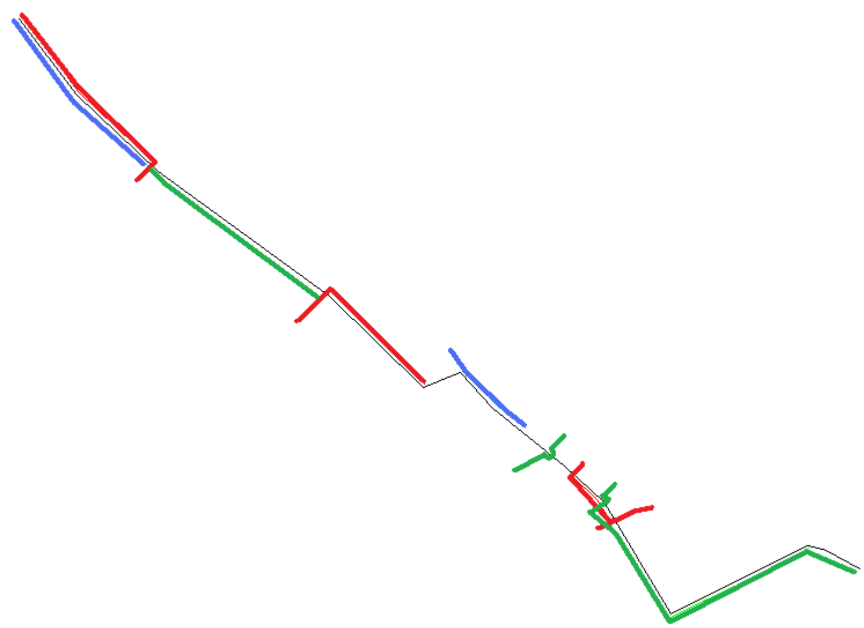


Figure 4.13: Titas Gas Utility Network Layout (Source TITAS Gas, Primary)

Where:

Red line: 16” @ 140 PSIG gas line

Green line 8” @ 50 PSIG gas line

Blue line: 6” @ 50 PSIG gas line

Future Developments

Today type of the work which is performed by the Titas Gas Co. is in fact an accepted and standard level of the work. Due to ease of access at top and no need of going any deeper in order to save the pipes, there is no future plan proposed so far in order to improve the location or the layout of the network which may interfere with tunnel construction in future.

Relocation and Settlements Issues

Gas flow is always a function of the pumps and the pressure applied in order to keep the flow constant and smooth and in desired speed. Inclination or any other natural element is considered in flow. Also due to flexibility and possibility of deformation as long as the settlement do not cause the cracks or any other breaking in the pipes, and as long as the inclination or deformation does not produce any pressure drop in the pipes, the existing network is reliable in case of settlement caused by the tunnel construction.

In case of dislocation and relocation there is a big challenge to face and that is about the presence of a large number of consumers which they should be supported from another supply or network. As the total project of tunnel construction takes of 2 to 5 years, there is a need over construction of a temporary network and make another network after the construction or filling is done. Again, large money and a great management are needed in order to accomplish this job.

4.3.2.4. Telephone and Fiber Optic Utility Network (BTCL)

This section of primary information is based on the interview with Mr. Anwar Husain at Mohakhali BTCL office at 16:30 at 25-Nov-2009

The most complicated, unpredicted and unclassified in location aspects is telecommunication systems in Dhaka. Usually elevated but recently they have planned for underground structure in order to accommodate the fibers. Although proposition by the DESCO and DPDC which can accommodate the present and future telecommunication network, BTCL is considering a project which they have already started in 1997 by ALCATEL Co. and is an underground structure at the depth of maximum 10 feet and network of 5 feet which is giving the network under the pavements.

Today the entire network is laid under the pavements already at the depth of 4 feet and covered in PVC pipes in order to stop the direct contact with the soil at the site.

As long as the route conflicts are concerned, they are covering a large span in elevated position and they are planning to go underground as it mentioned above.

Future Developments

As of today, the maximum depth that BTCL or BTRC have reached is 5 feet. In future development, following is the proposed profile in order to accommodate all of elevated and underground cables in one canal with specified manholes in order to classify and ease of maintenance. Although this proposal helps them to get through the challenges, but using the DPDC and DESCO proposal is easier and handier.

Relocation and Settlements Issues

As far as the settlement is concerned there is a great advantage that BTCL and BTRC network are completely independent from inclination or the settlement as far as the dimension of settlement in this thesis has considered. As long as the settlement caused by the tunnel construction does not disconnect that network for the flow, there is no difficulty faced in settlement. For definite there is some change and variations in current flow in the networks, but as they are very minor, fixing and taking care of them is a normal daily job for BTCL and BTRC and is out of the scope of this thesis.

In case of dislocation and relocation, as today‟s situation, due to elevation which the network is subjected to, there is no serious concern about the underground excavation in such a big matter. As the network is located above the ground, and availability of the network is having a less importance factor as compare to Electricity, WASA or Gas, no large challenges is considered to be faced.

4.3.3. Future Transportation Infrastructure Developments

4.3.3.1. Future Developments of Dhaka City

Based on book STP 2004, there has been six different strategies applied and suggested based on the population and land use scenario. Here are the projects suggested by STP 2004:

Line 3: BRT 3

This BRT line is planned to serve the central corridor and is based on Airport Road and the Ramna Area. It begins at the International Airport running via the Cantonment Area to Mohakhali. At this point the line will divert from Airport Road and pass Mohakhali Bus Terminal following Shaheed Tazzudin Road as far as Ramna. The BRT line will run in one direction in an anti-clockwise loop based on College Road, Phoenix Road and Nazrul Islam Sarani. The loop may be extended into the old city area via Kazi Alauddin Road, Nawab Yusuf Road, Islampur Road. Johnson Road, English Road and North South Road. This will also provide a good interface between the transit system and the waterways system at Sadar Ghat. As demand is shown to increase, the line could be extended to Uttura, Tongi and Gazipur in the north (STP 2004). Figure 4.14 indicates the location of BRT3.

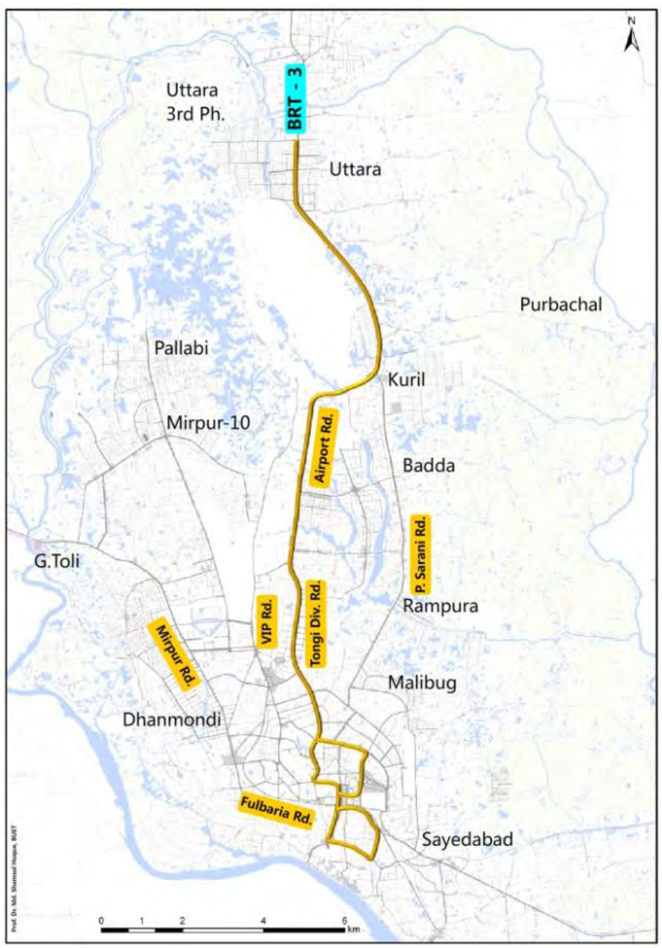


Figure 4.14: BRT 3 Proposed Line by DCC

Line 2: BRT 2

This BRT line is planned to serve the western corridor and is based on Mirpur Road and Zahir Reihan Sarani Road. It begins at the Gabtali Bus Station/Ferry Landing Stage and runs as far as Dhanmondi. At this point the line will cross over onto Zahir Reihan Sarani Road as far as Saidabad Bus Terminal where it will terminate. When the Gulshan-Jatrabari flyover is in operation, it would be possible to leap-frog some services (STP 2004). Figure 4.15 indicates BRT3 and BRT2 with respect to each other.

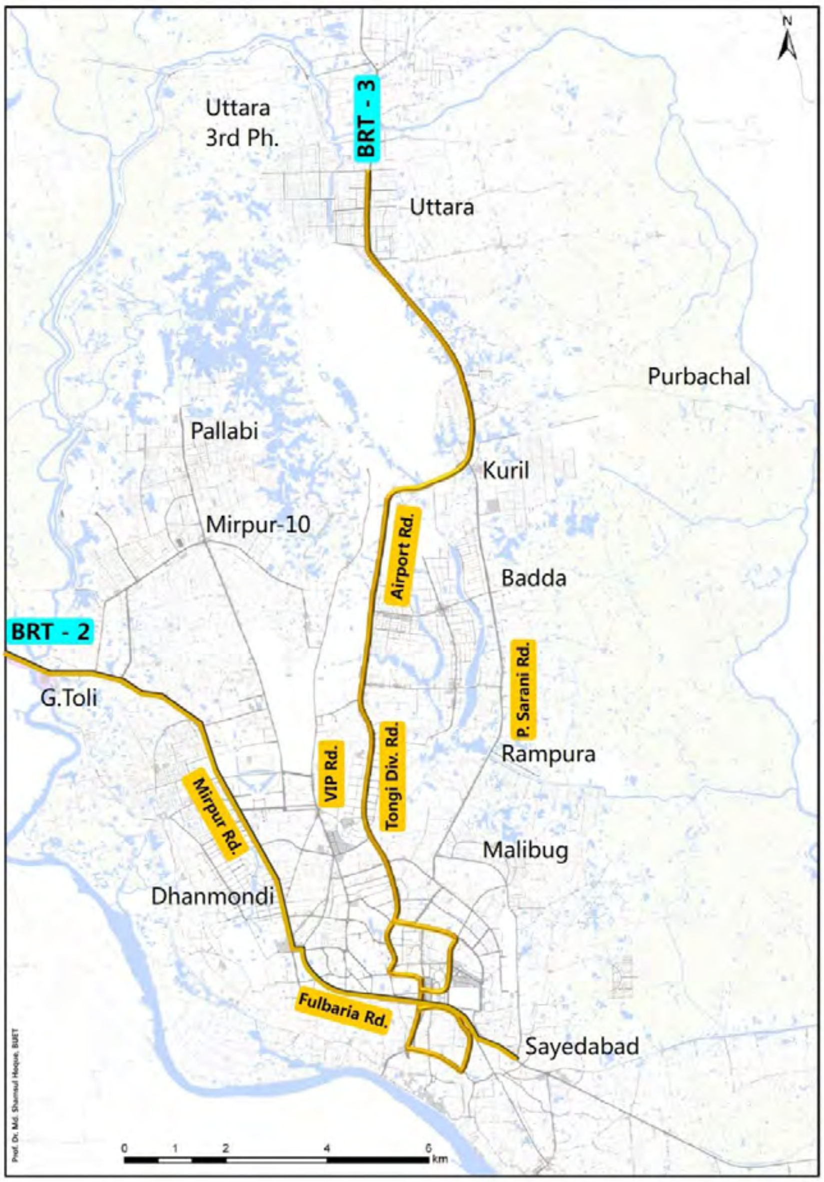


Figure 4.15: BRT 2 & BRT3 Lines Proposed by DCC

Line 1: BRT 1

This BRT line is planned to serve the eastern corridor and is based on Progati Sarani and DIT Road. It begins at Uttara and serves the International Airport then runs down Progati Sarani and DIT as far as Malibag. At this point the line will move onto the Outer Ring Road as far as Kamalapur Station and then south and east to terminate at Saidabad Bus Terminal. As demand increases, the line could be extended to Tongi and Gazipur in the north and to Demra and Narayanganj in the south. Figure 4.16 shows the BRT1, BRT2 and BRT3 in the same map.

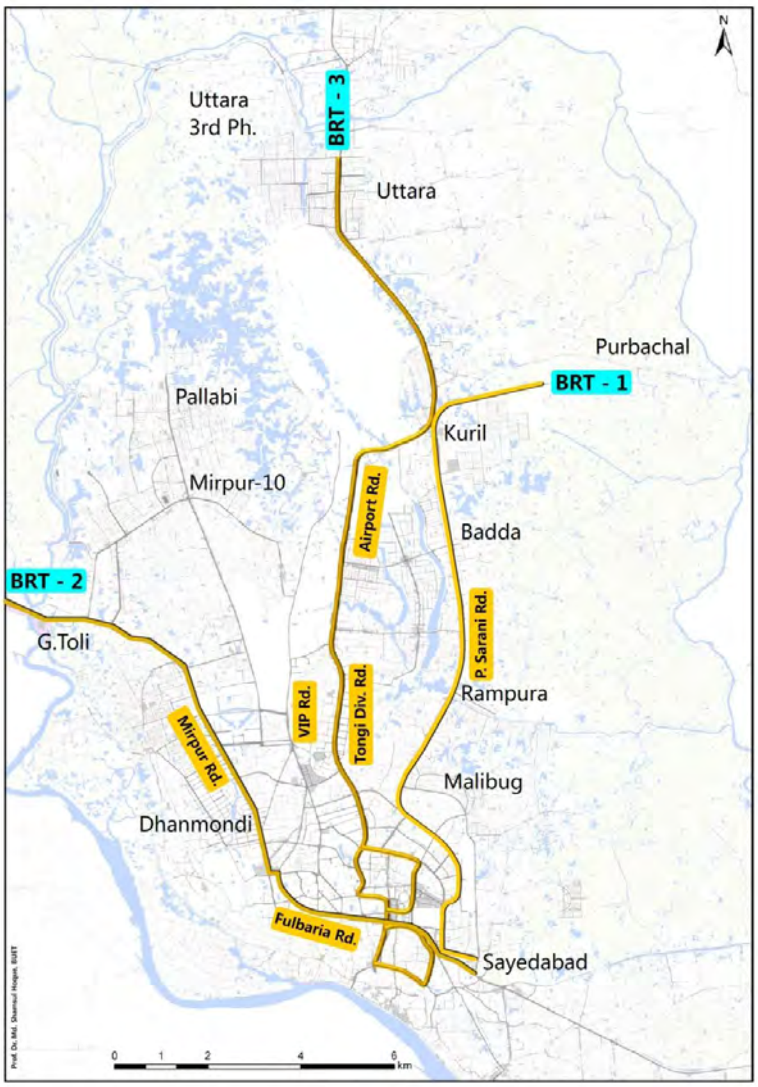


Figure 4.16: BRT 3, 2, 1 Proposed Line by DCC

In case of the MRT lines, STP 2004have suggested following 3 routes as the metro lines or MRT which in future they are supposed to be constructed. Following is the lines in sequence.

Line 4: MRT 4

This Metro line is planned to serve the central corridor and is based on use of the existing railway corridor. It begins at Uttura, serving the International Airport and could run at-grade possibly as far as the Cantonment Area at the north of New Airport Road. The Metro will then go underground serving Mohakhali, Tejgaon, Moghbazar, Khilgaon and Kamalpur Station terminating at Saidabad Bus Station. Due to the levels of passenger traffic demand on this corridor, once the Metro Line 4 is opened, there will not be a need for the BRT Line 3 on the upper sections of Airport Road. This will permit the Airport Road corridor to be released for highway usage where the traffic demand is shown to be high. This central corridor is a prime target for an elevated expressway connecting to the Gulistan-Jatrabari flyover. Figure 4.17 indicates the MRT4 in Dhaka city.

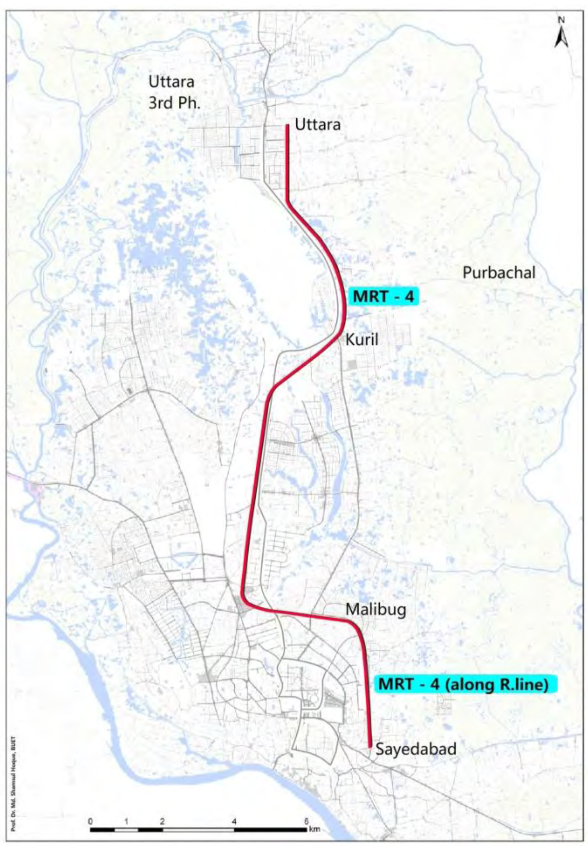


Figure 4.17: MRT 4 Proposed Line by DCC

Line 5: MRT 5

This Metro line is planned to provide two good east-west connections within the high density residential areas of Gulshan, Dhanmondi and Mirpur and the developing areas to the west of the Cantonment Area and is shown as a continuous loop. Commencing in Gulshan at Progati Sarani, the route follows Kamal Attaturk across Airport Road. The line serves Kafrul, Mirpur, Mohammadpur, Dhanmondi, moves east to serve Tejgaon (Farmgate) then Rampura before turning north to Badda and Gulshan. It is believed that this could be constructed above ground and could be implemented faster than an underground Metro construction. Figure 4.18 indicates MRT5 in Dhaka city.

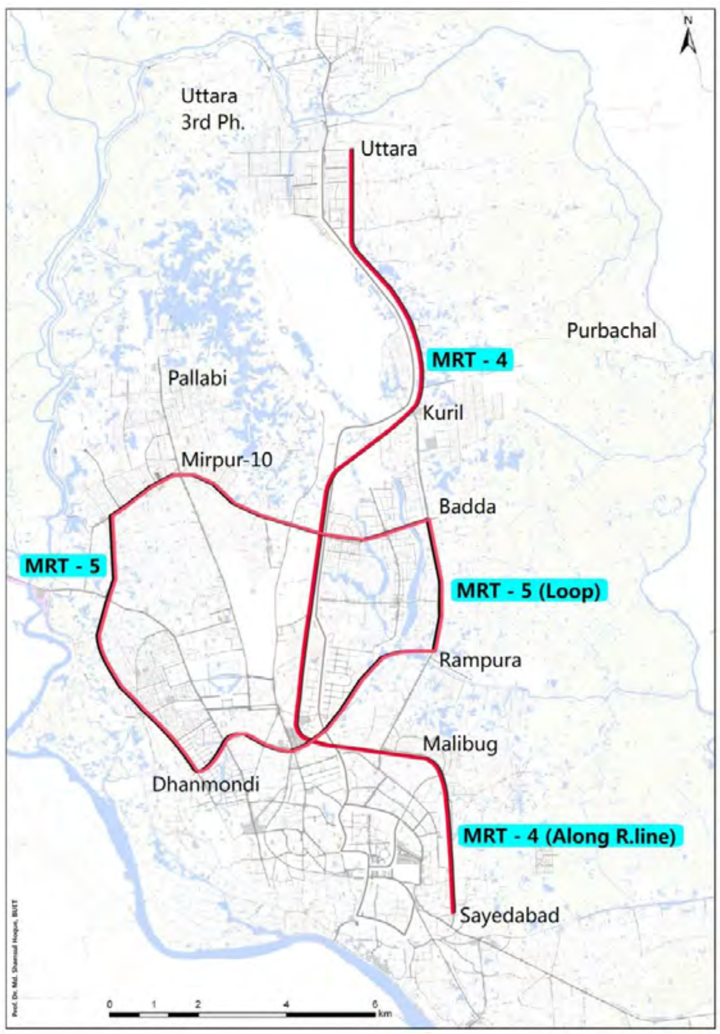


Figure 4.18: MRT 4 and 5 Proposed Line by DCC

Line 6: MRT 6

This Metro line is planned to provide a connection within the developing areas to the west of the Cantonment Area and the central area. The alignment is based on Begum Rokeya Sarani, Sonargan Road and Zahir Reihan Sarani. Commencing in Pallabi, the route follows Begum Rokeya Sarani as far as Tejgaon where it follows the alignment of Airport Road as far as the Sonargan Hotel. At this point the line follows Sonargan Road to Zahir Reihan Sarani terminating at Saidabad Bus Terminal. An option has been considered to move the alignment to pass through part of the Old City area although more alignment planning and feasibility is required to verify this. Figure 4.19 indicates all of MRTs in Dhaka city with respect to each other.

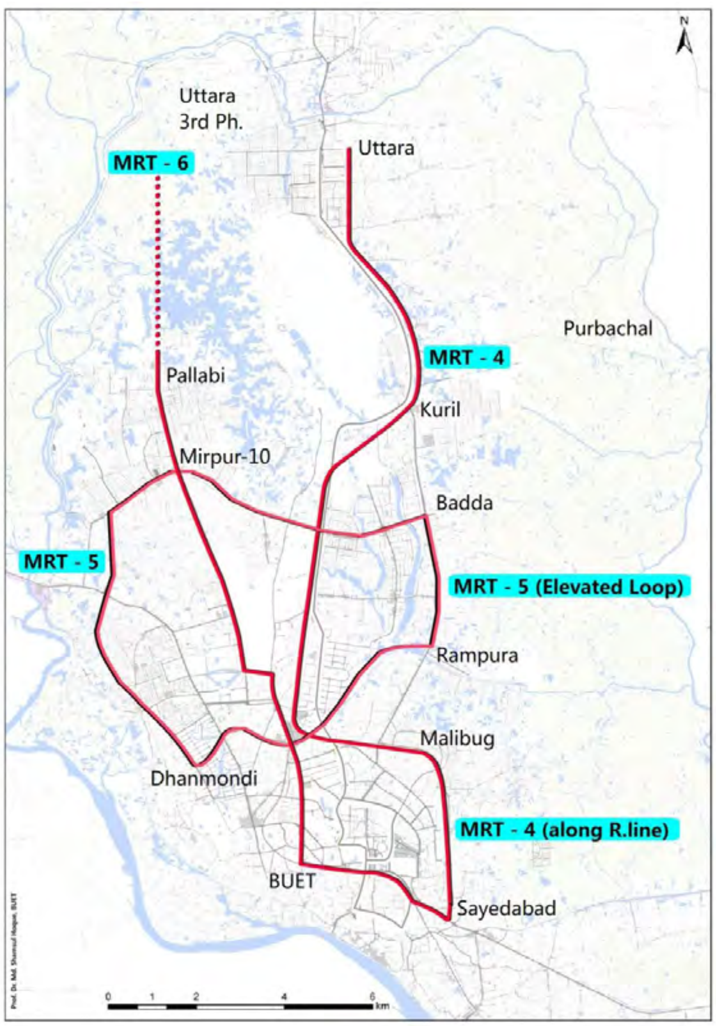


Figure 4.19: MRT 4, 5, 6 Proposed Line by DCC

Grade Separated Projects:

Based on the proposals suggested by the STP 2004 and by considering the Grade separated projects ahead for construction, following is a list of proposed grade separated projects in Dhaka city by Transportation improvements which are located on the route MRT6:

1. Elevated Narayanganj-Gazipur Expressway

Based on the map, it starts at north of Dhaka at point Gazipur and is covering the Airport road, VIP road, and Fulbaria road and reaching to Sayedabad exiting and Jatrabari and exits the south of Dhaka at Narayanganj by the total length of 32 km which covers the MRT6 route in Two sections, one section in Kazi Nazrul Islam road starting from Bijoy Sarani up to Sonargan Intersection by length of 1.67 km and second section in Fulbaria road started from Bokhshi Bazaar intersection up to Sayedabad which covers 4.53 km as indicated in the Figure 4.20 by the red lines at the side of proposed elevated highway by Bangladesh Bridge Authority (BBA).

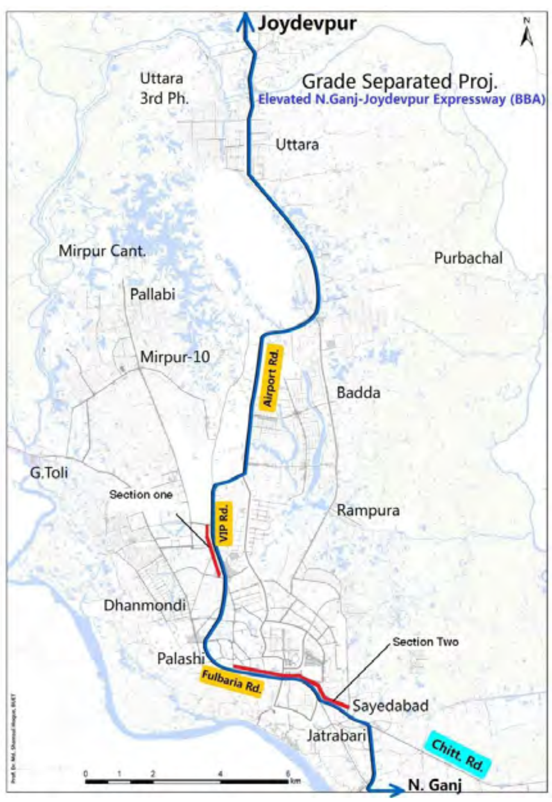


Figure 4.20: Elevated Highway Proposed Line by DCC

2. Flyovers and interchanges

As in case of any future constructions, there should be a comprehensive study regarding the future construction as they will definitely conflict in the underground structures particularly whenever there is a need for pile. Piles are penetrated at large depths which they will usually go deeper than metro lines and there should be enough alternatives in order to accomplish the construction of interchanges and flyovers.

As in case the DCC is concerned, following is a construction proposal of a Jatrabari Palashi flyover by total length of 6.63 km which covers the MRT 6 route by length of 2.87 km. This project is in need of piles which they will go much deeper than the metro lines. A comprehensive study should be undertaken regarding the alternatives possible for this challenge. Following is Figure 4.21 indicating the proposed layout of flyover by DCC which is lying on the MRT6 route.

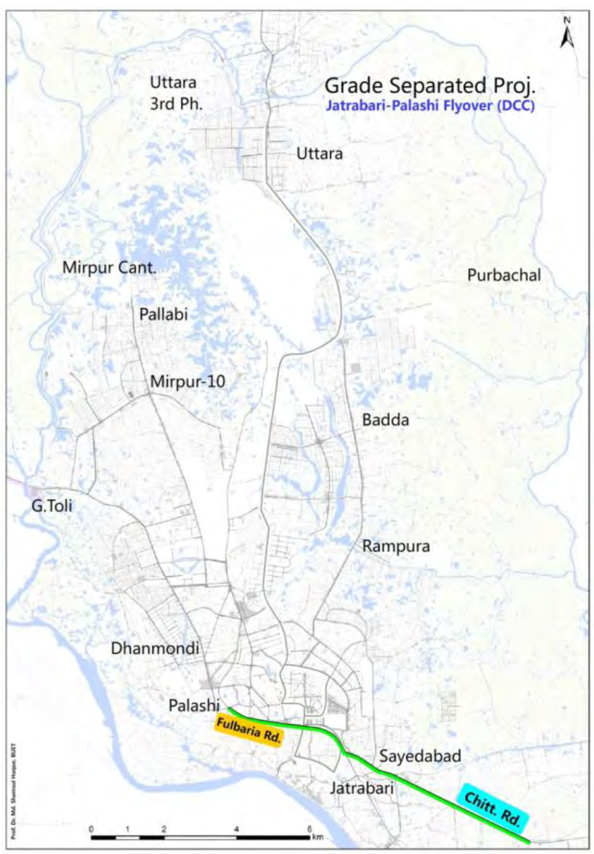


Figure 4.21: Jatrabari Palashi Flyover Proposed Line by DCC.

Underpasses:

Based on the future development by DCC following is plan showing the Underpasses which are located on the MRT6 route and may conflict each by MRT6. As the Under passages are located below level, soil strata lying between the tunnel and Under passages should be strong enough to support the underpass and eliminate the chance of collapse of Under passages in to the tunnel construction in future. This strongly suggests that at these locations integrated approach should be adopted in order to minimize the chance of any risk. Figure 4.22 indicates conflicts of underpasses and MRT6 along the route and following is the list of underpasses proposed by DCC along the MRT6 route:

1. Sonargan intersection Underpass
2. Bangla motor intersection Underpass
3. Sheraton intersection Underpass
4. Shahbagh intersection Underpass

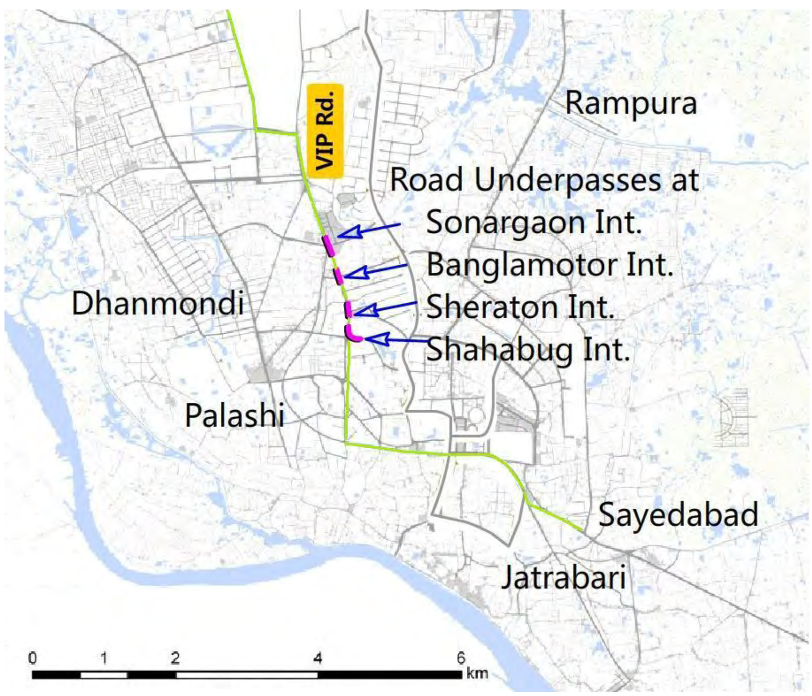


Figure 4.22: Location of Four Underpasses as Proposed by DCC

Based on the details explained above, here is a diagram indicating the relevance and future positions between BRTs, MRTs, elevated highway and underpasses in the same Figure 4.23.

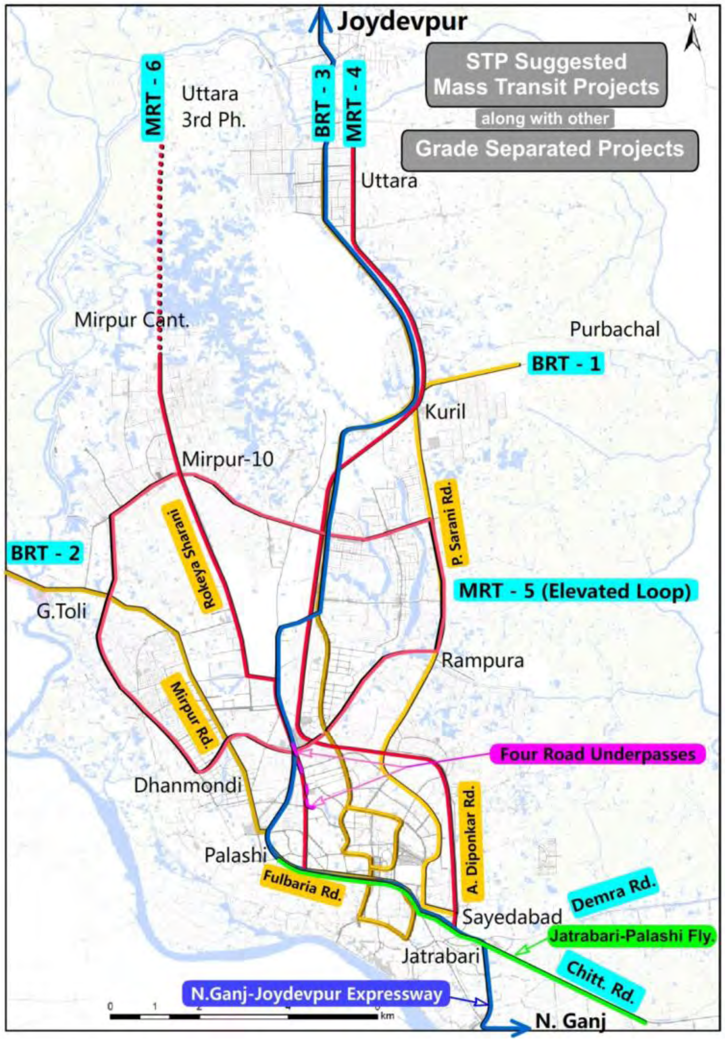


Figure 4.23: All Future Developments of Dhaka Proposed by Different Organizations

Based on the plan drawn above, here is the indication of different conflicts of the MRT6 with other proposed future developments of the Dhaka City Corporation (DCC) as well as Bangladesh Bridge Authority (BBA). Following is a plan drawn to show the different presence conflicts with their respective element along the MRT6 route. As this thesis goes on there should be a comprehensive research regarding the possible best solutions about the conflicts and the way to overcome the conflict. Presence of these conflicts makes the future developments facing a lot of challenges which some of them look completely impossible to solve. Based on each unique conflict there should be a solutions regarding elimination of conflict, or synchronization of the conflict elements with the other projects. Location of the conflicts and their respective elements are depicted in following Figure 4.24.

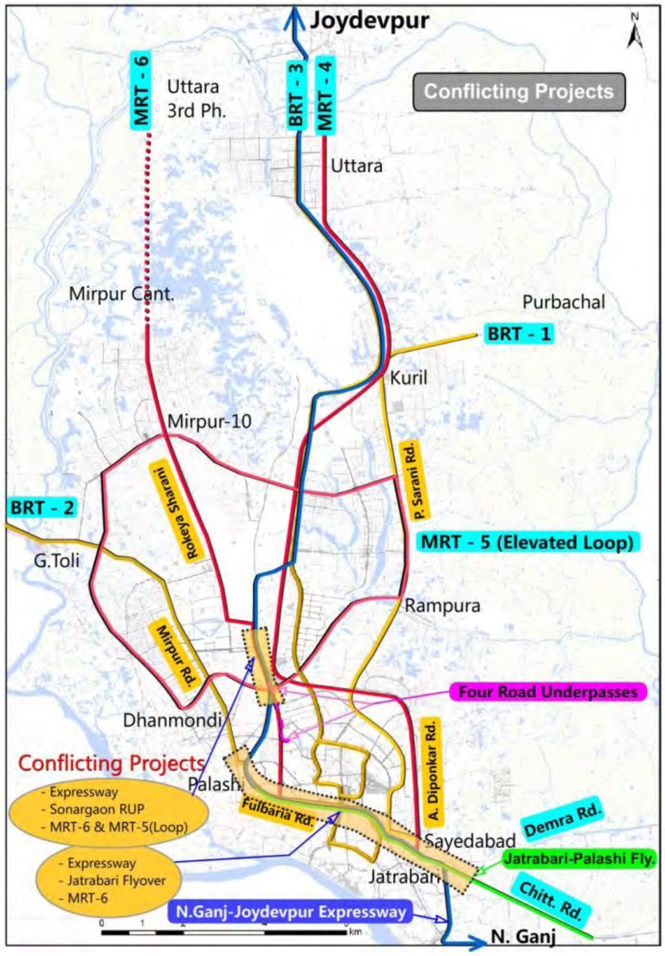


Figure 4.24: Conflicts Between Proposed Projects

By Close look of the Figure 4.23 it is found that conflicts are mainly defined in two sections:

1. Conflict of Elevated Expressway, four road Underpasses (RUP), MRT6 and MRT5 loop which is conflict of underpass, metro and piles of elevated Expressway underground.
2. Conflict of Elevated Expressway, Sayedabad road overpass, Jatrabari Flyover, and MRT6 which leads in an underground conflict of the piles and MRT6 on one hand and conflict of spatial facilities on the other hand.

Also here is conflict of the Underpasses, Flyover and elevated highway which all of them are lying on the MRT6 route in Figure 4.25.

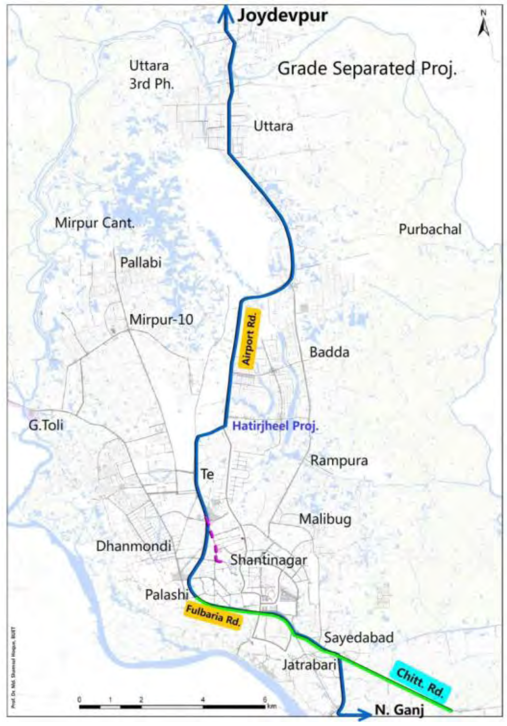


Figure 4.25: Elevated Highway and Jatrabari Palashi Flyover Conflict.

As long as the MRT lines are passing beneath the BRT lines due to no need of any deep excavation for foundation of BRTs there is no conflicts between the BRTs and MRTs. Here is a typical plan, as shown in Figure 4.26 which indicates the sections subjected to BRT and MRT in the same line.

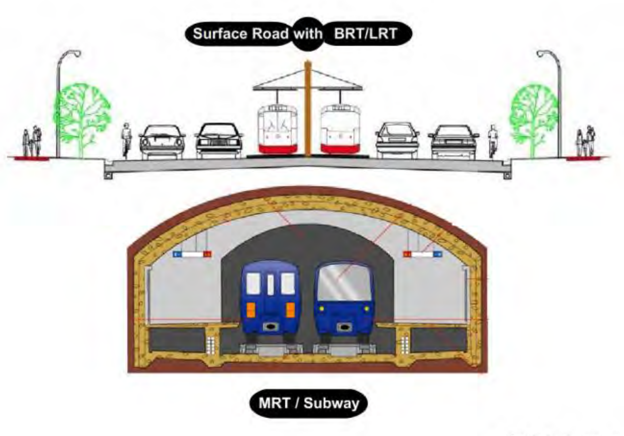


Figure 4.26: BRTs and MRTs Conflictless Positions

As long as the roads are not subjected to heavy loadings there is no need of any heavy foundation deep which may conflict by the MRT lines. But when there are some points that elevated highway or flyover is passing, need for foundations and piles will be problematic. As in the pictures below, Figure 4.27 the typical piling for the elevated highway is indicated and their relative position to MRTs in Figure 4.28.

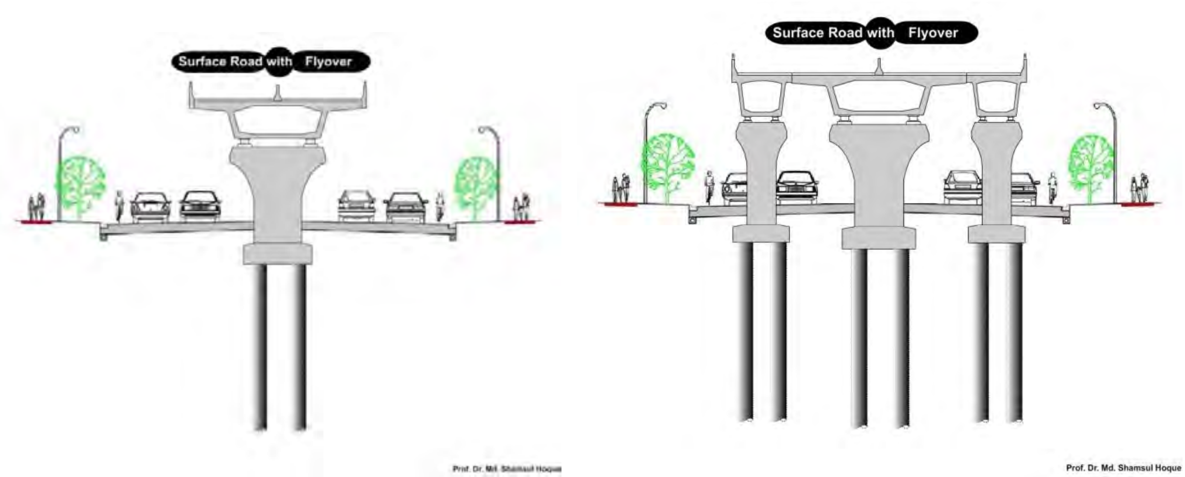


Figure 4.27: Elevated Highways and Flyover Piles and Foundation With Respect to At-Grade traffic, a) Typical Cross Section of Flyover, and b) Typical Cross Section of Flyover Along With Entry Exit Ramps.

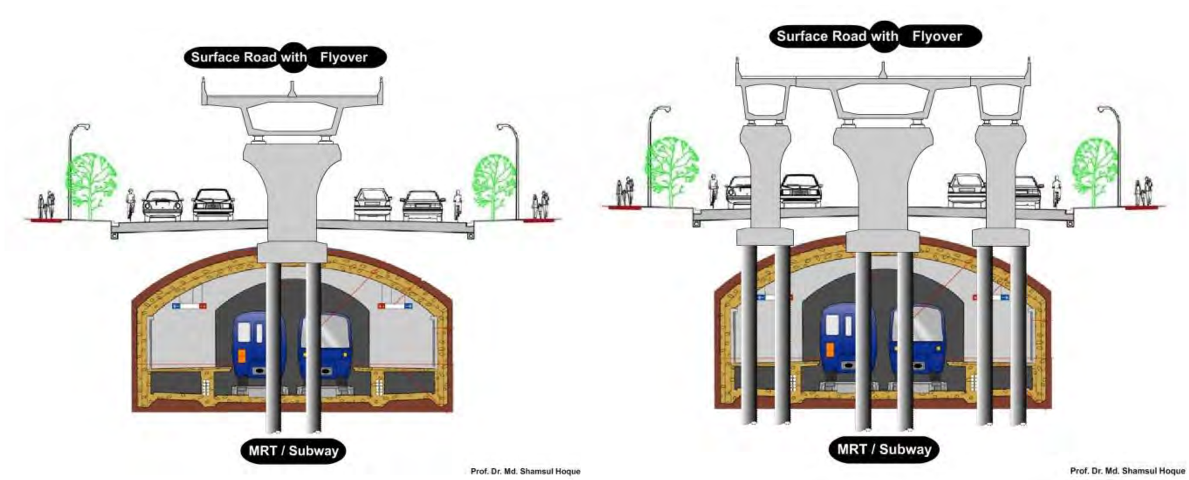


Figure 4.28: Elevated Highways and Flyover Piles and Foundation Conflict With Respect to MRT6

As indicated in the above presence of elevated highway due to having pile system at the center is having large conflict with all three of the BRTs, MRTs and underpasses. As the BRT lines are completely removed and MRT lines should go deeper or get displaced in order to remove the conflict.

4.3.4. Large Buildings

One of the great challenges which tunneling is always in touch with is the soil loading pattern. Dhaka city pattern is included by a lot of congested areas near by the arterial routes which are a great concern in tunneling design. Despite the proper depth considered for the tunnel (60 feet) presence of the large buildings near by the selected MRT6 route is a great concern. Based on the primary data, collected from Questionnaire survey a set of present large buildings is made in order to find the most critical point in the selected route as the loading is concerned.

This survey is only based on the buildings available by the route side, in offset of maximum 30 feet and more than eight storey buildings.

Based on field survey undertaken, Pallabi area up to Bijoy Sarani is only subjected to 5 large buildings but the most congested area in this view is interval between Bijoy Sarani and Shahbagh intersection which is having a total number of 28 large buildings which 15 of them are located between the Saarc Fuara and Bijoy Sarani road. Also there are 3 large buildings in the Dhaka Chittagong Highway near by the Sayedabad bus station. Following is a Google Earth satellite picture shown in Figure 4.29 indicates the presence of the buildings in the congested area named above also a typical plan is drawn in order to show the presence of large buildings in the route in Figure 4.30.

Figure 4.29: Google Earth Picture of Concentration of Large Buildings in MRT6 (source Primary Field Survey)

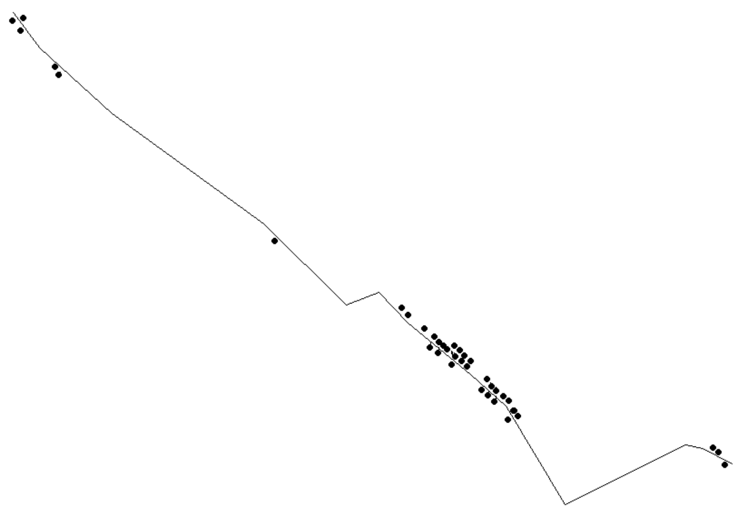


Figure 4.30: Large Buildings Concentration Along the Route. (Source Primary Field Survey)

4.4. Tunnel construction

4.4.1. Construction Methods Application

Based on the methods already discussed in the literature review, there are mainly three construction methods which they are discussed in their own aspects in here. Although not all of the aspects may get included in this research but the main outlines are highlighted so they will be considered in future studies.

Main three methods in the world are:

1. Tunnel Boring Machine (TBM)
2. Cut and Cover
3. New Austrian Tunneling Method , Sequential Excavation Method (NATM, SEM)

4.4.1.1. TBM

As described in chapter 2(literature review), this method is consist of application of an expensive boring machine in the site which is excavating and constructing in the same time in the same site fully automated. As it is not affecting the above at-grade structures or elements it is a traffic free method which does not affect the Dhaka city traffic network which is already at a critical stake.

From utility networks point of view as it is not having any conflict by any of the layouts mentioned above, as long as the proper depth is considered there is no difficulty faced in utility distribution network.

From future developments point of view, based on the projects proposed by the STP 2004, proper alignment, depth and lining should be taken care of. As of ongoing of this research, Dr.MD. Shamsul Hoque has already undertaken proper research about what are the best solutions in order to avoid the conflict between the future projects of the STP 2004 and the proposed metro line of MRT6 in Dhaka city. So the application of TBM as a regard of above two aspects is applicable and logical.

4.4.1.2. Cut and Cover

As described in the chapter 2, nature of this method is to excavate the site form the top and implant the metro profile and stations and filling back, there should be no above lying preset structure or any future excessive loading. Also the site should be obstacle free in order to apply this method. Due to this case, Cut and Cover tunnels cannot be constructed below the buildings or any other structures. So in case of Dhaka city, the implementation of metro should be under roads only if it is limited to this method of construction.

Traffic point of view, as the road pavement is subjected to opening for a period of a few years, the moving traffic at-grade should be shifted as well. One of the great concerns about the economical efficiencies of a project is how much time saving is happening to the traffic also, as there are construction period going on, how much is the total loss due to time in the traffic meanwhile of the construction. This case is considered second. First question is whether is there any alternative provided to the traffic and if it is what the efficiency is. As considering this route, there is no alternative possible to be assigned as the corridor selected is passing form the main arterials of Dhaka city also in some areas like Pallabi and section 10 there is no route available except the only present one which shows a lot of almost impossible challenges in this regard.

Utility network layouts point of view is of great importance in this method. Presence of utility lines means removal of the utility line, once, make an alternative for the consumer once more, twice, and after the completion of the job, reconstruct the network in the proper location (removal and relocation) as the third network. In some cases of the utility networks such as electricity network, they are impossible to be removed from the place and be replaced in future as commented by DESCO managers;" there is one option, demolition and reconstruction". But electricity is not sensitive to future settlements in soil. Also some networks like WASA networks or gas network, although removal and relocation is possible for them due to nature of the network as conduits and pipes, but there is a lot of difficulties in supply the demand for the consumers meanwhile of the construction.

Also due to removal of all above overlaying soil and filling back, the soil strata is disturbed and has lost the bond. So future settlements may occur and heavy loading of structures are not advised.

Any of the utility lines are having an importance factor, which based on that there should be a great concern for the removal, utility lines such as gas, electricity and water and sewage are vital and large, but telephone network is not a important deal or not having any great importance factor as of presence of Mobile services today.

4.4.1.3. NATM, SEM

This method is a handmade version of TBM but in a smaller scale and perhaps it is the most old method, as the ancient insisters used to do it for water achievements and water wells in past.

As described in literature review chapter, this method is in need of location for shaft construction, same size and dimension as of a TBM method, but much lesser excavation as compare to the Cut and Cover method. This method is mainly based on the application of soil strata strength to carry its own weight. It is completely based on local knowledge of the soil in the site, and it is independent of any foreign technology or foreign engineering.

As no specific expensive technology or science is needed this method is carried out with same simple available machinery as used for the cut and Cover method but with a lower cost as compare due to lower volume of excavation and no filling back. Also due possible use of the shafts in future as the station, there is no need for excavation in order to construct the station as it is not the case for TBM or Cut and Cover.

From traffic point of view due to nature of the method, it is having no conflict with above networks, traffic flows, or any excavation is needed in top, this method is only in need of the shaft and as there is no need of road closure or excavation, there is no need of any alternative route regarding this method. Also due to the same reason there is no need for removal and relocation of the networks in order to reach the maximum depth.

Also as the overhead soil remains untouched in future there will be no partial settlements in the above soil strata as some utility lines such as WASA network is very sensitive to.

Table 4.1: Comparison of NATM, Cut and Cover, and TBM in the MRT6 Route.

SI	Description	NATM	Cut and Cover	TBM
1	Profile construction	Yes	Yes	Yes
2	Stations construction	Yes	Yes	Yes
3	Earthwork excavation volume	Small	Large	Small
4	Earthwork Fill back volume	No	Very large	No
5	Transportation of earthwork	Small	Large	Small
6	Utility lines relocation need	No need	Needed	No need
7	Earth retention systems	Shorter but heavy	Longer and heavier	Short and Heavy
8	Deep excavation costs	Small	Very large	Small
9	Alternative route aspect	Applicable	Not Applicable	Applicable
10	Cost in Increase By length of the project	Length does not affect the cost per km	Length does increase cost per km very large	Length reduces cost per km
11	Limitation to road alignment	No	Yes	No

4.5. Case study of Iran Tehran Tunnels

4.5.1. Tehran

In case of recognition of the best possible and applicable method of construction of metro rail in Dhaka, a journey to Islamic Republic of Iran, Tehran was conducted. In this trip, different tunnels constructed in Tehran were considered to find the possible similarities in challenges and difficulties as the Dhaka is facing today. Out of three different underground projects of Tehran almost all them have been identified and studied in order to find the best solution for

Dhaka. The data and the information presented in this section of the thesis is a result of different site seeing and interviews as well as questionnaire survey conducted to collect the primary data from Tehran metro Co and PERLIT Co. Also this trip is included by almost 800 pictures of the sites visited which due to lack of space in the thesis pictures are not indicated in here however two important photographs are presented in Appendix C.

History of tunneling in modern era is of 100 years old in Iran, and in ancient Iran for water horizontal wells (Qanat) and mining it is almost 3000 years. As Iran does all of its underground projects based on local knowledge due to sanctions imposed here is a great point raising:

If Iran with a local knowledge of tunneling can accomplish its own tunneling projects, Bangladesh with present situation can do it much better.

4.5.2. Introduction

Tehran, capital of Islamic Republic of Iran, is the largest city in the Middle East and is the 16th most populated city in the world with a population of 8,429,807. Population density of 10327 p/km^2 as the most populated city in the Middle East by total area of 730 km^{2}and it is because that Tehran is subjected to immigration of people from all around Iran. Now from each 9 Iranian one leaves in Tehran permanently and out of each 5 Iranian one works permanently in Tehran. Iran is having a GDP of 830 billion $ per year (2008, 17th in the world) and is having a per capita GDP of 11,202 $ per year (Wikipedia).

4.5.3. Tehran Transportation systems

In case of highways metropolis of Tehran enjoys a huge network of 280 km highways and of interchanges, ramps, and loops (180 km). In 2007 there were 130 kilometers of highways and 120 kilometers of ramps and loops under construction (Wikipedia).

4.5.4. Tehran Underground

As of today Tehran is having the main three underground projects, two of the operating and the third one is ready to operate in the February 2010. The main three projects are

- Tehran metro
- Resalat tunnel
- Tohid tunnel

4.5.4.1. Tehran Metro

Tehran metro was planned first in 1970. Although Iranian revolution in 1979 and Iran Iraq imposed war was delaying the project for 8 years, the project started the first line of service in 2001. The main objective of Tehran metro is composed of eight lines which now there are three at operation (1, 2 and 5) with 128 km of the length in service and 81 stations handling yearly 416 million which is of 1.15 million passengers every day standing as the world 28th largest metro. This project is supposed to be completed before 2016 and it is to have the train frequency of 2 minutes which drags Tehran metro in top ten in the world. Only lines 1 and 2 are expected to carry 4 million passengers per day on their best service. Following is a plan which indicates the present Tehran metro available lines in Figure 4.31(Wikipedia).

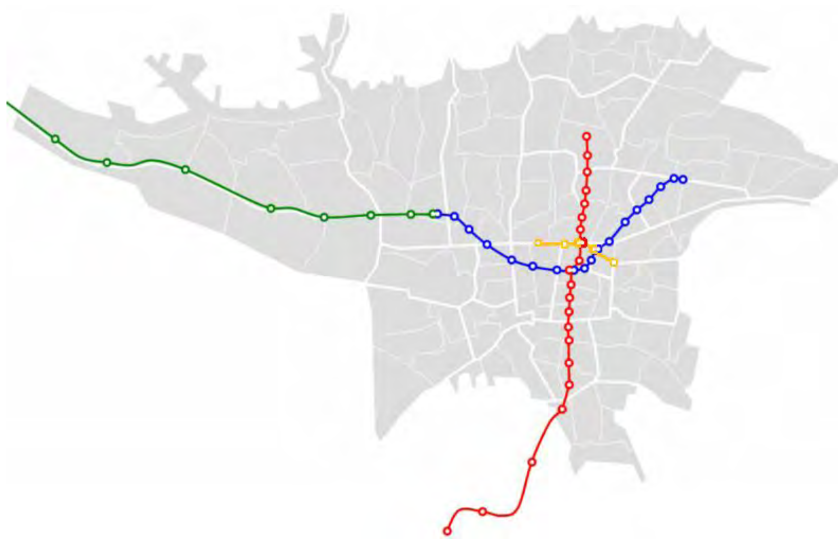


Figure 4.31: Tehran Metro Lines in 2009 (Tehran Metro Co.)

Figure 4.32: Tehran Metro 2009

4.5.4.2. Resalat tunnel

At the time of the construction it was the largest underground project at its own aspects. The first highway tunnel in the Middle East by Intelligent Traffic Control System (ITCS) (Iran Engineering association). Resalat highway (which the western part is called Hakim highway) is an East –West highway in Tehran. The most challenging part of this project in traffic point of view is located at the center of traffic of Tehran passing between Africa Sq Kurdistan Highway. Resalat tunnel is a double tunnel with 17 meter width and 11 meters height of RCC structure. Each tunnel is located at the distance of 3.5 meters from other covering the total length of 2x950 m. project started in1997 and started operation in 2006. Total project was carried out by MAHAB GHODS CO. & PERLIT CO. Total project was carried out using NATM SEM method of constructing and 38 steps and 135 sub steps was included regarding completion of total project. Total cost estimated for the construction was 130 million dollar. Figure 4.33 shows the exit of tunnel in west side and Figure 4.34 shows the entrance.

Figure 4.33: Resaalat Tunnel with Intelligent Traffic Control System.

Figure 4.34: Resaalat Tunnel Portal Entrance.

4.5.4.3. Tohid Tunnel

Same as the Resalat tunnel, due to successful operation and efficiency of the Resalat project, Tohid pair tunnel was started in 2007 by the length of 2x3003 meter and same method of the construction NATM, SEM. The PERLIT Co was the in charge of all aspects of construction and management of the tunnel. This tunnel by the width of 37 meters and double carriage way and total excavation height of 11 meters is the largest underground project in the country saving 400,000 lit of petrol everyday and 1 million hours of time. Chamraan highway is one of the largest highways of Tehran with It connects north of Tehran to center Tohid square and from there it is connected to the south by Navab highway. Total project is of 300 million $ and it is constructed in 28 months including 3800 staff.

4.5.5. Application of NATM

Tehran metro was counteracted by composition of all three methods. TBM was the main method and NATM, SEM was used in needed sections where the TBM or Cut and Cover were not applicable. Both of Tohid pair tunnels and Resalat pair tunnels where their respective largest dimension underground project in the country and both of them are made by the NATM, SEM method. In case of ramps located in the route, Cut and Cover method was used in order to accomplish the task but the full section of the tunnel was constructed by NATM method.

4.5.6. Route Analysis

Selected route with total length of 3.41 km connects the Chamraan highway (12 km length) and Navab highway (5.2 km length) in Tehran which are two of large north south corridor highways by total length of 17.1 km. they are both located on the same route, which due to narrow and improper location of the connection between these two highways, there have always been a huge bottleneck effect despite of large capacity of the both. Although there is a lot of alternative route available in the site, but this bottle neck was always the most preferred one.

Selected route is also subjected to a large number of congestions and at-grade intersections. Total selected route regarding the construction including all the ramps and details was 3.003 km which it was covering 11 intersections all in east west direction, perpendicular or oblique.

Also the selected route is subjected to presence of two metro lines which they are constructed by TBM method and NATM method, which are located at indicated points in the Figure 4.35.

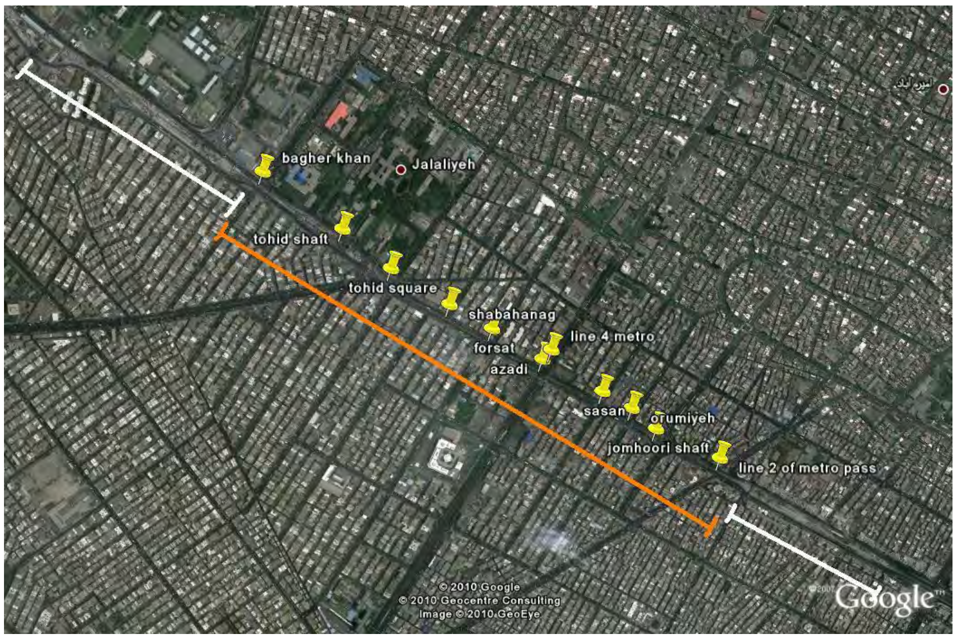


Figure 4.35: Tohid Tunnel Construction Method Parts.

4.5.7. Sequence of the Job

After the site surveys and designs, the project started by construction of the four shafts and two ramps (total of six). Following is the name of the construction camps staring from the north:

1. North ramp
2. Tohid shaft
3. Niyayesh shaft
4. Azadi shaft
5. Jomhoori shaft
6. South ramp

Figure 4.36 indicates the Jomhoori shaft constructed in Tohid Tunnel project also Figure 4.37 indicates the same project shaft view from below.

Figure 4.36: Jomhoori Shaft

Total project length is 3003 meters, 2648 meters of that is tunnel and the rest is the ramps. Ramps are constructed by Cut and Cover and Profile of the tunnel is made by NATM method. As shown in the Figure 4.35 orange line indicates the NATM section, and white line indicates the Cut and Cover section of the project.

Figure 4.37: Shaft View from Bottom

After the location of the shafts is selected, cranes and machinery are installed for construction of the shafts and ramps, reaching to the maximum of 100 feet depth. Then machinery started excavation in both direction toward the north and south in the shafts and one direction of either north or south in the ramps by NATM. Here in after total of 36 steps is included starting from opening of gallery one, reaching to the last step of the pavement finishing, and decoration, total of 137 sub steps. Figure 4.38 indicates the Opening of gallery 4 from the total 36 steps.

Figure 4.38: Application of NATM Method in Tohid Tunnel Tehran 2009.

After completion of the profile of the tunnel, shafts are used as the stations of Sakardo ventilation or water well reservoir. Also the Azadi shaft is planned to be used for ventilation, fresh air blow and tunnel management systems. Based on plans the Azadi shaft is planned to be set next to a building which is exhaust system and management building of the tunnel in the same time. Figure 4.39 indicates the section that shaft is to be used as ventilation and management in the same time. After the tunnel construction, is there is any possible use of the shafts they will accommodate the demand, or they may get filled by the proper material. In case of Tehran Tohid metro, none of the shafts were filled up; they were all used for ventilation and polluted air recycling. As indicated in Figure 4.39 the used shaft of Niyayesh was later used as air ventilation and management center.

Figure 4.39: Section of Azadi Shaft and Management Building

4.5.8. Challenges

The Tohid tunnel was subject to so many challenges in the construction. But due to nature of NATM method, solutions are in site always and each of them is unique to their specific site as well. Following is a list indicating the different main challenges in the construction of the Tohid tunnel.

4.5.8.1. At-grade Traffic Diversion:

Despite the very congested area and importance of at-grade intersections at north and south ramps for the total network of transport, and as the ramps was supposed to be constructed by Cut and Cover, specific site of the ramps were subjected to route diversion. As the specific alternative route is considered, it was available, but due to entrance and beginning of the points of meeting of these two highways, PERLITE company decided to widen the road to its maximum width in order to accommodate the cut and cover excavation and flowing traffic in the route in the same road in the same time. So the surrounding present authorities, mainly municipality and army, moved back their walls in order to widen the road to its maximum potential. After the construction is finished, the dislocated walls will be relocated and road will return to its original position. Wherever the site was subjected to the Cut and Cover method, (in north and south ramp) same scenario is applied.

4.5.8.2. Unpredicted Water Flow

One of the greatest challenges in the selected underground route was underground water flow channels, with no specific route of flow, with no data available to identify the source or the location as well as quantity. Due to nature of NATM method, the solutions are always available in the site. In this challenge, whenever a flowing stream was discovered, it was filled by RCC and covered by proper blocks in order to stop the flow (Figure 4.40). Also water proofing of the tunnel was applied in that particular section. As the water flow streams in this part of street are pretty common and large in number, there has been so many of similar cases in the excavation and construction process.

Figure 4.40: Water Flow Isolation in the Wall

4.5.8.3. Metro Lines

In the selected route, a great concern was presence of two metro lines. Line 2 station (already under the service) and line 4 of metro profile (under construction of TBM). As the present underground metro lines are located at the depth of 14 meter maximum for line 4 and maximum depth of 11.6 meter for line 2 stations.

As there is no possible intersection between the present metro line and Tohid tunnel, the tunnel profile have to pass beneath of present metro lines which leads the profile of the tunnel to the depth of 30 meter (almost 100 feet) maximum in the discussed point.

4.5.8.4. Congested Surface Traffic and Collapses

As of any tunnel construction, a very great challenge to overcome is to reduce the possible collapse of the soil in upper strata. Although proper hesitation factors are considered in this aspect, but possibility of collapse always exists. In case of any NATM tunnel, collapses usually appear in small scales, as it has been happening in the Tohid tunnel once (Figure 4.41). Collapses are dangerous when they are affecting the at-grade roads as the collapse may cause the flowing traffic vehicles to fall in the cavity.

Figure 4.41: At-grade Collapse of the Tunnel

4.6. Overview

Analysis of the route indicates a complex network with absolutely no orientation. This makes the selection of tunnel construction method a big challenge. Out of the limitations and characteristics of this thesis NATM method is selected as the best method of construction.

As the current situation of the route is considered, analysis of the route is a great role in construction method selection. There have been so many researches and signs which indicate the need and importance of metro demand in Dhaka city. By complete analysis of the route, it is recommended to use the NATM method in case of the MRT6 as it is cheaper than two other methods and it is applicable as far as the challenges are concerned.

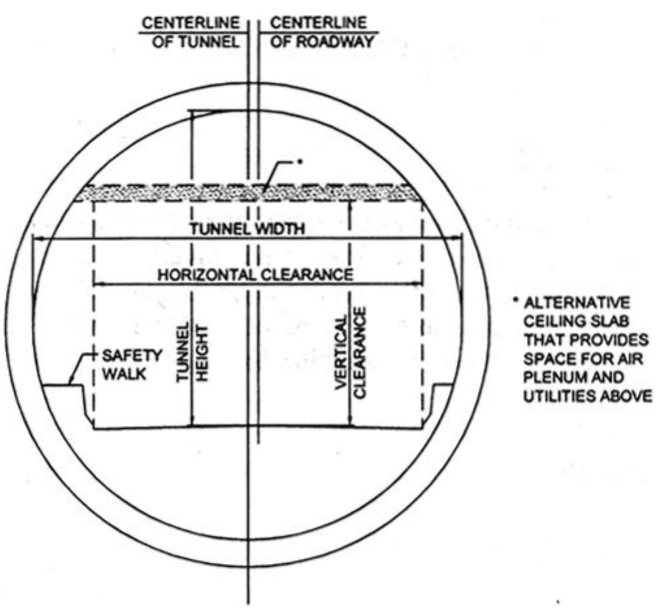
5.1. General

As it has been discussed earlier in chapters 2 and 4 the proposed route of MRT6 is selected for metro system in Dhaka in this research starting from Pallabi up to Saidabad. Type of tunnel and possible section for the profile of the tunnel is selected based on the typical structures used for metro system. As the size of the tunnel excavation of the profiles is always based on number of the tracks and clearance requirements, so double box structure that would accommodate the double track has been selected.

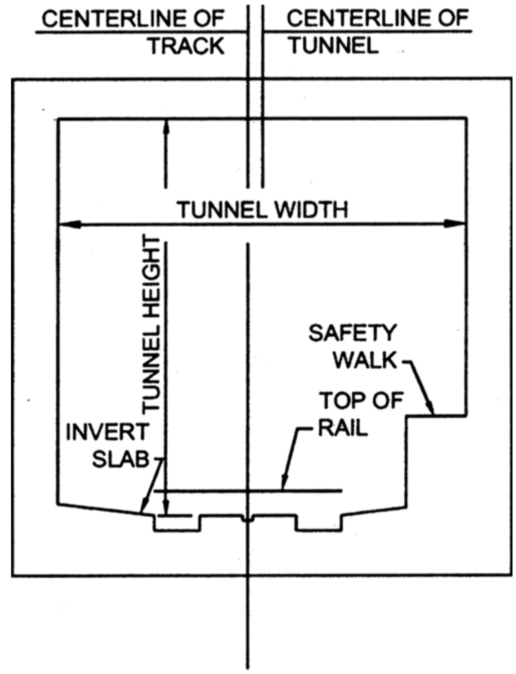
5.2. Typical Tunnel Metro Sections

For a railroad, transit, or vehicular tunnel, selection of cross section is dependent on vertical and horizontal clearances, number of lanes or tracks, type of ventilation system, and the method of construction. Typical cross-section configurations for cut and cover construction method are circular, octagonal, arch and rectangular. The configuration for a two lane single bore is best suited to a circular or octagonal shape tunnel, which structurally is the most efficient. The flat-bottomed arch shape is suited for multilane single or multiple railways have center or side duct locations, which reduce the depth of the structure and dredging. Figure 5.1 and 5.2 show the typical shapes for rail transit tunnels. These shapes typically relates to the method of construction and ground conditions in which they are constructed. The shape of rail transit tunnels often varies along a given rail line. These shapes typically change at the transition between the station structure and the typical tunnel cross section. However, the change in shape may also occur between stations due to variations in ground conditions. The configuration of tunnel structure can depart from the typical section to accommodate a typical track alignment or grade. When system standards mandate that stations be designed with a center platform, the track centers will need to be widened through an appropriate transition length upon approaching the station. Occasionally, it will be advantageous to gradually change the alignment and grade to the “over and under” positions in which one track lies above and in line with the other. In general, the configuration of the tunnel structure must be subordinate to system requirements for track alignment and grade.

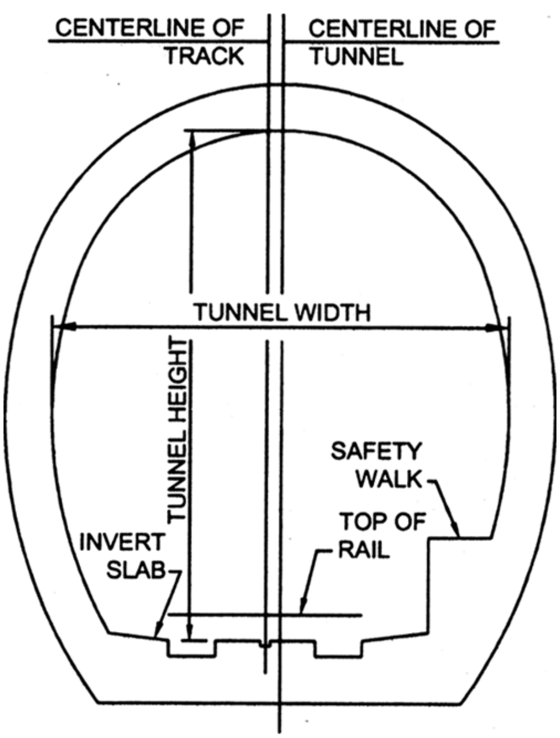
However, when the stations are designed with side platform, the track centers will be same upon approaching the station.

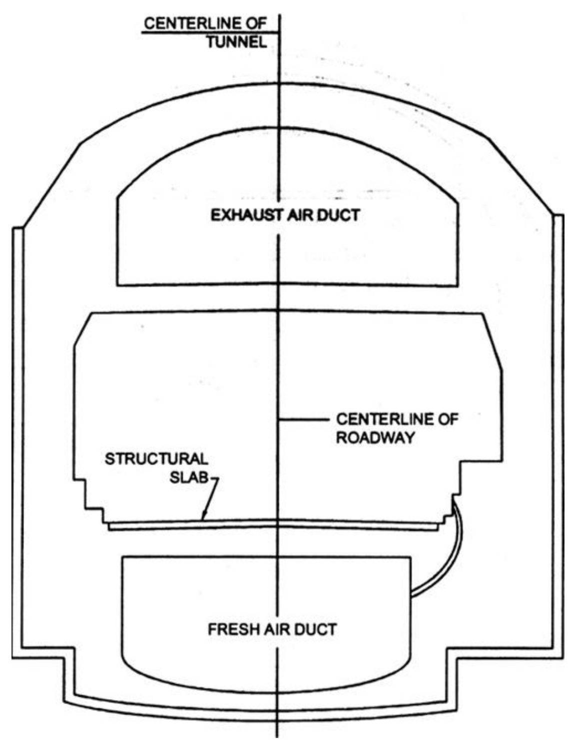


a.Circular Tunnel



b. Single Box





c. Oval Tunnel d. Horse shoe tunnel

Figure 5.1: Circular, Single Box, Oval and Horse Shoe Tunnels (FHWA, 2005)

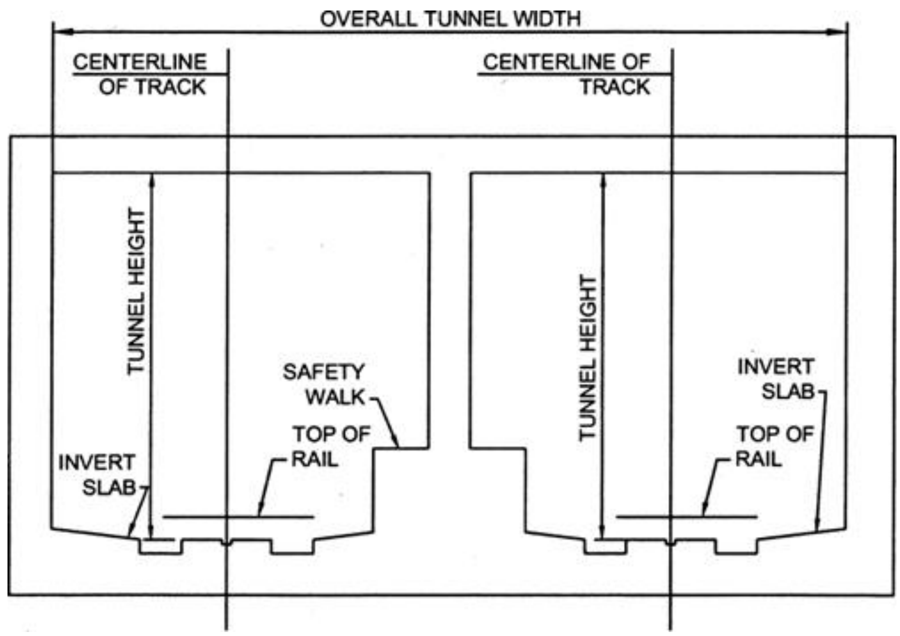


Figure 5.2: Double Box Tunnel Section.

Thus, the alignment and grade for the double box construction can be the same at joints section between tunnel structure and the station building. As a result, no extra volume of materials will be required for this arrangement of double box section. For a cut- and- cover double box subway line structure, the station is usually of the side platform type (Bickel et al, 1997). A box type structure is generally recommended in areas where the cost of concrete is less relative to the cost of sheet (Bickel et al, 1997).

5.3. Route Characteristics

Selected route for Dhaka city metro is selected as MRT6 (described in chapter 4) from the book STP 2004 out of three MRT lines suggested. It provides the north south corridor connecting from south in Saidabad and in future developments to MRT4 in Uttura making a parallel north south loop of metro. Total length of the selected project is 15.21 km and it is a single profile double track rail line.

5.4. Metro Railway Stations

This route is offering 12 stations which during the construction they are used as facilitation shafts in order to accommodate the ventilation and machinery as the transportation channel between the ground level and profile under excavation and at end of the construction process they will serve as stations. Each station is a typical design assumed and designed by Waheed in 2008 as the 3 stories reinforced cement concrete structure.

This selected route has a good potential regarding the different sites available for shafts construction. Following is a list of stations and the satellite pictures of the site observed by the researcher in order to find the proper station offset as well as proper location in order to serve the metro.

- Pallabi station
- Section 10 station
- Kazipara station
- Taltola station
- Agargaon station
- Farmgate station
- Karwaan bazaar station
- Shahbagh station
- BUET station
- Banga bazaar station
- Kaptaan bazaar station
- Sayedabad bus station

All of the stations are assumed to be in the variation of almost one kilometer from each other so that they will cover all of the rush areas in the way completely and properly (Figure 5.3). Also as the nature of Dhaka city is very congested and all of the residential buildings and commercial buildings are located in closed and high density areas, the station are designed in a close offset so that they will all of the route properly. Among all of the stages selected, there is only two station away from each other at the interval of almost 2 km and it has been located between Agargaon and Farmgate which the reason is the presence of old airport on one side and parliament in a very close distance so that the total area is not much congested and it gives a chance of more vacancies.

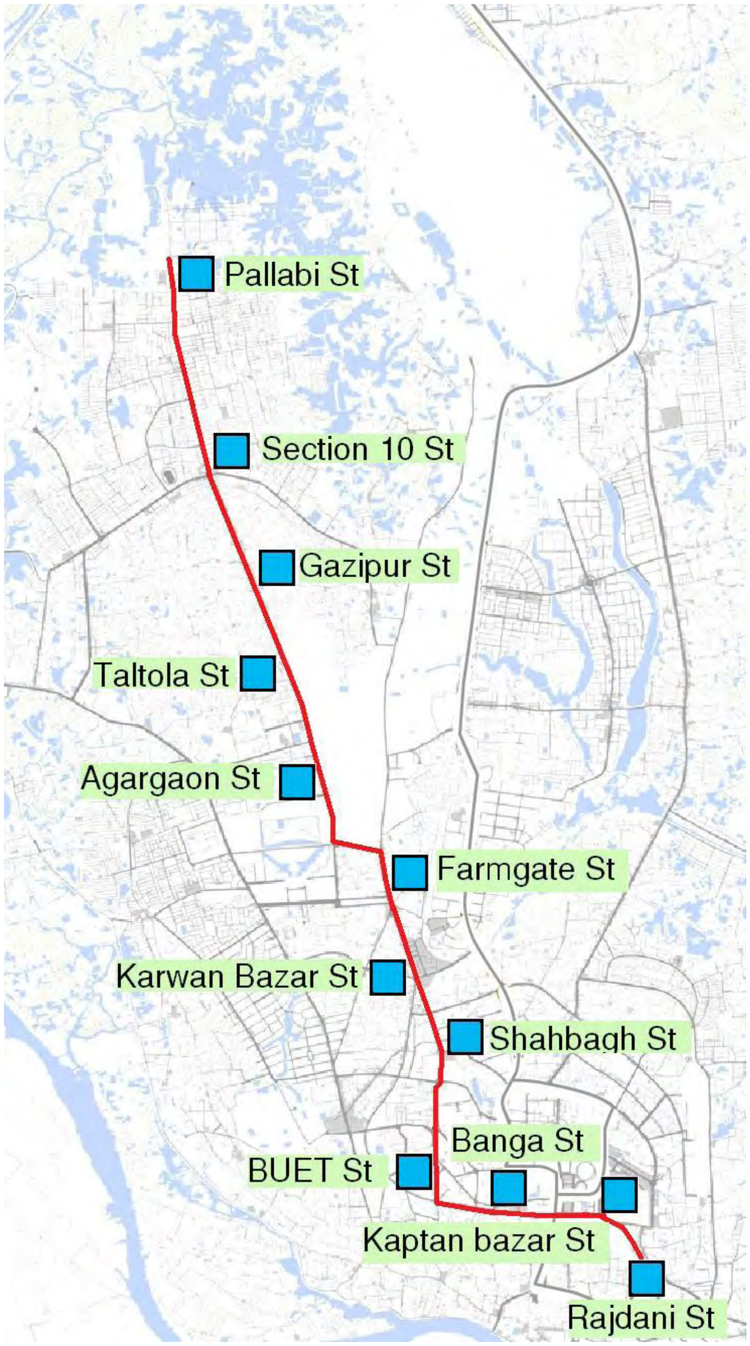


Figure 5.3: Proposed Metro Route and Stations.

As due to presence of parliament area and old airport, there will not be any construction, neither residential nor commercial in this are in future. Following is Table 5.1 which shows each of the stations and their respective distance to other station in a sequential path.

Table 5.1: Stations Proposed for Dhaka Metro System and Their Respective Distances

Station name	Distance from Last Station(m)	Distance to next station(m)
Pallabi	0	2004
Section 10	2004	1111
Kazipara	1111	1074
Taltola	1074	1036
Agargaon	1036	2487
Farmgate	2487	1210
Karwaan bazaar	1210	1197
Shahbagh	1197	1784
BUET	1784	1042
Banga bazaar	1042	1030
Kaptaan bazaar	1030	1060
Sayedabad bus station	1060	0

Based on site survey of the researcher each of the stations above is having a good possible location to be used as shaft construction and station construction purpose. Following is the Figures 5.4 to 5.15 which indicate the location of each site with satellite pictures.

Figure 5.4: Pallabi Station

Figure 5.5: Mirpur Section 10 Station

Figure 5.6: Kazipara Station

Figure 5.7: Taltola Station

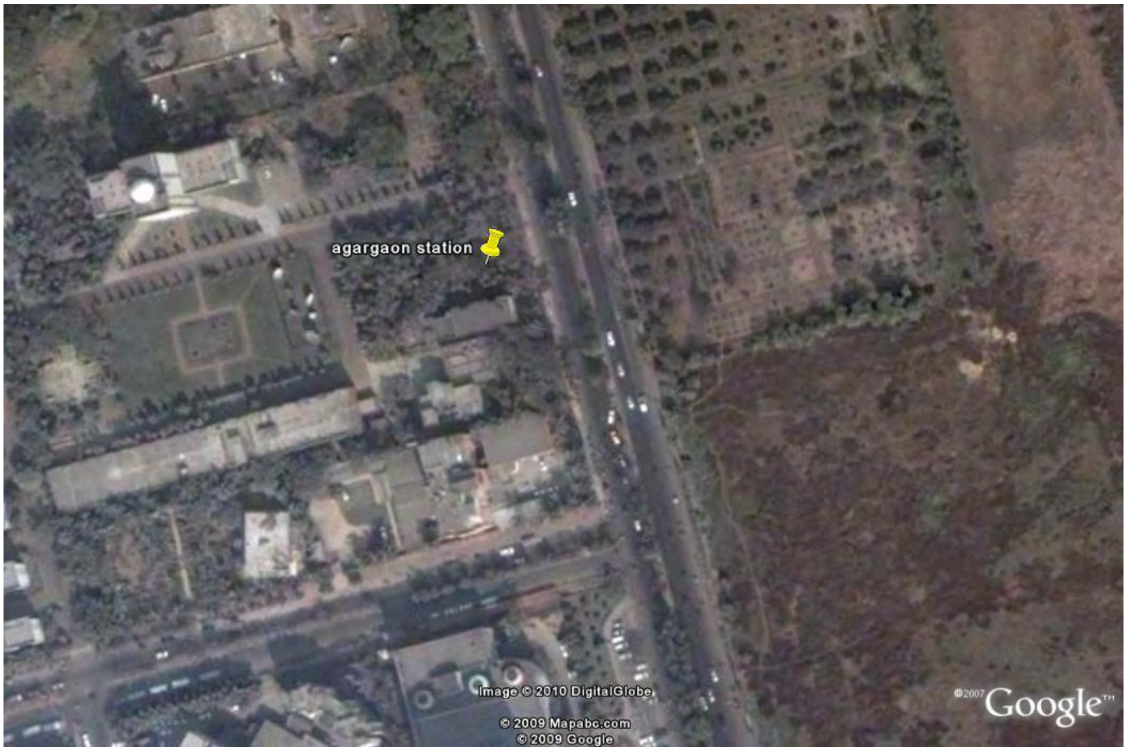


Figure 5.8: Agargaon Station

Figure 5.9: Farmgate Station

Figure 5.10: Karwaan Bazaar Station

Figure 5.11: Shahbagh Station

Figure 5.12: BUET Station

Figure 5.13: Banga Bazaar Station

Figure 5.14: Kaptaan Bazaar Station

Figure 5.15: Sayedabad Station

5.5. Construction Method

Construction method in tunneling is a function of different present parameters. Although there are different construction methods available, there is always a compromise between different possible construction methods. Developments of the underground structures are developing day by day. As each site is having its own unique characteristics and properties and challenges, there is a unique construction method developed and modified in each respective site. As each of the construction methods are having advantages and disadvantages, each site is having a combination of two or three methods which keeps the total project in progress as it has been the case for India metro recently and all other underground structures in the world. Different factors are affecting the total excavation process such as:

- The soil condition
- Present underground structures
- Pattern and characteristics of the alignment
- Length and depth of the project
- Availability of the land at the surface
- Water table variations
- Type of use of underground structure

5.5.1. Description of the Method of Construction

Based on the layout drawn and selected, total length of 15.21 km is considered to be constructed. Due to type of the method, there should be different shafts excavated at the intervals of almost 1 km in order to reach the maximum depth required so the total number of 12 shafts is proposed to be constructed. As in this thesis due to obstacles lying above, minimum depth of 60 feet (18.3 say 20 meters) is considered in order to eliminate any chance of settlement and no conflict with layouts and networks.

In order to start the construction, there should be shafts excavated which based on questionnaire survey of the researcher, for this purpose to some extend land is available, and there should be a survey undertaken regarding the availability of the lands ownership for shafts excavation which in future they will turn into stations. Minimum diameter of shafts is considered to be 15 meter which makes the machinery and equipments accommodation and transportation possible. Also at the above there is a list mentioned of possible and applicable lands for the shafts and stations possible for excavation.

5.5.2. Tunnel Construction Process

Tunnel construction starts by excavation of shafts. As the shafts are constructed there proper labor and machinery should be shifted in the shaft in order to start the tunnel profile excavation. In Excavation of tunnel profile, different sequential excavation steps are considered which are known as galleries. Number of the galleries is decided on the soil type and section dimensions. Each gallery is designed in such a way that its excavation does not cause the collapse of interfere with other galleries as shown in Figure 5.16 for the proposed section. Section of a tunnel is designed as a double carrier single profile tunnel which accommodates both of terrains in one trench, giving more space and ease of aero dynamicity to the main tunnel and enough space in order to accommodate other utility lines such as inspection facilities in the tunnel. Final section is included by two piles located at the sides and open at the middle and supported by the arch in which provides more efficient and easier construction. Also after the finishing the total tunnel construction profile, the shafts constructed at the beginning are used as the station vacancies and are subjected to stations construction. In order to construct the tunnel, two main stages are considered, one is shaft construction, and second is profile construction. NATM approach is different in alternative cases, based on the soil properties, different Steps are designed to reach the desired section. As in this thesis total of seven (Figure 5.16) Galleries are assumed considering the size of the tunnel and soft nature of the Dhaka soil in order to achieve the final profile of the tunnel. Figure 5.16 indicates the different galleries assumed during the suggested excavation.

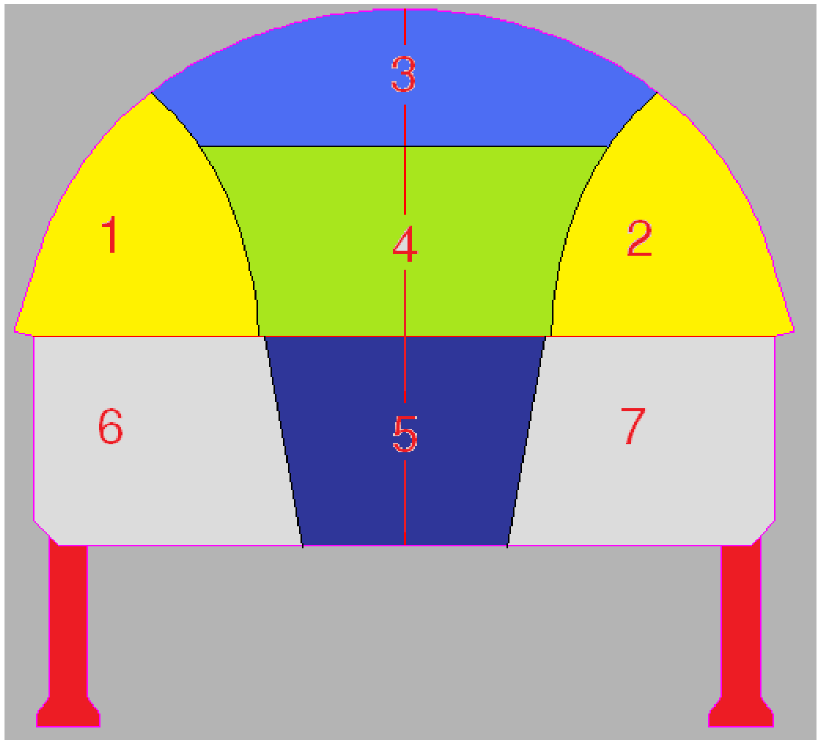


Figure 5.16: Galleries in the Section

5.5.2.1. Step 1; Construction of Shafts

In order to reach to the maximum depth of the section total of 12 shafts are to be constructed which they will be used in future as the stations. Each shaft is accompanied by proper cranes and machinery as well as industrial ventilations and material elevators which they will serve as the access as well as supply of the material to the main profile during the construction, selected at the intervals of minimum one kilometer and maximum of two and half. Following is Figure 5.17 showing the shafts positions and depth. After the excavation of shafts in order to preserve the soil properties as the future station construction is concerned there should be shotcrete applied just after the excavation.

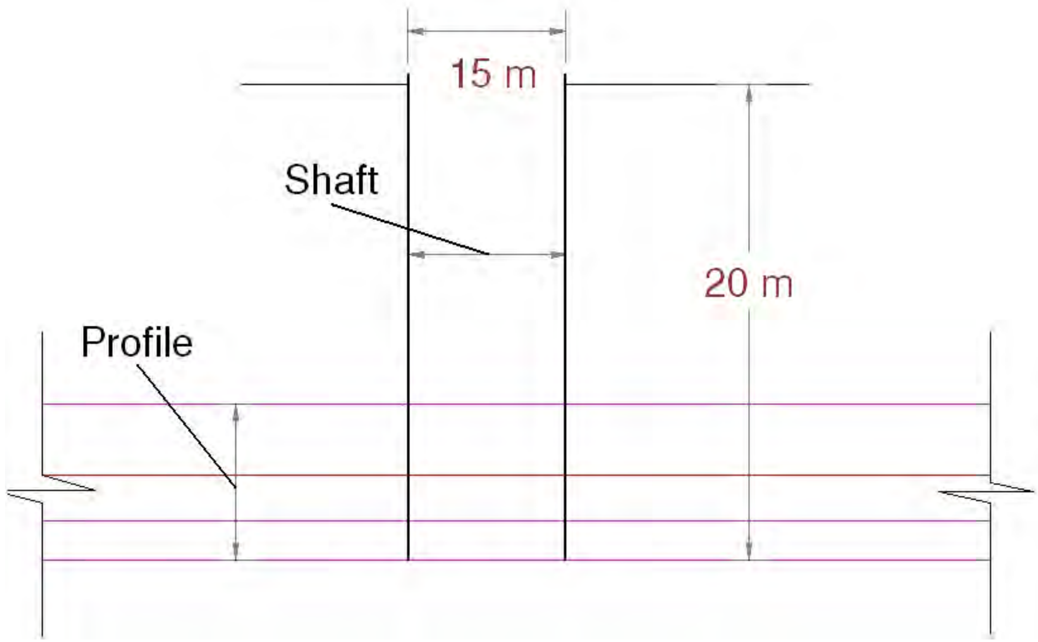
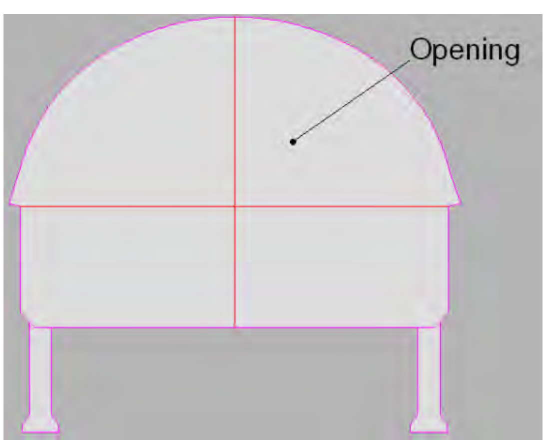
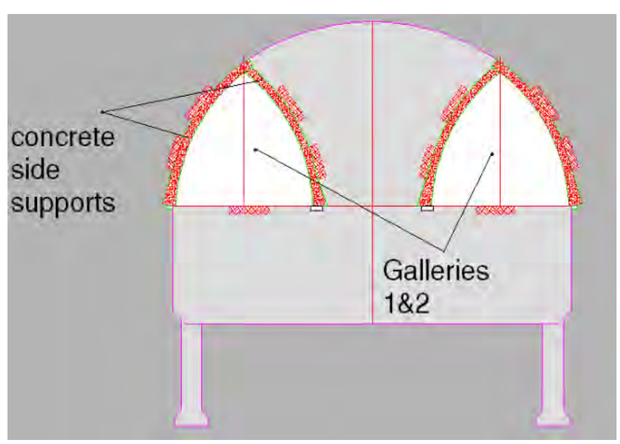


Figure 5.17: Shafts Schematic Excavation

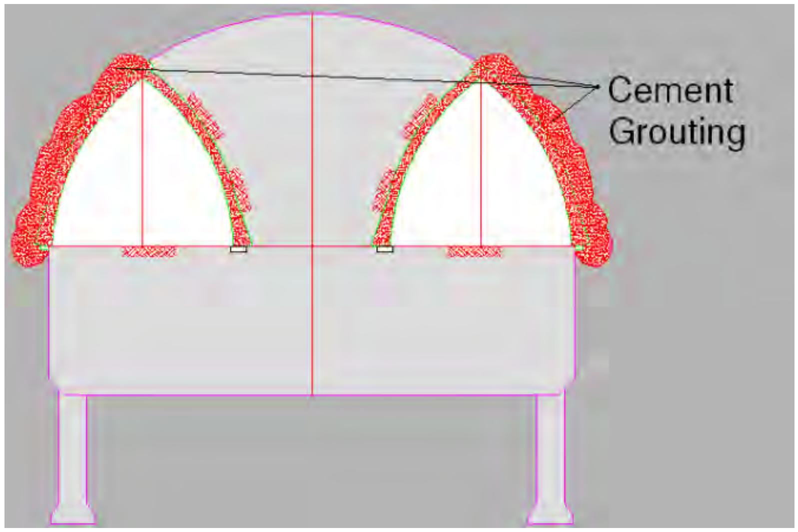
5.5.2.2. Step 2; Opening of Galleries 1 and 2

In this step, which is the first openings in the whole section, first galleries are excavated. Galleries 1 and 2 and support the above soil by help of temporary concrete shells opening at both sides which will allow the middle soil to remain untouched and gives the opportunity for side piles in place. Then proper grouting is made in order to give the lateral support to the galleries excavated. Figure 5.18 a, b and c show the steps in Galleries 1 and 2 openings.





a).Excavating Full Section **b)** Opening of Galleries 1 and 2.



c) Cement Grouting

Figure 5.18: Step 2, Opening of Galleries One and Two

5.5.2.3. Step 3; Piling and Mechanical Joints

After the construction of the galleries 1 & 2 side piles are constructed in place. As the above soil is resting on its own supportive strata, there is not much large piles needed in order to support and piles can be constructed in place. Figure 5.19 indicates the location of piles and galleries 1 and 2.

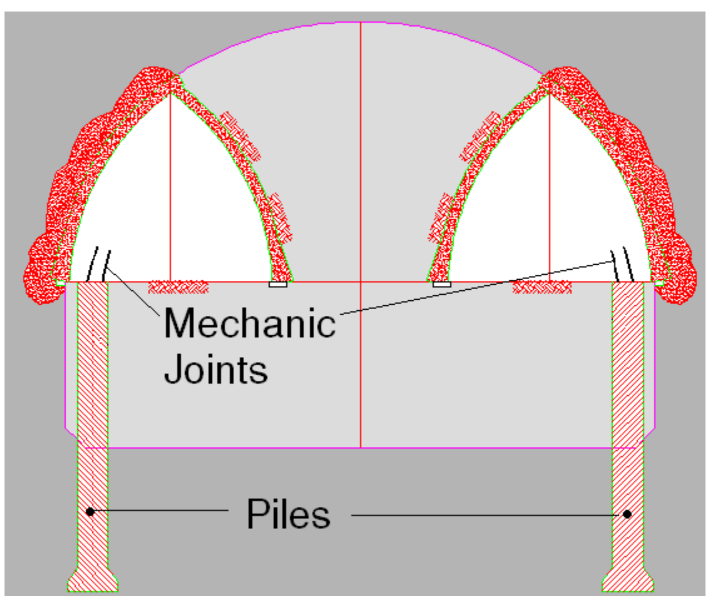


Figure 5.19: Step 3, Piling and Mechanical Joints

5.5.2.4. Step 4; Arch Side Reinforcement

In order to help the soil to carry its own load, arch is supported by reinforced concrete. In this step, reinforcement needed for the concrete arch is installed and tied in order to be used in future concrete casting. Also box feeders are installed in order to fill the future concrete casting in side walls for support of the arch, as well as lateral support of the soil in place. Figure 5.20 indicates the items in Step 4 of the section excavation.

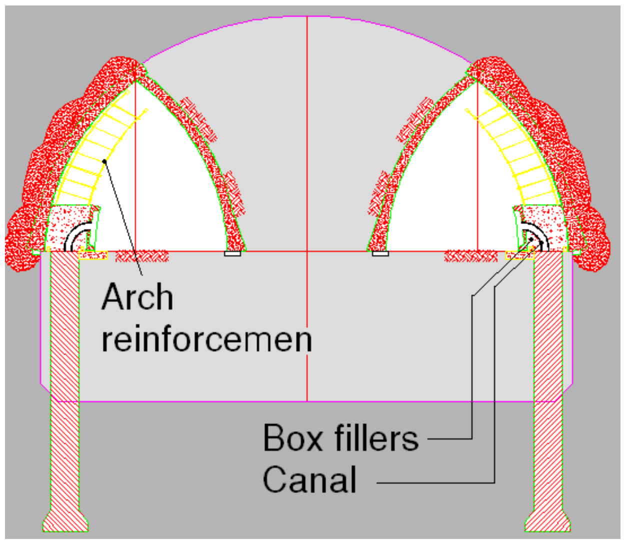


Figure 5.20: Step 4, Arch Side Reinforcement

Box fillers are the canals made precast and installed in order to fill the space at back of the piles and sidewalls.

5.5.2.5. Step 5; Opening of Gallery 3

In this stage opening of gallery 3 starts. First there is an excavation of one meter which leads into an opening which will be widened in next step in order to reach the complete gallery 3. Also opens the top of gallery 4. Figure 5.21 indicates the opening of gallery 3

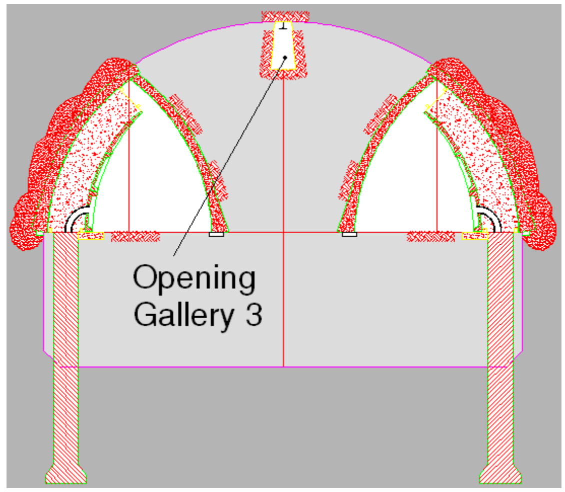
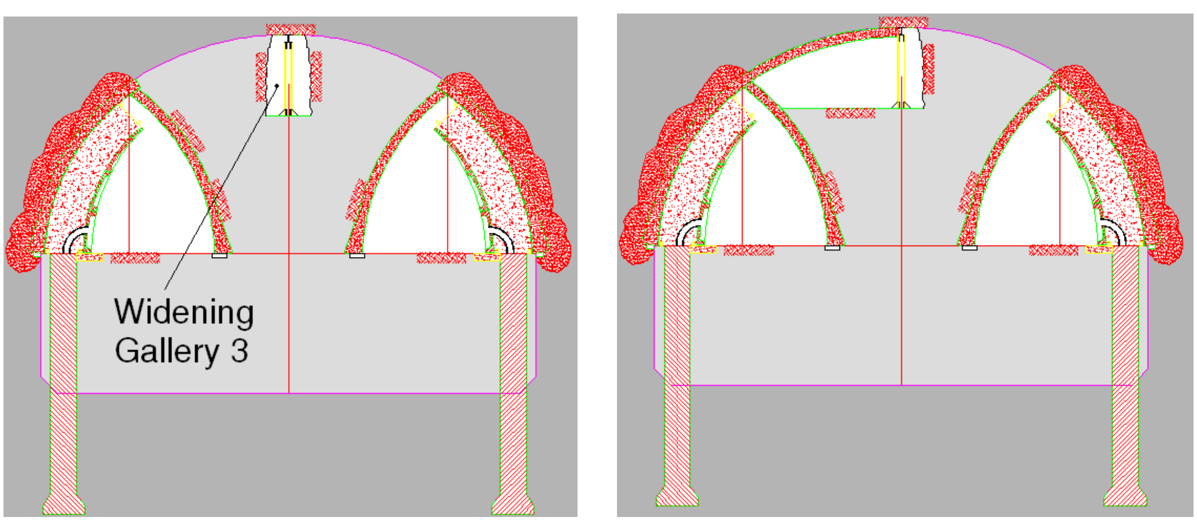


Figure 5.21: Step 5, Opening of Gallery Three

5.5.2.6. Step 6; Arch Pose

Up to this step, full arch is out and total load of arch is carried out by the soil strata. Each level of the excavation which is opening a soil surface should be executed perfectly and based on the design. Also as soon as the soil surface is reached to its maximum excavation, there should be immediate shotcrete in order to avoid any chance of weathering. In this stage the shotcrete is at its most important scale as all of the above soil collapse takes place in the arches. Based on the soil properties there can be one vertical steel support in order to support the above soil if necessary. Precise care should be undertaken. Cement grouting should be performed in the last step. Figure 5.22 indicates the different steps undertaken in Opening of gallery 3.



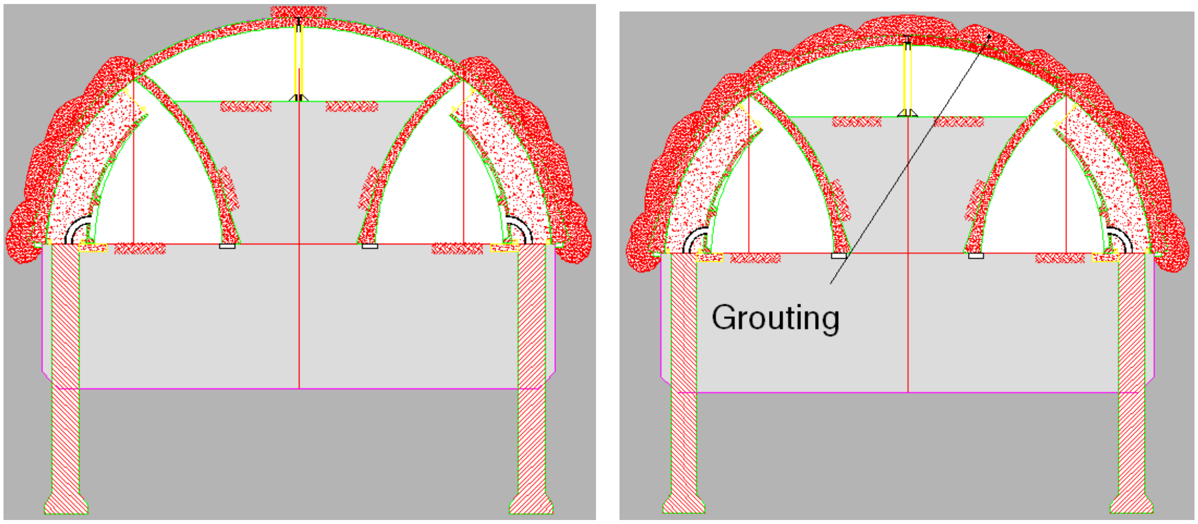


Figure 5.22: Step 6, Arch Pose

5.5.2.7. Step 7; Gallery 4

In this stage, gallery 4 is opening. Based on soil properties, there can as many as galleries needed in order to undertake the steps. In this stage half of the section excavation is in the open. Gallery 4 is excavated and supported by the steel section in cases necessary. Also lateral supports to the galleries 1 and 2 are removed as the half section is complete. Figure 5.23 indicates the changes in opening of gallery 4

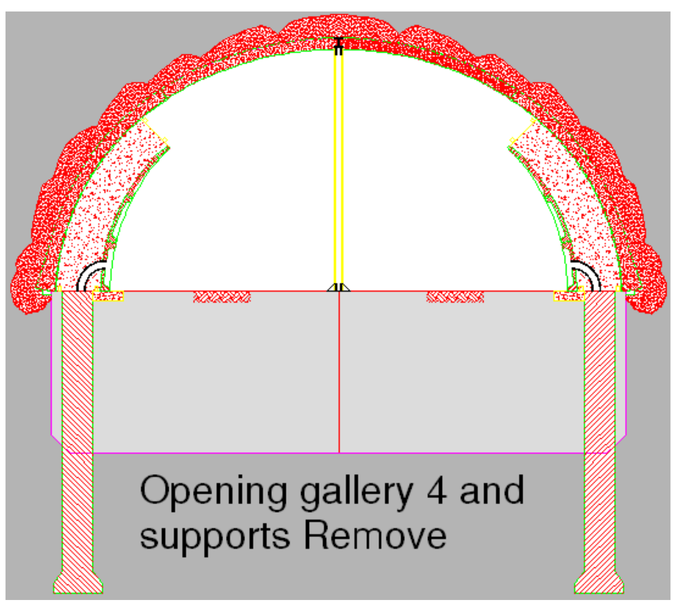


Figure 5.23: Step 7, Opening of Gallery 4

5.5.2.8. Step 8; Arch Reinforcement

In step 4, reinforcement is already done and casted the concrete in sides as it is desired to support the arch. In this step it will continue the reinforcements to its fullest scale and will connect the both sides in reinforcement. Then it will cast them in the next step. By help of the casting, arch is complete and also the half section is complete, as the total procedure for support construction is complete, here in after more metro specification is concerned. Figure 5.24 indicates the casting of the arch in section.

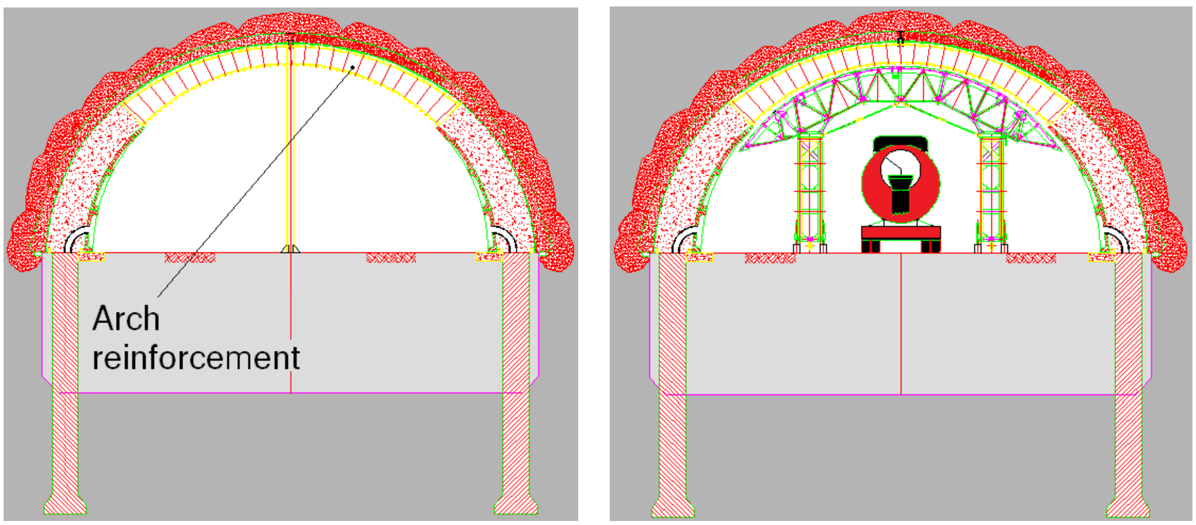


Figure 5.24: Step 8, Casting of Arch

5.5.2.9. Step 9; Gallery 5

In this step, gallery 5 excavation starts. It is also the start of second half of the excavation. In this step section is excavate up to the deepest level of the tunnel as the future rails and needed pavements will be installed on top of that. Figure 5.25 indicates the opening of gallery 5 in step 9 for the section.

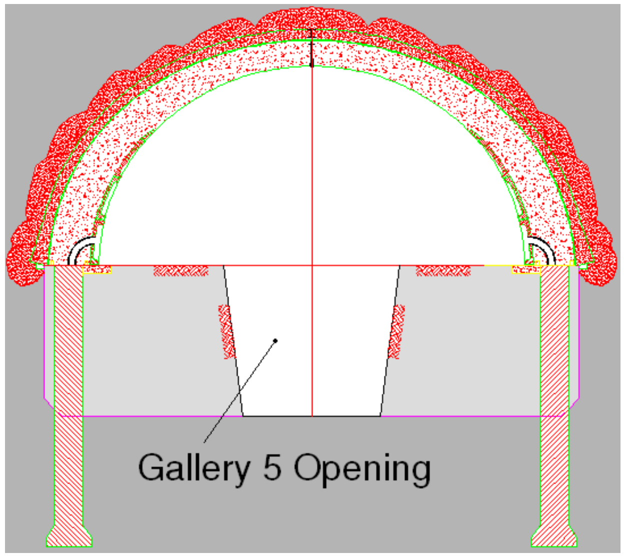


Figure 5.25: Step 9, Opening of Gallery Five

5.5.2.10. Step 10; Galleries 6 and 7

In this step, side piles are posed. As they have been casted in place before. Also reinforcement in the side walls and at back of the piles is done and ready to be filled by Box feeders. By opening of galleries 6 and 7, total excavation process is over. Figure 5.26 indicates the opening of galleries 6 and seven in the section. Figure 5.26 indicates the removal of galleries 6 and 7 in step 10.

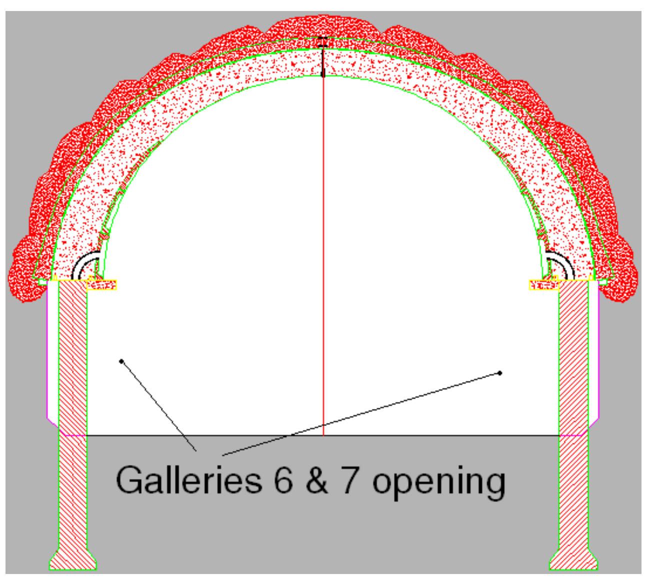


Figure 5.26: Step 10, Opening of Galleries Six and Seven

5.5.2.11. Step 11; Separating Walls

As the galleries 6 and 7 are open, the soil at back of the side piles is ready to shotcrete as they should be done just after the excavation. Then a separating wall is constructed in concrete material which separates the soil from the inner ambience. Also cement grouting is executed in back side walls. Figure 5.27 indicates preparing of separating walls performed in step 11.

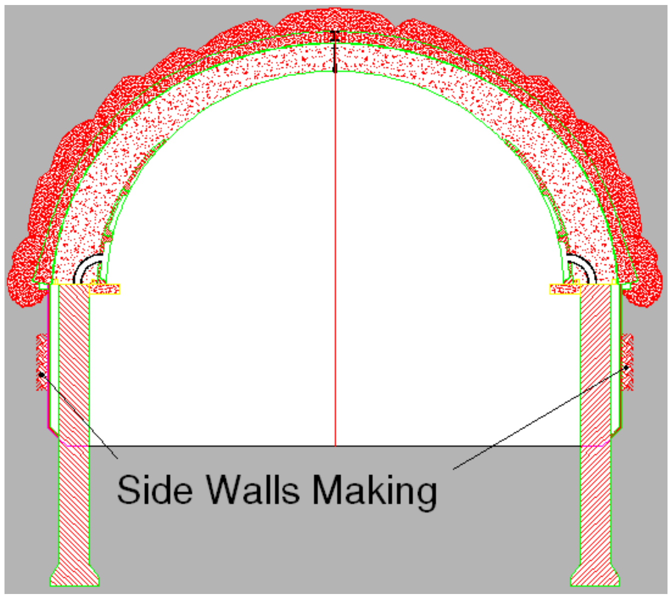


Figure 5.27: Step 11, Construction of Side Walls in Section

5.5.2.12. Step 12; Side Walls

As the separating walls are finished, in the gap between the piles, there is a reinforcement placed in this step which they are connected to mechanical joints in the top, then casting by concrete is performed and a load carrying wall is made in order to fill the gap between the piles and has a supportive role for the above arch as well, it is a structural purpose wall. Figure 5.28 indicates the side walls construction and grouting if required for this step.

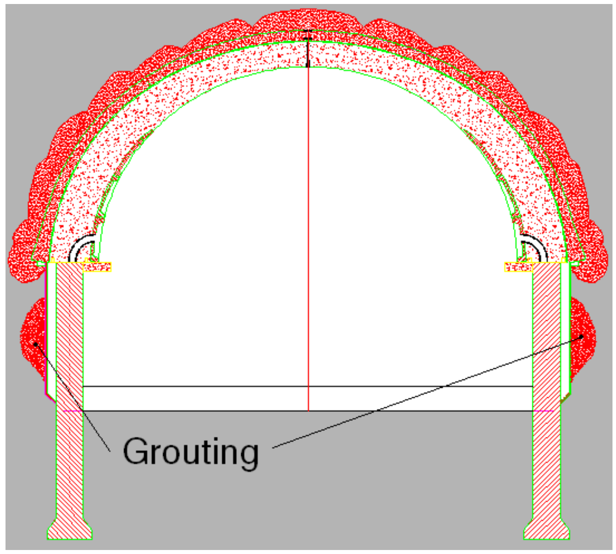


Figure 5.28: Step 12, Lateral Grouting of Walls

5.5.2.13. Step 13; Pavement Construction

In this stage, based on the demand and the characteristics of the terrain which is serving in the lines, as well as total loading expected, with respect to soil bearing capacity, a concrete flat slab is designed and cast in place which allows the rails to be installed at the top of the concrete slab. Figure 5.29 indicates the installation of pavements and rails in the section for MRT purpose.

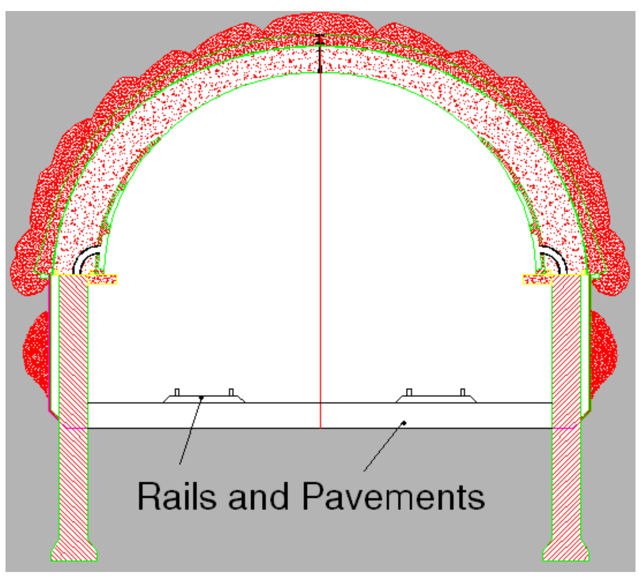


Figure 5.29: Step 13, Construction of Pavement and Installation of Rails

5.5.2.14. Step 14; Stations

As the stations are designed before, shafts are a suitable place for stations construction. It is a 102 feet in 62 feet structure reinforced concrete structure. Subway line with both center platform and side platform are possible for metro rail systems. Central platform require changes of alignment of track. The track centers need to be widened through an appropriate transition length upon approaching the station. However, for side platform, the same alignment can be used. Separation of the passengers for metro in two alternative directions is also possible. For a cut-and-cover double box subway, it is recommended to use the side platform type metro station (Bickel et al, 1997). A side platform type station is therefore suitable for metro line in Dhaka city. Waheed (2008) proposed a plan of a metro station for Dhaka (Figure 5.31). Similar station was used for Daikai station in Japan (Umehara et al. 1998). Height of the platform from the rail used for train is from 800 mm to 1200 mm (Wikipedia). The height of a railway platform usually varies between railway systems. Heathrow Airport Ltd specified their platform height at 1100 mm above rail level for the Heathrow Express rail service to and from Paddington Station (Wikipedia). Figure 5.30 shows a station box section with central platforms for the Silicon Valley Rapid Transit Project (Burns, 2007). Figure 5.32 shows the cross section of the proposed subway station. There are six columns inside the stations which have dimensions 36 in x 36 in. Clear spacing between the columns exist 25 ft longer direction and 20 ft in shorter direction. The platform height above plinth level is 3.5 ft. Total length of the platform is chosen as 500 ft. A provision two staircase and two escalators are included in the station

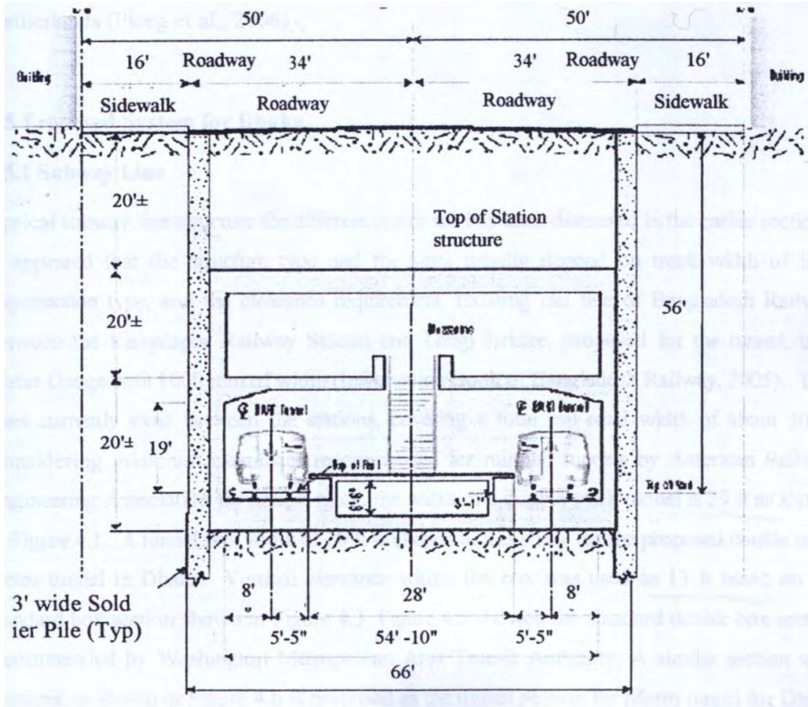


Figure 5.30: Station Box with Central Platform (Burns, 2007)

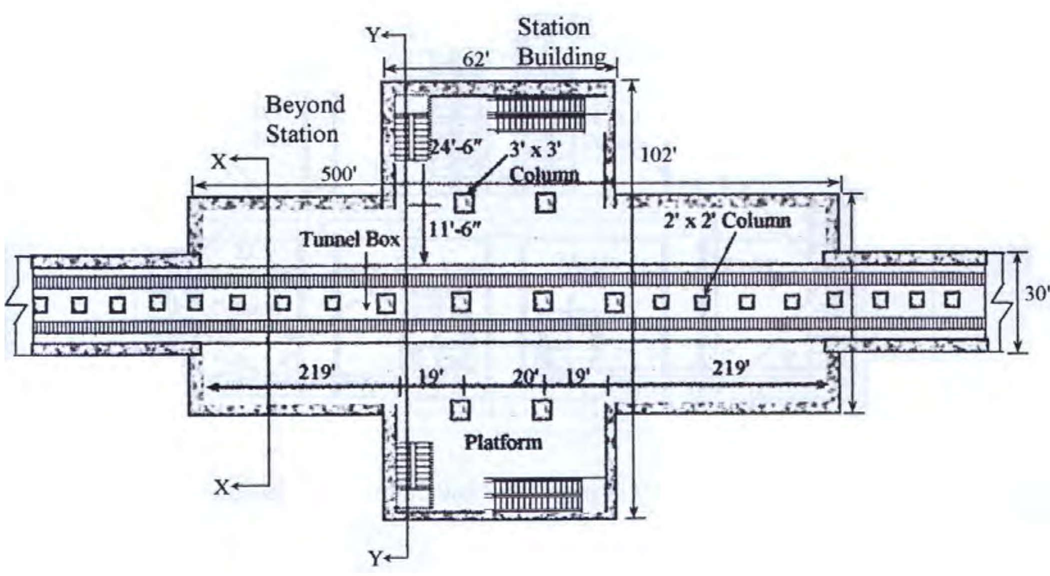


Figure 5.31: Cross Section of Station Building in Y-Y Direction (Not to Scale) (Waheed, 2008)

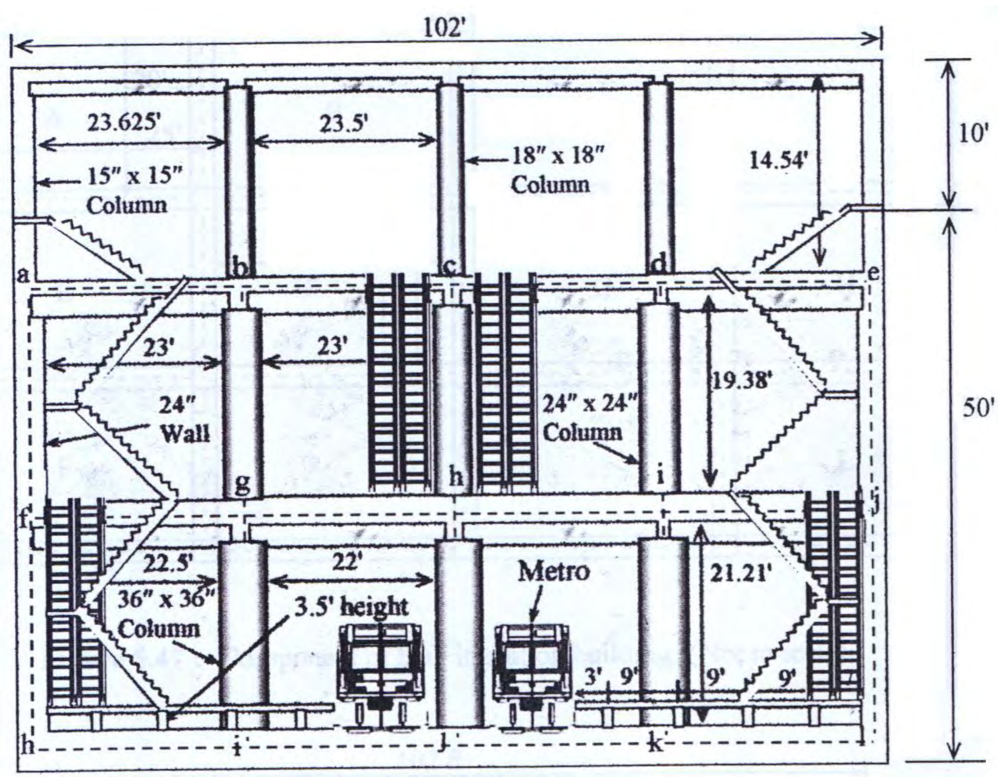


Figure 5.32: Cross Section of Station Building in Y-Y direction (Not to Scale) (Waheed, 2008)

Step 15; Facilities and Utilities

In this level, as almost all of the underground section regarding the construction is complete, here in after construction is concentrated on fixtures and utility demands of the metro line such as electricity and lighting, commuters facilities etc. any fixture or facility needed should be installed in this stage.

6.1. General

Cost estimation of tunnel project along the selected route has been estimated considering the proposal of different earth retention system analysis performed by Waheed (2008). Also an estimation of cost for material and equipment would be required to determine suitability of tunneling for Dhaka city. Although due to nature of NATM and Cut and Cover method of construction not much expensive or rare machinery and equipments are used. The bill of quantity and cost is determined on basis of “Schedule of Rates for Civil Works (PWD 2006). This chapter is divided in to two main parts: (1). Cost for earth retention systems (2). Cost for tunnel structure including the profile and subway stations (3). Utility lines cost (4). Comparison of NATM method cost and Cut and Cover costs.

6.2. Earth Retention System

KAWSAR MD.ABDUL WAHEED has undertaken a research in 2008 as M.Sc thesis in BUET in which indicates in case of Dhaka city, the best pile system to be applied in case of metro construction is application of diaphragm wall with the bracing which in all of the different cases is proved to be more economical ranging from 19% up to 23.5% cheaper as to the study of 4 different cases of soil available in the Dhaka city (Waheed 2008). As a neighbor country with same life pattern and more complex of challenges and difficulties in metro construction Delhi metro has undertaken the NATM tunneling method for the last section of Delhi metro including the same diaphragm wall method of earth retention system which shows the applicability of the diaphragm wall in earth retention system as long as the NATM is concerned for Dhaka. As in this study it is measured that the total length of the selected route is 15.21 km and as the Waheed have already calculated that piles are the diaphragm wall by cost average of 360 million Tk per km as in this case it is total of 5,475.6 million Tk for total profile construction of earth retention system.

6.3. Tunnel profile construction

Construction of tunnel involves earth work and tunnel structure construction. Both of excavation and structural costs are included in the cost of tunnel structure section. For the designed profile, total length of 15.21 km is selected as the total route excavation length.

6.3.1. Earthwork

This stage is considered of excavation of the profile of the tunnel. One of the greatest savings of NATM shows up in here. In case of Cut and Cover the total section has to be removed and filled back in future but in case of NATM there is no huge full section excavation also there is no large filling back. Also the cost of transport of excess excavates of soil is reduced.

Earth cutting and sand filling is included in this section. Also dewatering cost is included in this section based on the information provided by PWD (2006). Excavation should be done in the alignment and transported out through the shafts in NATM method. After installation of earth retention system, soil is excavated and tunnel structure is constructed.

Assuming the same section for both of NATM and Cut and Cover, up to maximum depth of 15.24 (50") meters for Cut and Cover, calculated profile earthwork volume is 2,119,582 m^3 for cut and cover method, as of 15.21 km of the length of the route, the total cost for **Cut and Cover** method is **Tk 81.98 million** (Table 6.2). Assuming the same section for NATM as the profile dimension, volume of soil excavation for NATM is 769,626 M^3 and the total cost of the excavation for the profile of tunnel for the **NATM** is **Tk30.79 million** based on PWD 2006(details in Table 6.1).

6.3.2. Tunnel Structure

In order to make a comparative study between NATM and Cut and Cover similarities assumed in the sections of NATM and Cut and Cover. Both of the assumed to be constructed as RCC structure and in the same dimension. Although due to change in method of excavation, there will be very small changes in the section design, but in this thesis both of the sections are assumed to be structurally the same.The structure of profile of the tunnel is a 9.20 x 5.5(=18"x 30") meter of the RCC. The cost of structure was including, RCC structure, shuttering the supports, steel fabrications cement plasters and paintings. Total cost of construction of structure of the tunnel for **Cut and Cover** was calculated as **Tk. 6,130.5 million** (Table 6.2) and was **Tk. 5,229.68 million** for **NATM** (Table 6.1) as of total length of the project including the total earthwork as well.

Table 6.1: NATM, SEM Profile Construction Cost Estimate

SI	Description of Work	Unit	Rate	Qty	Cost (million)
1	Earth work excavation	M^3	40	769,626	30.79
2	Palisading and dewatering protection	M^3	244	769,626	187.79
3	Dewatering deeper than 1.5 meter	M^3	425	769,626	327.09
4	18” Sand filling by coarse sand	M^3	652	763,451	497.77
5	3” Soling	m^2	162	139,121	22.54
6	Single layer polyethylene sheet	m^2	22	445,455	9.80
7	3” DPC	m^2	676	139,121	94.04
8	RCC with Stone Chips (1:1.5:3)				
	Flour slab concrete	M^3	6126	106,035	649.57
	Roof slab concrete	M^3	6126	106,035	649.57
	Side walls concrete	M^3	6195	73,517	455.44
	Middle columns concrete	M^3	6195	7,353	45.55
	Wall and columns capital concrete	M^3	6195	22,621	140.14
9	Shuttering the supports				
	Roof slab	m^2	488	139,119	67.89
	Side walls	m^2	319	120,596	38.47
	Middle column	m^2	319	13,699	4.37
	Wall and column capital	m^2	319	46,395	14.80
10	Steels fabrication				
	Fabrication of 60grade 25 mm deformed bar	Quintal	5400	194,481	1,050.20
	Fabrication of 60grade 16 mm deformed bar	Quintal	5400	51,950	280.53
	Fabrication of 60grade 12 mm deformed bar	Quintal	5400	19,567	105.66
	Fabrication of 60grade 10 mm deformed bar	Quintal	5400	26,911	145.32
11	Minimum 6mm thick cement plaster	m^2	99	487,475	48.26
12	Plastic paint for wall and ceiling	m^2	89	377,528	33.60
	TOTAL CIVIL COST OF CONSTRUCTION				**4,899.18**
13	Electrification costs	m^2	967	139,121	134.53
14	Ventilation costs (4%)	-	-	-	195.97
	TOTAL CONSTRUCTION COST				**5,229.68**

Table 6.2: Cut and Cover Profile Construction Cost Estimate

SI	Description of Work	Unit	Rate	Qty	Cost (million)
1	Earth work excavation	M^3	32	2,119,582	67.83
2	Extra rate for exceeding 1.5 meter	M^3	7	1,910,963	13.38
3	Extra rate for exceeding 10 meter	M^3	1.06	728,781	0.77
4	Palisading and dewatering protection	M^3	244	2,120,656	517.44
5	Dewatering deeper than 1.5 meter	M^3	425	1,912,000	812.60
6	18” Sand filling by coarse sand	M^3	652	763,451	497.77
7	3” Soling	m^2	162	139,136	22.54
8	Single layer polyethylene sheet	m^2	22	445,455	9.80
9	3” DPC	m^2	676	139,112	94.05
10	RCC with Stone Chips (1:1.5:3)				
	Flour slab concrete	M^3	6126	106,035	649.57
	Roof slab concrete	M^3	6126	106,035	649.57
	Side walls concrete	M^3	6195	73,517	455.44
	Middle columns concrete	M^3	6195	7,353	45.55
11	Wall and columns capital concrete	M^3	6195	22,621	140.14
	Shuttering the supports				
	Roof slab	m^2	488	139,119	67.89
	Side walls	m^2	319	120,596	38.47
	Middle column	m^2	319	13,699	4.37
	Wall and column capital	m^2	319	46,395	14.80
12	Steels fabrication				
	Fabrication of 60grade 25 mm deformed bar	Quintal	5400	194,481	1,050.20
	Fabrication of 60grade 16 mm deformed bar	Quintal	5400	51,950	280.53
	Fabrication of 60grade 12 mm deformed bar	Quintal	5400	19,567	105.66
	Fabrication of 60grade 10 mm deformed bar	Quintal	5400	26,911	145.32
13	Minimum 6mm thick cement plaster	m^2	99	487,475	48.26
14	Plastic paint for wall and ceiling	m^2	89	377,528	33.60
	TOTAL CIVIL COST OF CONSTRUCTION				**5,765.58**
15	Electrification costs	m^2	967	139,080	134.53
16	Ventilation costs (4%)				230.62
	TOTAL CONSTRUCTION COST				**6,130.65**

6.3.3. Utilities

Utilities for the tunnel box are considered for nonresidential standards. As of total area is 139,080 m^2 and the total cost of that is **Tk. 134.53 million** based on PWD 2006.

Ventilation cost is considered as 4% of the construction cost at the cost of **Tk 195.97 million.**

6.4. Stations

The proposed layout for Dhaka metro line is included of 12 stations. Each station is located of variable intervals at the approximate average of 1 km (Table 5.1). Stations are considered as three storeys RCC structure building in the excavated shafts for NATM and in the specific sites for Cut and Cover. In Case of NATM all of the shafts are used meanwhile of the construction, so the shafts are constructed before the construction of the main profile of the tunnel and in case of future design difference there can be easy opening and widening for the shafts. But in case of Cut and Cover, stations are constructed during the filling of the site or in side spaces.

6.4.1. Earth work

Number of shafts are 12 with assumed 15 meter diameter and excavation of 30 meter depth each. As long as the construction is undertaken, shafts are used as the transportation and facilitation channels, so they are excavated at diameter of 15 meter. As the construction finishes they are used as station location. As Waheed have designed the station as the dimension of 102 feet width and 62 feet length which is the area of 608 m^2 and it is larger than the minimum dimension needed for the shaft as 15 meter diameter, for the earth work of the stations dimensions required for stations are considered as of excavation and needed earthwork.

Quantity of the earth work for the stations of NATM and Cut and Cover is the same as the stations are to be of the same structure. Each station is included of 3 storey RCC structure with escalators and proper passenger"s service designs. All the details are included regarding the designing in the Appendix of the thesis.

Total cost regarding the earthwork of each station is Tk. 21.94 million and the. Assuming the total 12 number of the stations, total cost for earthwork of all of 12 stations is **Tk.263.32 million.**

6.4.2. Structure

Structure of stations is assumed to be the same for both of the methods. It is consisted of 3 storey RCC structure and the cost estimate is assumed by Waheed. Cost estimates starts from RCC structure up to the painting and air conditioning systems installation. All aspects included in each of 12 stations. Total structure is at the cost of Tk.67.53 million and as of 12 stations, total cost for structures of 12 stations is **Tk. 810.39 million** same for the both methods. Details of Calculation are included in Table 6.3.

Table 6.3: Stations Cost Estimate Details for NATM and Cut and Cover Method of Construction

Sl. No.	Description of the Work	Units	Rate	Qty	Cost (million)
1	Layout and marking	M^2	7	1,700	0.01
2	Shore protection work	M^2	579	5,300	3.07
3	Earthwork in excavation	M^3	32	25,650	0.82
4	Extra rate for exceeding 1.5 m	M^3	7	23,150	0.16
5	Extra rate for exceeding 10 m	M^3	1.06	9,100	0.01
6	extra rate for protected by palisading and dewatering	M^3	244	25,650	6.26
7	extra rate for dewatering exceeding 1.5 m	M^3	425	23,150	9.84
8	18" sand filling	M^3	652	700	0.46
9	3" soling	M^2	162	1,530	0.25
10	single layer polyethylene sheet	M^2	22	1,530	0.03
11	3" DPC	M^2	676	1,530	1.03

Contd... Table 6.3

Sl. No.	Description of the Work	Units	Rate	Qty	Cost (million)
12	**RCC Works**				
	in ground floor Concrete	M^3	6126	1,615	9.89
	in slab concrete (roof of 1st and 2nd flour)	M^3	6126	927	5.68
	Extra rate in slab concrete (roof of 1st and 2nd flour)	M^3	94	927	0.09
	In Side walls concrete	M^3	6195	1,274	7.89
	Extra rate in Side walls concrete (roof of 1st and 2nd flour)	M^3	92	1,068	0.10
	in column concrete (roof of Ground, 1st and 2nd flour)	M^3	6195	101	0.63
	Extra rate in columns (GF, 1st and 2nd flour)	M^3	92	86	0.01
	In Beam concrete (roof, 1st and 2nd flour)	M^3	6126	1,214	7.44
	extra rate in Beam concrete (roof, 1st and 2nd flour)	M^3	94	910	0.09
	In stair case concrete (GF, 1st and 2nd Floor)	M^3	6309	27	0.17
	Extra rate In stair case concrete (GF, 1st and 2nd Floor)	M^3	94	21	0.00
	in lintel(2nd floor) concrete	M^3	6101	3	0.02
	Extra rate in lintel concrete(2nd floor)	M^3	94	3	0.00
13	**Shuttering and necessary supports**				
	in ground floor shuttering	M^2	306	1,362	0.42
	in slabs shuttering (roof, 1st and 2nd floor)	M^2	488	2,438	1.19
	extra rate in slabs shuttering (roof, 1st and 2nd floor)	M^2	23	2,022	0.05
	in side walls shuttering	M^2	319	2,183	0.70
	extra rate in side walls shuttering (2nd and 1st floor)	M^2	16	1,719	0.03

Contd… Table 6.3

Sl. No.	Description of the Work	Units	Rate	Qty	Cost (million)
	In columns shuttering (2nd, 1st and)	M^2	319	539	0.17
	Extra rate in columns shuttering (2nd, 1st and)	M^2	16	472	0.01
	In Beams concrete(roof, 2nd, 1st floor)	M^2	386	500	0.19
	extra rate in Beams concrete(roof, 2nd, 1st floor)	M^2	39	375	0.01
	in staircase shuttering (2nd, 1st and GF)	M^2	390	100	0.04
	Extra rate in stair case shuttering (2nd, 1st and GF)	M^2	39	75	0.00
14	fabrication of 60 grade 25 mm deformed bar	Quintal	5400	2,177	11.76
15	fabrication of 60 grade 16 mm deformed bar	Quintal	5400	1,141	6.16
16	fabricating of 60 grade12 mm deformed bar	Quintal	5400	302	1.63
17	fabrication of 60 grade 10 mm deformed bar	Quintal	5400	499	2.69
18	125 mm thick brick wall	M^2	423	13,005	5.50
19	minimum 12 mm thick cement plaster	M^2	109	305	0.03
20	minimum 6 mm thick cement plaster	M^2	99	6,718	0.67
21	10 mm thick color situ mosaic	M^2	921	2,884	2.66
22	plastic emulsion paint to inner wall and ceiling	M^2	89	5,170	0.46
23	cement paint to outer walls	M^2	62	305	0.02
24	supply, fitting and fixing of stairs rails	M^2	3710	35	0.13
25	supply, fitting and fixing collapsible	M^2	2892	13	0.04
26	supplying, fitting and fixing of windows grills	M^2	1167	168	0.20
27	supplying, fitting and fixing of Steel glazed window shutter	M^2	3297	168	0.55
28	supplying, fitting and fixing of M.S door shutters	M^2	3400	65	0.22
29	painting of doors and windows shutter	M^2	101	110	0.01
30	provision of drip course	Rm	47	116	0.01
31	roof top parapet	M^2	953	92	0.09
				Construction Cost	**89.56**
32	Lightings and Escalators	station	-	-	30

Contd... Table 6.3

Sl. No.	Description of the Work	Units	Rate	Qty	Cost (million)
33	Air-condition and ventilations	station			64.4
Total Cost For One Station Construction					**183.96**

6.4.3. Utilities

Cost of lightings and escalators per station is assumed **Tk. 30 million.** Air-condition and ventilation is about **Tk.64.4 million** as it has been the same cost for Kolkata metro. Thus utility lines for stations building is **Tk.94.4 million.** Costs included in Table 6.3.

6.5. Utility Lines Relocation Costs

6.5.1. Introduction

Calculation of utility lines cost in this matter is a bit tricky and difficult to predict as the main utility providers are not precise about the total dislocation and relocation quantity and expenses. Based on primary data collected regarding the different layouts available in the selected route as indicated in chapter 4, and based on one case study, in Dhaka estimation provided by the authorities is subjected to 3~5 times growth in 4 years interval.

The estimates included in this section is result of case studies and experience of relocation and removal of the utility lines provided by respective utility providers submitted to BUET in august 2005 regarding the Jatrabari Gulistan flyover construction. As there has been different conflicts regarding the flyover and utility lines underground, construction firms assumed total of 25 crore regarding the dislocation or removal of the utility lines in 2003. But based on the estimates submitted by utility providers in year 2005, 25 crore was not even fulfilling for one of utility providers expenses.

From the both methods considered in this thesis, NATM method is having no conflict or no need of dislocation and relocation of the utility lines. All of the calculations included in this section are in regard of Cut and Cover method and not NATM, so the cost estimated in this section is added to total cost estimate in Cut and Cover method.

6.5.2. WASA

Based on estimate submitted by WASA to BUET in 2005, **Tk.6.724 million** per km is needed in order to replace and to locate a new layout in the alternative route. Base on the total route of 15.21 km, total length is subjected to water distribution system in 15.21 km, sewerage collection layout is covering 7.52 km of the total route and drainage and storm water collection system is covering 9.48 km. as the total route is involved by water distribution network, so in shadow of excavation of this layout, other networks of WASA may get replaced as well and there is no extra charge of excavation for them. Total cost estimated for replacing and relocating of WASA utility lines in the route is **Tk. 102.272 million.**

6.5.3. Electricity

Based on the estimated by DESA (which is now divided to DESCO and DPDC) in 2005 regarding the same project of Jatrabari Gulistan flyover the cost is estimated at **Tk. 3.853 million** in case of replacement of 1 km of the arterial network. As of presence of full length of the route in the selected arterials of 132, 33 & 11 KV lines in the all length of section, all full length is considered as excavation route by length of 15.21 km at the total cost of **Tk. 58.604 million.**

6.5.4. Titas Gas

As the cost estimate for all of the utility providers is concerned, cost estimation of dislocation and relocation of a project is almost four times larger than the normal installation as the alternatives have to be found, analyzed, constructed and used in first phase, and then redesigned, analyzed, and constructed in the second permanent route and due to temporary use of the alternative, capital costs are higher as compare to permanent use in long run. It is the same case with Titas Gas co.

Based on the estimate provided by Titas Gas Co. to BUET regarding the Jatrabari Gulistan flyover, for the total length of the projects (3.5 km), total cost was estimated as Tk 84.23

million regarding the project which is a **Tk 24.07 million per km**. As of presence of 13.3 km of the total route, the cost estimated for dislocation and relocation of Titas Gas utility network is **Tk 320.09 million.**

6.5.5. BTCL

Out of the different networks applied and served by the BTCL, as telephone, and internet lines and fiber optics, some of them are partially elevated and some are underground. Due to flexibility of network in case of repair and relocation, present network is subjected to so many land elevated or underground variations, and so, not much estimate could be conducted so far. Based on the interview with the respective BTCL authorities, they have mentioned a very inaccurate number of almost 5-6 million in case of relocation of the lines in the site. As so many of them are not underground, and there is no data available in this route regarding the elevated or underground network, cost of **3 million Tk per km** is considered per km in this case. As of total length of 15.21 km, total estimated cost of **Tk. 45.63 million.**

6.6. NATM and Cut and Cover Comparison

Nature of NATM and cut and cover are a bit different from each other. NATM usually poses less cost as compare Cut and Cover. Following is Table 6.4 indicating different comparative elements influencing the total cost estimate for both of the methods.

Table 6.4: NATM Vs Cut and Cover Cost Elements

SI	Description	NATM	Cut and Cover
1	Profile construction	Yes	Yes
2	Stations construction	Yes	Yes
3	Earthwork excavation volume	Small	Large
4	Earthwork Fill back and future costs	No	Very large
5	Transportation of earthwork	Small	Large
6	Utility lines relocation need	No need	Needed
7	Earth retention systems	Shorter but heavy	Longer and heavier
8	Deep excavation costs increase	Small	Very large
9	Cost of traffic diversion	No	Yes

Out of different elements considered above, the most effective ones are 1,2,3,6. Despite of great importance of all factors, some of them are not included, as they are out of this scope. Fill back costs, transportation of earth excavated costs are not included in this study.

Based on the Figures and proposed different methods in this thesis, NATM method and Cut and Cover, cost estimation is undertaken. Each method is consisting of two main parts as the construction aspect, construction of the profile of the tunnel, which is including all details starting from the earthwork up to the end of the structure, and Stations construction which is including all the aspects starting from earthwork and completes the Stations structure. Based on the calculations, here is a tabular form indicating the total cost of NATM and Cut and Cover method in Table 6.5. All the costs are in Million Tk.

Table 6.5: NATM Vs Cut and Cover costs

Construction Method	Tunnel Profile Cost (Million)	Stations Cost (Million)	Utility Lines Relocation Costs	TOTAL (Million)	Cost per km (Million)
NATM	5,229.68	2,207.52	0	**7,507.2**	**493.57**
Cut and Cover	6,130.65	2,207.52	573.066	**9,392.99**	**617.56**

First phase of the construction regarding the profile construction of the both methods causes a large difference of cost between NATM and Cut and Cover. By looking at the calculations included in the Table 6.1 and Table 6.2 it is obvious that the difference is included in the earthwork section. NATM is excavated and constructed through the shafts and the profile but Cut and Cover is constructed in full section of the route and filling back, so the volume of the excavated soil and the cost for accommodation of excavated soil (which is not included in this section) is added as compare to NATM.

Second part of the cost estimation for construction of the both methods is regarding the stations, as the both methods are using the same stations, both of methods are carrying the same cost in this aspect.

Third phase which brings the Difference in the Total costs of the projects is dislocation and relocation of the utility lines, based on the questionnaire survey in the sites which in case of Cut and Cover, all of the networks have to be dislocated and replaced after the Cut and Cover method. Due to expensive nature of providing of the alternatives to the network, this section is imposing large costs to the cut and cover method of construction. In NATM method, as the excavation is performed by using the shafts, no utility line is disturbed or dislocated.

Based on the information provided and calculations included, both of the NATM method and Cut and Cover methods are estimated and cost-wise they are analyzed. Based on data in Tables, 6.1, 6.2, 6.3, and 6.4 following is Figure 6.1 indicating the different aspects of NATM and Cut and Cover method in MRT6 route in compare to each other.

In the following Figure 6.1, variation of different elements of NATM total costs is indicated with respect to same correspondent Cut and Cover method parameters. This graph indicates that the main costs difference of both method lies in tunnel section or utility lines.

Figure 6.2 indicates the total costs included in all tunnel construciton process undertaken in this thesis. As compare to all aspects, NATM shows a more efficient and more econimic option. NATM stands as **25.12%** cheaper as compare to Cut and Cover method. Also Figure 6.3 indicates the comparative cost between NATM and Cut and Cover in total Ratio.

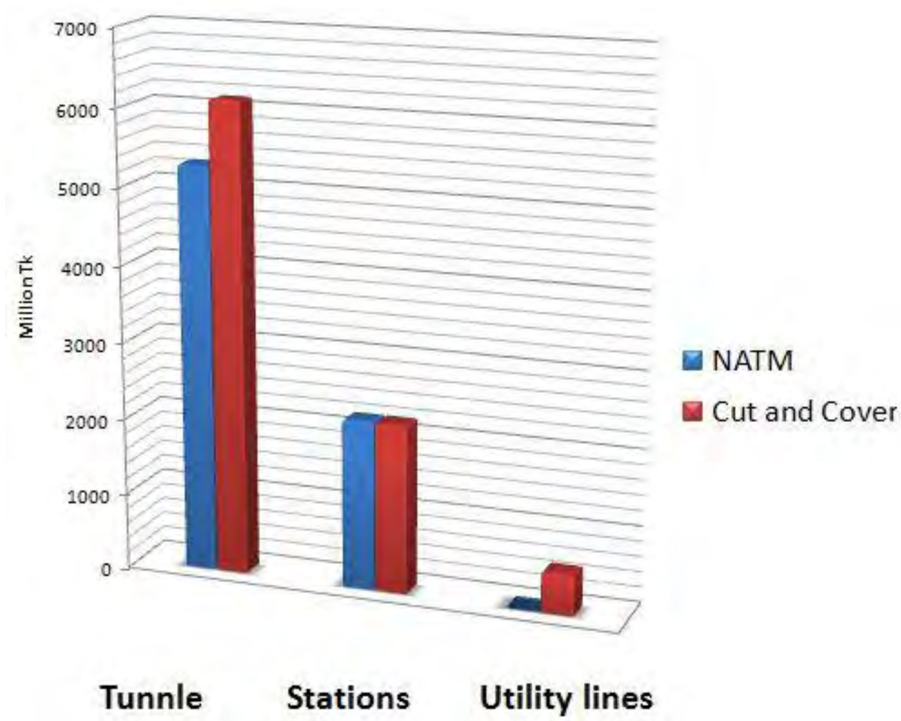


Figure 6.1: NATM and Cut and Cover Classified Costs

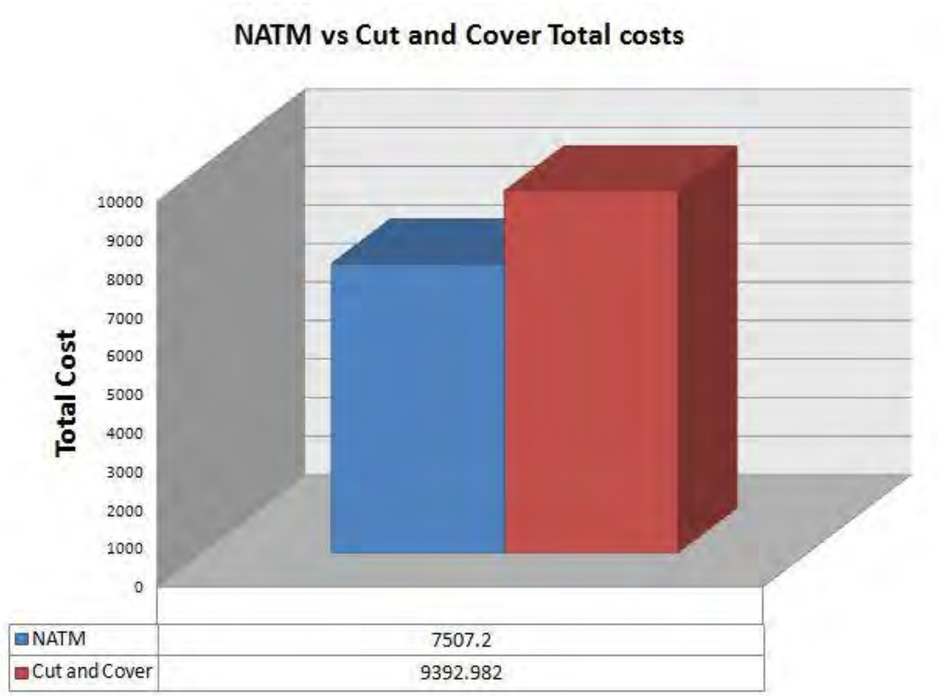


Figure 6.2: NATM and Cut and Cover Total Cost Comparison.

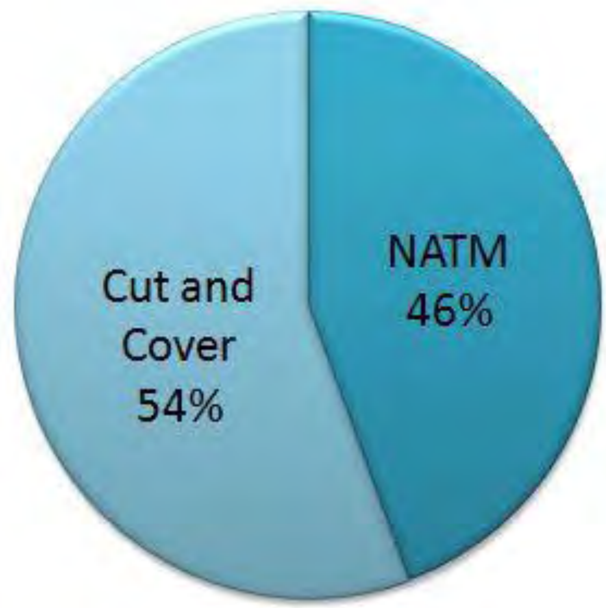


Figure 6.3: NATM and Cut and Cover Total Ratio.

Table 6.6 and Figure 6.4 compares the cost of NATM and Cut and Cover and Flyover construction, for Dhaka city. As compared to the flyover construciton by cost of **Tk.1335 million per km** Cut and Cover is **Tk. 617.56 million per km** and NATM is **Tk.493.57 million per km**.

Table 6.6: variation of costs between metro rails and Flyovers.

Structure Type	Total Construction Cost (Million)	Cost per km (Million)
NATM Metro	7,507.2	493.57
Cut and Cover metro	9,392.99	617.56
Mohakali Flyover	1495	1335

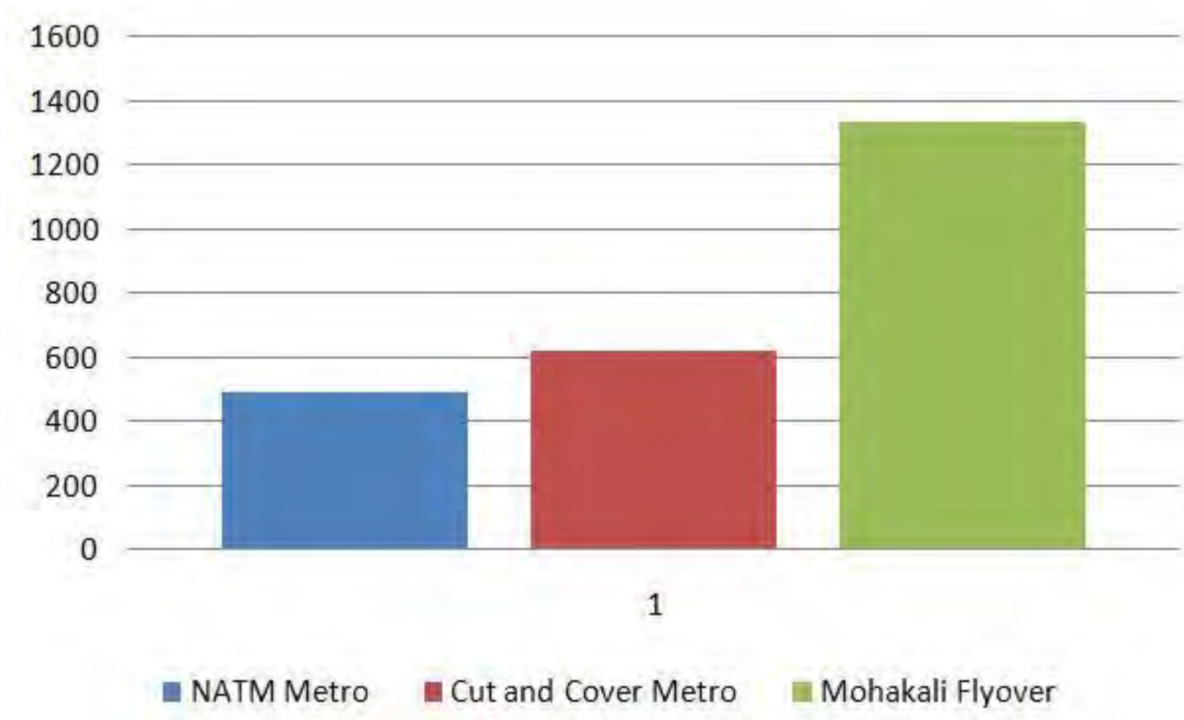


Figure 6.4: Variation of costs per Km for metro rail tunnels and flyover.

Also it is to notice that the cost of Mohakhali Flyover indicated in the Figure 6.4 is included the total costs of project including the contractor benefits. The Cut and Cover and NATM method are considered only in Tunnel construction. The costs estimated in these two methods are only covering the tunnel construction method.

6.7. Overview

Based on different methods considered in this thesis, and based on present MRT6 route characteristics and at-grade situation, NATM shows more suitability and more efficiency as compare to Cut and Cover in all traffic aspects. Also NATM shows that total construction process is a more economical option as compare to Cut and Cover (Figure 6.3).

NATM total cost of construction is **Tk.7,507.2 million** and Cut and Cover is **Tk. 9,392.99 million.** For NATM total project cost stand of **Tk.493.57 million** while for Cut and Cover, it is **Tk.617.56 million** per km.

7.1. General

Underground metro is known to be one of the most efficient solutions to traffic problems of congested cities. For Dhaka an underground metro system is desired to eliminate the traffic congestions and related problems so an exploration study regarding the construction of the metro in Dhaka city is performed in this thesis.

The specific objectives were to propose the appropriate route for Dhaka metro system and to propose the route alignment, stations, and the respective land locations and site needed for this purpose. Also out of different possible methods of construction, including all aspects of Dhaka, suggesting one method as the most beneficial and appropriate. The last objective was to undertake a very comprehensive field survey to identify the present as well as future facing challenges in Dhaka metro construction system.

In order to achieve the objectives on the thesis accordingly relevant primary and secondary data were collected. In this chapter the findings of the research work is summarized.

7.2 Route selection

In order to identify the best route for this study a comprehensive study of STP 2004 is undertaken. Based on the researches made, Dhaka is composed of mainly four north south corridors, Azimpur road, airport road, Rokeya Sarani road and Rampura DIT road. Out of three MRT lines suggested, MRT4 is located along the at-grade rail road with a large setback and no difficult challenge also a lot of researches have taken this route as the main topic. MRT5 is standing in circular loop from in east west direction which is a second importance as compare to travel demands in Dhaka, as far as the MRT6 is concerned. MRT6 is located on one of the four main north south corridors of Dhaka passing from the most congested Farmgate to Saidabad section which is having a large travel demand in the routes of Dhaka.

7.3. Route Characteristics

An underground tunnel alignment beneath the at-grade road starting from Pallabi passing from Rokeya Sarani to Bijoy Sarani and Airport road, reaching to Saidabad by total length of 15.21 kilometer is chosen for this study. The at-grade road is having the variation of 16 meter in 896 meter of the route and 6533 meter of 25 to 30 meter, 7781 meter of 30 to 35 meter. Total route is subjected to 84 T junctions, 14 cross junction and three roundabouts.

7.3.1. Challenges

In order to identify the challenges facing in this project a field survey was conducted in order to identify the challenges faced during the construction. All of data collected in this section are primary data collected from the field survey or from respective authorities or even from the field engineers in order to identify the challenges.

7.3.1.1. Large Buildings

A field survey was conducted in order to identify the available infrastructures on the selected route which may influence the total tunnel construction as the selection of type of tunnel construction method and design of tunnel are function of at-grade structures. On the other hand, underground excavation may cause the nearby structures to settlements or collapse. Based on survey conducted, it is revealed that buildings are located at the offset of 17 meter maximum from the centerline of the metro alignment. Numbers of the large buildings is 37 on the route which may affect the design of the metro, or may get affected by the metro excavation. The most density area is mainly located between Shahbagh intersection to Farmgate by total of 28 buildings are just before the Bijoy Sarani road which are located at the offset of 14 to 15 meter form the center line of the metro route. Possible Displacement, settlements and chances of collapse of nearby infrastructure has a direct effect on earth retention systems and total tunnel alignment and sections. Due to concentration of large building in these areas, earth retention systems are to be designed and applied on higher standards.

7.3.1.2. Utility Lines

A field survey was conducted to identify the utility networks available in the route. Presence of utility lines in the route affects the total cost of the projects as well as the method of construction. Also future settlements of the tunnel may cause the partial settlements to the networks which the networks behave differently to that based on their own flexibility. Based on collected data, there are four main utility lines in the route selected. Before, during or after the construction responses of the utility networks are identified in this section. For each network, present situation, possibility of dislocation and relocation and future response of the network to soil possible settlements is concerned and identified. All of the networks identified in here are subjected to road widening as they have been installed in the footpath first, then due to widening of the road, they are all located at the road pavements today.

Following is the findings in case of utility lines challenges face during the construction:

- BTCL: some of the network is located above the ground partially and some extend is located underground. Lack of proper planning makes the management of relocation but confusing. It is the easiest to handle during the construction process as the network is flexible and almost cheap to replace and relocate as compare to other utility network relocation costs. Also due to flexibility of the network, possible settlements of the network as long as the wires are not disconnected are not a big challenge. As BTCL has already started the developments and organizing the network underground, future development plans are clear and predictable in order to synchronize the construction of the tunnel and utility networks.
- Electricity: network is divided to two parts DESCO part and DPDC. DESCO is covering the Begum Rokeya Sarani starting from parliament up to the Pallabi and DPDC covers the rest of the route length. All of the arterials are located in the pavement at the offset of maximum 5 feet from the sidewalk and at maximum depth of 5 feet. Arterials are of 132, 33, and 11 kV cables which in case of tunnel construction and need for relocation, they should be demolished, temporary alternative provision during the construction and permanent network provision at end of the construction process. Relocation and replace of the network is very difficult in management and very costly in demolition and reconstruction. Also the future developments for both of the DPDC and DESCO are the same. It is a concrete box starting from 1 feet depth at the depth of 2.25 meter was shown in chapter four with enough room to accommodate the all of BTCL and Electricity network lines. In case of settlements, as long as the settlement does not exceed large depths which cause large deformation in the network, it is not a big problem.

- Titas Gas: is the second tough network to deal with as of need of consumer to continuous connectivity of the network. Laid in maximum depth of 5 feet and offset varying from 3 to 8 feet from the side walk and having a constant electric current in the body of the network in order to keep the network sparkle free for hesitation of any chance of fire. Arterials by diameters of, 16, 8 and 6 inches are locating along the route, specified in the chapter four available all along the route. As same as Electricity network, relocation, provision of the temporary alternative network during the construction and provision of the permanent network after the construction is much costly as compare to single installment of present network. It is a complicated and costly task to accomplish. As far as the future possible settlement is concerned, although no specific structure is supporting the network today, but the arterials show a good resistivity to partial settlements. As long as the settlements does not produce any crack or any settlements larger than 50 cm (as it produces the level variation and gas pressure reduction), network is undisturbed, but in case of cracks or any chance of settlements more than 50 cm, a very quick action is needed in order to eliminate any chance of explosion or firing. As of today no specific future plan is decided for this network which makes the tunnel construction a little unclear about the future.
- WASA: the most complicated and the most difficult one to handle in this project. As of permanent need of water distribution and waste water collection from the consumers, and due to large dependency of the consumers all over the city. It is divided in main three categories:
    - Water distribution: covering 15.21 km of the route. Laid at the depth of 5 to 10 feet and offset of 3 to 5 feet from the sidewalk. Having the largest arterial size of 1200 mm diameter. No supporting structure, so very sensitive to partial settlements, due to pressure drop and leak effects. Relocation and replacement is almost four times larger than initial installation of the network. As of today no future developments plans is considered.
    - Sewerage water collection is the second developed in Dhaka city in size aspect. By the total length of 7.38 km and is not developed in the route above the Bijoy Sarani road. Located at the offset of 3 to 10 feet and maximum depth of 25 feet starting from 3 feet from ground level with largest diameter of

1800 mm. collected sewage is flowing by gravity so any partial settlements disturbing the network and developing the partial settlement will cause huge difficulties for the network. Relocation and settlement is a very complicated, very time consuming and very costly and needs redesign of the network and arterials branches in all aspects. As of today no future development planned is considered for this part of the network.

- Strom water collection is covering the total length of 9.43 km and is available in the route at the offset of 3 to 10 feet and is located at the maximum depth of the 25 feet starting from 3 feet below the ground level. Flow is designed for peak flow and the flow is under the gravity rules in the slopes provided to flow. So the total network is very sensitive to any settlements or openings. As of today no future development plans in considered for this utility network.

7.3.1.3. Future developments of Dhaka

During study and research of this thesis it was identified that the selected route in some sections is planned for future developments suggested by STP 2004. All of those developments are carrying some conflicts and interaction with the metro construction process, during the construction and after finishing the process. All of the projects are divided in main three categories indicating the presence and their location as well as the properties and conflicts with each other. Based on the primary data collected all of the aspects of the construction process of these projects will need a large synchronization and harmony. As of today, if any project is developed without harmonizing by other projects in the surrounding environment it will cause the other projects to face very challenging construction or even impossible to develop. Following is the categories and their respective projects:

Grade Separated Projects

Two projects proposed by STP 2004 are located on the route selected for metro construction. Following is the projects and their respective locations and conflicts:

- Elevated Narayanganj-Gazipur Expressway (BBA) starting from Airport road at North of Dhaka and reaching to VIP road, Palashi and Saidabad, total project length having the conflict by the MRT6 route is 5.11 km in two sections, one starting from Bijoy Sarani up to Saarc intersection by length of 1.67 km and second section is in Zahir Reihan road starting from BUET and reaches to Chittagong highway up to Sayedabad bus station by length of 3.44 km. The foundation and the piles required for this project has a direct location conflict by the BRT lines proposed in the route as well as MRT6 line located underground.

- Jatrabari Palashi flyover by the total length of 2.87 km conflict with MRT6 and BRT located on the route, proposed by the DCC. This project is having the conflict with MRT6 in foundation below the ground surface, BRT in at-grade level and Elevated Highway in grade separated conflicts.

At-grade Projects

Along the considered route the only at-grade proposed project is BRT2 proposed by STP 2004. As the BRT2 line is located at the mid section of the road, future construction of Elevated Expressway and Jatrabari Palashi flyover is located at the mid section of the same road as well. Although the presented BRT2 line does not pose any conflict with MRT6 as the levels are different, but at-grade BRT2 line and elevated projects named should be synchronized with each other.

Underground Projects

MRT6 route is in conflict by four underpasses of Sonargan intersection, Bangla motor intersection, Sheraton intersection and Shahbagh intersection proposed by DCC. All of them are located at the Kazi Nazrul Islam road and Airport road. Although the total length of them is not large as compare to MRT6 length, but they show the conflicts as underground passages. Proper depth consideration should be mentioned during the construction in order to eliminate any chance of collapse or soil strata bound loss in future. Following is the list if underground projects:

- Sonargan intersection Underpass
- Bangla motor intersection Underpass
- Sheraton intersection Underpass
- Shahbagh intersection Underpass

7.4. Selection of Construction Method

Based on different studies out of the tree main methods of construction, TBM method is a much costly method as compare to two others despite of different advantages that it has got. Although cut and cover method and NATM are cheaper but as the long route of MRT6 is concerned, selecting between two methods will be narrowed based on limitations and challenges. Following is the list of findings and applicability of Cut and Cover and NATM method in the selected route:

- As the cut and cover method is executed through the full section excavation of soil, Cut and cover needs the access from the top which limits the cut and cover only to the at-grade route roads and opens spaces layout, there is no possibility of passing below the existing structures. But NATM does not need that access as it is excavated through the shafts constructed,
- By increasing the depth NATM shows not much change in excavation volume and not much cost for profile construction, as the profile goes deeper, only shafts are constructed a bit deeper as compared to before. In Cut and Cover, by every height of the profile adding to the dept desired, quantity of the soil needed to be excavated will be 2 times larger. On the other hand, deeper Cut and Cover tunnel needs stronger and heavier supports for the walls at the side, so application of Cut and Cover for deep tunnels is very illogical and impossible due to cost increase in volume of excavation, fill back and their costs, as well as cost of stronger earth retention systems needed.
- As cut and cover needs to excavate the full section any underground structure or any network utility laid between the road surface and desired tunnel location is subjected to modification, dislocation and relocation, or even permanent alternative provision which all of them carry a large cost imposing to the tunnel metro project. NATM is doing this section by using the shafts, and there is no conflict with the utility lines or other structure lying in between the road surface and desired profile location, due to lesser conflict, there is no need of relocation or modification of any present utilities.
- Cut and Cover method as destroys all the soil strata bound at its top, filling backs are subjected to different settlements in future. Response of any utility line, or network, or structures constructed to that settlement is different based on their own natural

flexibility to settlements, partially or fully section. But this is not the case for NATM as the soil bound is not lost.

- As the soil bound is lost in Cut and Cover method in future no heavy structure or heavy loading can be applied to the soil as the settlements will occur based on compaction imperfections, this is not the case for NATM

7.5. Dhaka Proposed Metro

A metro line and its respective stations as well as their stations location are proposed in this thesis. A primary field survey was conducted to find the proper locations as well as proper spacing and interval between the stations to propose a logical layout. Total length of 15.21 km of route, starting from Pallabi passing through Rokeya Sarani, Bijoy Sarani, Airport road, Kazi Nazrul Islam road, and TSC square, Shahid Minar road, and Reihan Sarani road, Dhaka Chittagong highway up to Sayedabad bus station is selected for this route.

Total of 12 stations are proposed in the route. Stations are: Pallabi, Section 10, Kazipara, Taltola, and Agargaon, Farmgate, Karwaan bazaar Shahbagh, BUET, Banga bazaar and finally Sayedabad bus station. All of the stations are located at the intervals of almost one km with some variations.

A primary field survey was undertaken in Islamic Republic of Iran"s capital Tehran city in 4 months period. Study in the Tehran was performed on different underground constructed projects and their construction methods, in order to identify the most appropriate method for Dhaka city metro. Based on that field survey in Tehran, a section compatible with NATM and applicable for construction of metro in Dhaka city metro is proposed. This section is considered as the total of 15 steps in order to accomplish the shafts, section of profile and stations for the proposed metro system of Dhaka.

7.6. Cost Analysis

A comprehensive study about the cost estimate is undertaken in this thesis for NATM and Cut and Cover method. As of difference costs included in each of the methods, both of the methods are estimated in order to find the most affordable method of construction based on different field survey data collected from Dhaka and from Tehran.

Stations and earth retention systems are considered and applied similarly to both of the methods. Main aspects of difference in cost for methods of construction are about type of excavation, and utility lines challenges. NATM is having a much smaller volume of excavation of the soil as compare to Cut and Cover, also NATM does not interfere with the above network of utility lines which Cut and Cover does. In both of these cases NATM shows a more affordable cost of construction. Considering all aspects of construction, NATM total cost is Tk. 7,507.2 million and Cut and Cover total cost is Tk. 9,392.99 million. As compared to each other NATM stands cheaper by 25.12% as compare to Cut and Cover method.

Not all aspects of the NATM and Cut and Cover are included in this section. There are a lot of minor details, unpredictable for this study. Presence of each of them is a more cost for Cut and Cover, not the NATM method.

7.7. Limitations of the Study

Despite of full time nonstop efforts undertaken in this thesis, due to lack of manpower and time constrains as well as unpredictable details, following is the limitations of this thesis:

- Lack of comprehensive soil study makes the design of section of NATM and Cut and Cover different. Change in design of NATM causes more efficient and economic cost analysis for NATM which decreases the NATM total costs.
- A field survey is needed to identify the concentration and effect of large buildings on the soil beneath, in order to have proper design for saving the both at-grade structures and underground structures.
- Some aspects of cut and cover cost analysis are not included in this thesis. Almost all of the costs of soil transportation and filling back are not included. Also costs due to settlements caused by the cut and cover method to other future structures and networks.
- Total cost affecting the city traffic flow for the traffic diversion of Cut and Cover method in the at-grade level is not included in cost estimates.

7.8. Recommendations for Future Study

For future tunneling regarding the metro or any other underground structures in Dhaka, following aspects are to be considered

- A fully detailed study of soil characteristics along the selected route is needed, so the earth retention system and specific section for NATM is used which is more efficient.
- A detailed field survey is needed regarding the ownership and possibility of construction of stations sites.
- Because of long length of route and variable water table in the Dhaka, a comprehensive study and cost analysis of application of TBM method along the route is recommended. Although application of TBM is a large capital cost, but due to large length TBM method is an applicable method of construction. As the route of MRT6 (15.21 km) is connected to MRT4 (20 km length) in future, TBM machine and technique may be economically efficient method to be used in route MRT4 as well. Total length of project will be 35.21 km.
- A comprehensive study is recommended in order to synchronize the future developments of Dhaka future developments and propose the proper solutions. Each of synchronizations is very vital for the other projects.
- A comprehensive study regarding the future costs of utility networks dislocation and relocation is suggested.

7.9. Conclusions and Recommendations

This study indicates the Metro underground system for Dhaka as mass rapid transit option and solution to Dhaka city today‟s congestion problem is applicable and possible. Proposed MRT6 route by STP 2004 is selected as the Dhaka metro underground system. Selected route is of total length of 15.21 km and subjected to different large challenges during and after construction. Also a lot of challenges may get faced by future developments in Dhaka due to Underground Metro system. Main challenges faced today are large buildings available on the route which makes the challenges for earth retention systems, present utility lines available on the route which they need to be relocated during the construction and the future developments of the Dhaka city which needs the proper design harmonization and synchronizing for all of the projects.

Main three different methods of construction have been reviewed and considered for this project. Based on different field surveys and data collection it is found out that out of these three, NATM and Cut and Cover method are the best selection as compare to TBM. Based on challenges and route characteristics identified in this study, it is cleared that NATM method shows more applicability and easier execution as compare to Cut and Cover.

A cost estimate is undertaken in this study regarding the comparison between NATM and Cut and Cover which. Estimate performed in this thesis indicates that NATM method is cheaper by 25.12 % as compare to Cut and Cover due to lesser excavation volume and no need of relocation of utility lines.

This study has proposed a metro route, stations and their locations, as well as the section applicable for the Dhaka metro in NATM method. The proposed section is suggested based on different field surveys performed on different Iranian underground projects in Tehran in recent years. The stations and their respective locations have been identified by a field survey performed in the route in order to identify the possible and available sites for stations construction. Also the route selected is suggested by STP 2004 and selected from 3 proposed metro lines of the same study.

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APPENDIX A

MAPS ALONG TUNNEL ALIGNMENT

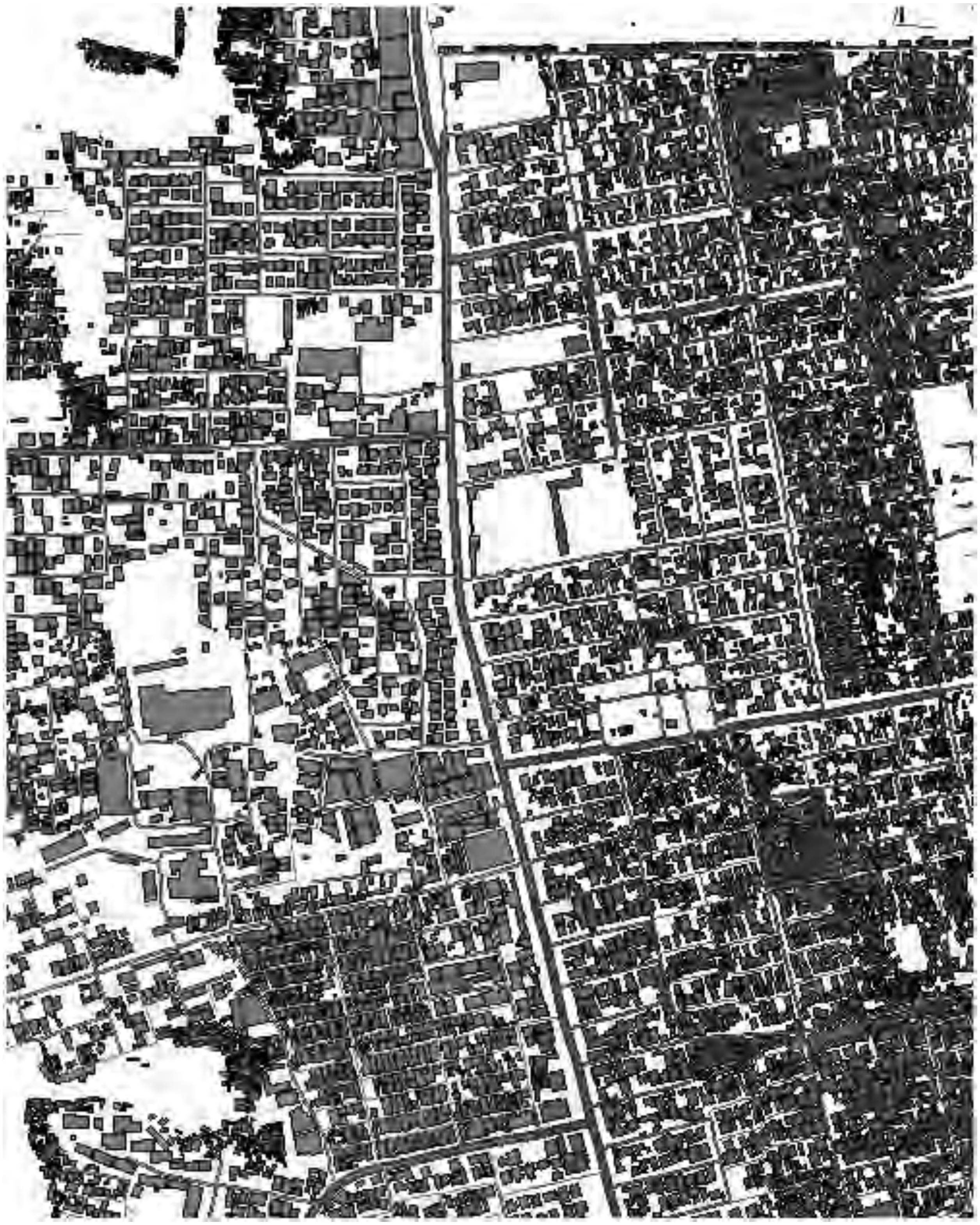


Figure A-1: Map-1 (Pallabi to Section 11)

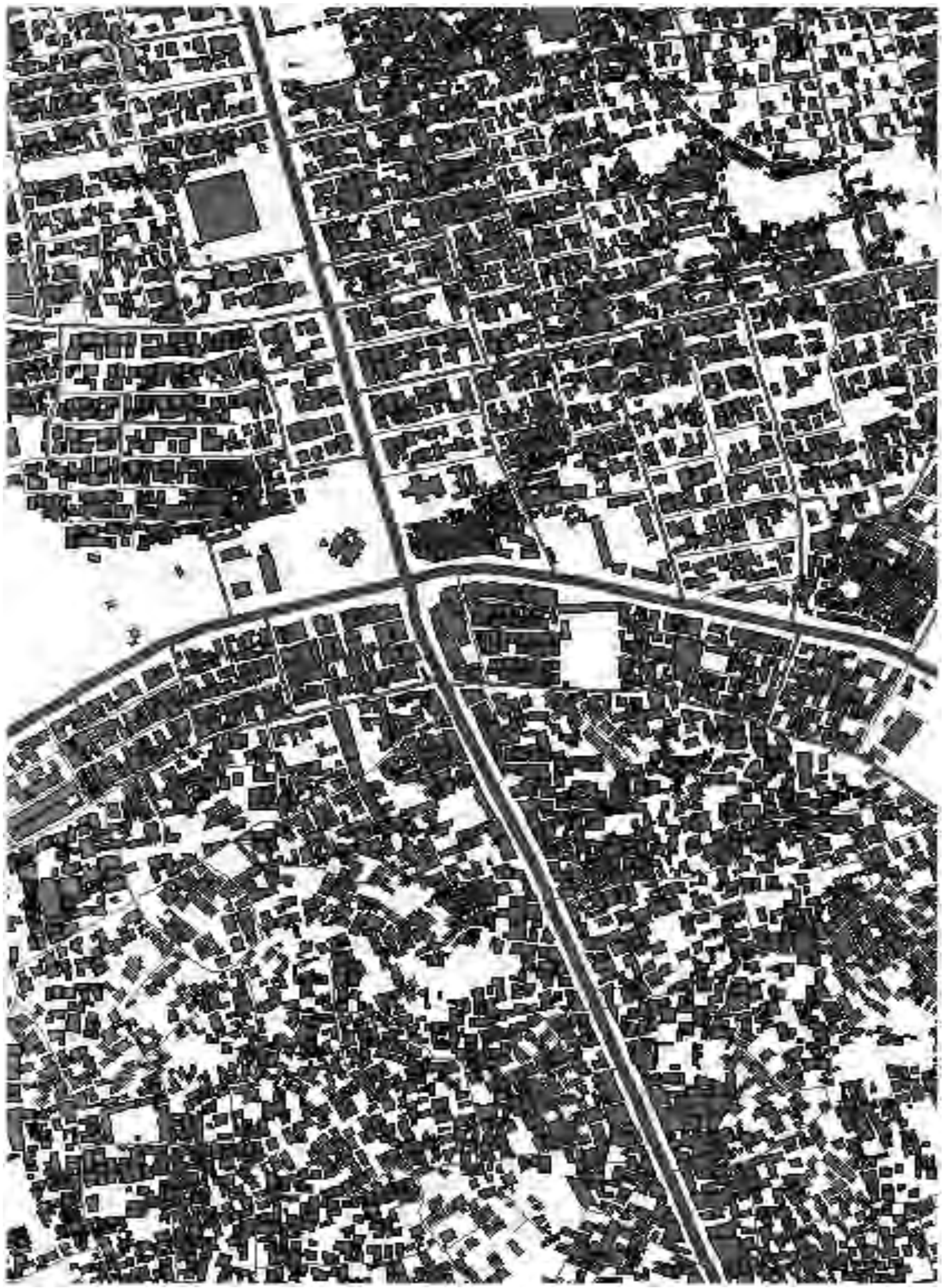


Figure A-2: Map-2 (Mirpur Section 10 to Kazipara)

Figure A-3: Map-3 (Gazipur to Taltola)

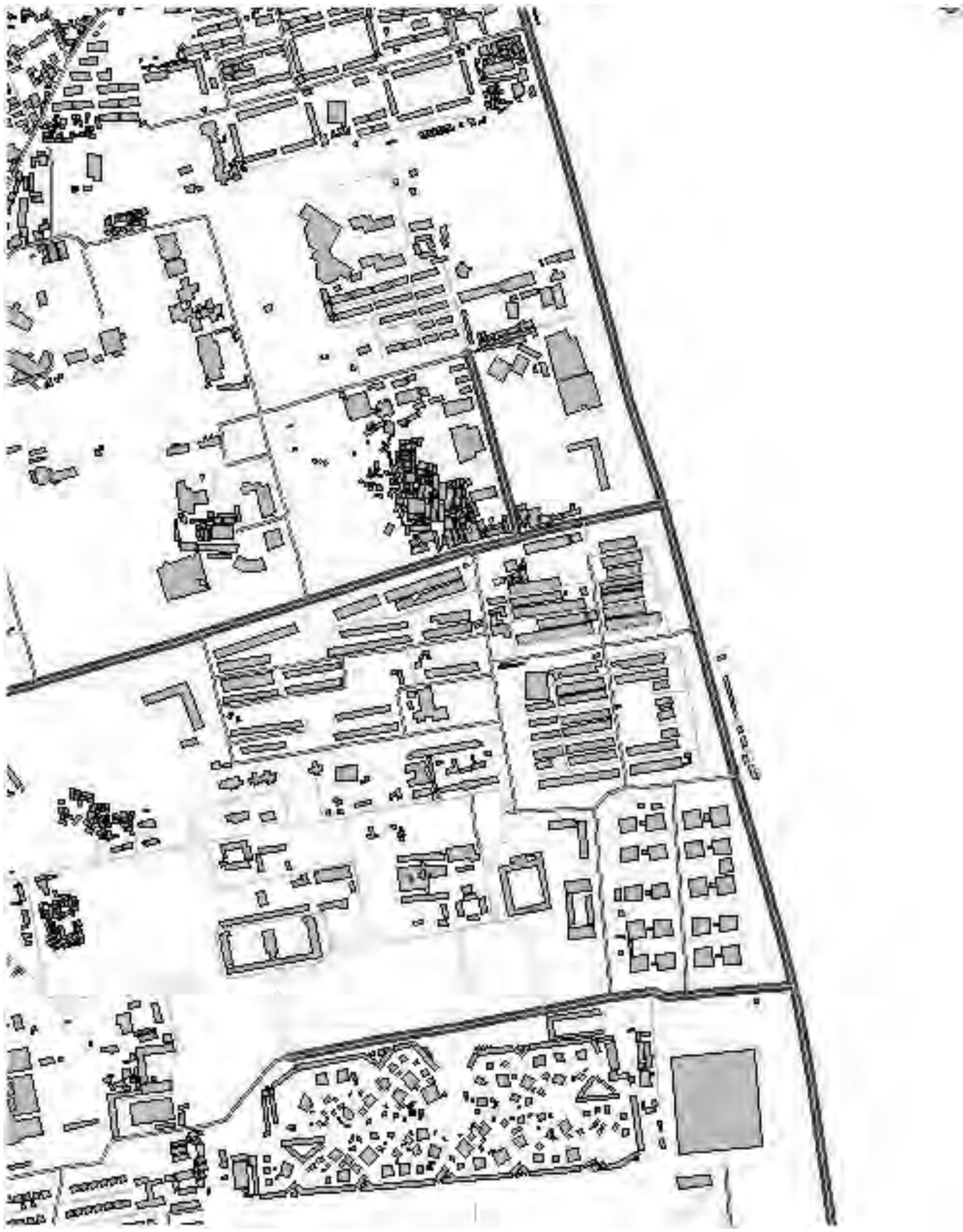


Figure A-4: Map-4 (Parliament to Taltola)

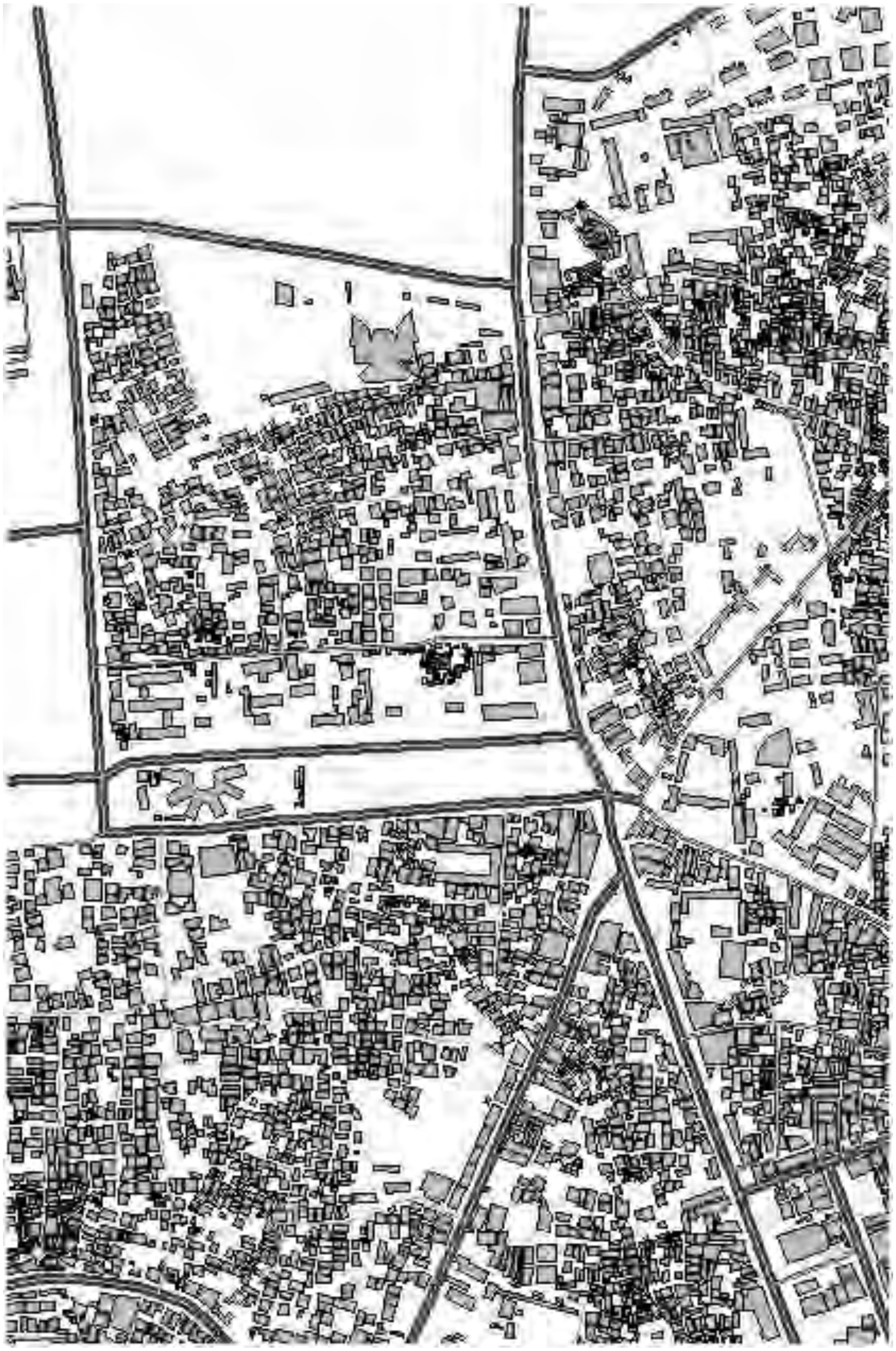


Figure A-5: Map-5 (Farmgate to Karwaan bazaar)

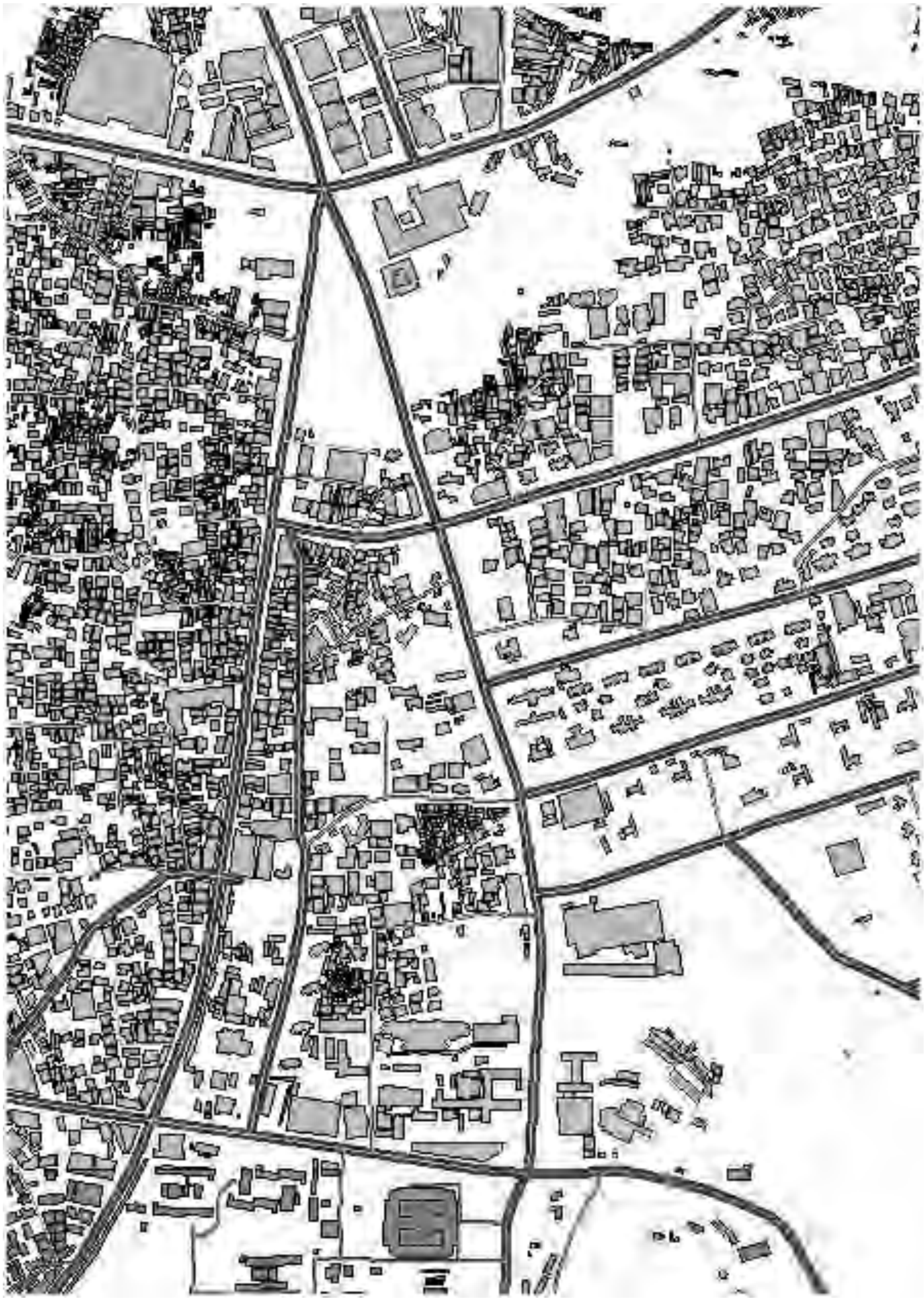


Figure A-6: Map-6 (Saarc Fuara to Bangla Motor Intersection)

Figure A-7: Map-7 (BUET to Sayedabad)

APPENDIX B

COST ANALYSIS

NATM, SEM Profile Construction Cost Estimate

SI	Description of Work	Unit	Rate	Qty	Cost (million)
1	Earth work excavation	M^3	40	769,626	30.79
2	Palisading and dewatering protection	M^3	244	769,626	187.79
3	Dewatering depper than 1.5 meter	M^3	425	769,626	327.09
4	18" Sand filling by coarse sand	M^3	652	763,451	497.77
5	3" Soling	m^2	162	139,121	22.54
6	Single layer polyethylene sheet	m^2	22	445,455	9.80
7	3" DPC	m^2	676	139,121	94.04
8	RCC with Stone Chips (1:1.5:3)				
8.1	Flour slab concrete	M^3	6126	106,035	649.57
8.1	Roof slab concrete	M^3	6126	106,035	649.57
8.3	Side walls concrete	M^3	6195	73,517	455.44
8.4	Middle columns concrete	M^3	6195	7,353	45.55
8.5	Wall and columns capital concrete	M^3	6195	22,621	140.14
9	Shuttering the supports				
9.1	Roof slab	m^2	488	139,119	67.89
9.2	Side walls	m^2	319	120,596	38.47
9.3	Middle column	m^2	319	13,699	4.37
9.4	Wall and column capital	m^2	319	46,395	14.80
10	Steels fabrication				
10.1	Fabrication of 60grade 25 mm deformed bar	Quintal	5400	194,481	1,050.20
10.2	Fabrication of 60grade 16 mm deformed bar	Quintal	5400	51,950	280.53
10.3	Fabrication of 60grade 12 mm deformed bar	Quintal	5400	19,567	105.66
10.4	Fabrication of 60grade 10 mm deformed bar	Quintal	5400	26,911	145.32
11	Minimum 6mm thick cement plaster	m^2	99	487,475	48.26
12	Plastic paint for wall and ceiling	m^2	89	377,528	33.60
	TOTAL CIVIL COST OF CONSTRUCTION				**4,899.18**
13	Electrification costs	m^2	967	139,121	134.53
14	Ventilation costs (4%)				195.97
	TOTAL CONSTRUCTION COST				**5,229.68**

Cut and Cover Profile Construction Cost Estimate

SI	Description of Work	Unit	Rate	Qty	Cost (million)
1	Earth work excavation	M^3	32	2,119,582	67.83
2	Extra rate for exceeding 1.5 meter	M^3	7	1,910,963	13.38
3	Extra rate for exceeding 10 meter	M^3	1.06	728,781	0.77
4	Palisading and dewatering protection	M^3	244	2,120,656	517.44
5	Dewatering deeper than 1.5 meter	M^3	425	1,912,000	812.60
6	18" Sand filling by coarse sand	M^3	652	763,451	497.77
7	3" Soling	m^2	162	139,136	22.54
8	Single layer polyethylene sheet	m^2	22	445,455	9.80
9	3" DPC	m^2	676	139,112	94.05
10	RCC with Stone Chips (1:1.5:3)				
10	Flour slab concrete	M^3	6126	106,035	649.57
10	Roof slab concrete	M^3	6126	106,035	649.57
10	Side walls concrete	M^3	6195	73,517	455.44
10	Middle columns concrete	M^3	6195	7,353	45.55
11	Wall and columns capital concrete	M^3	6195	22,621	140.14
11	Shuttering the supports				
11	Roof slab	m^2	488	139,119	67.89
11	Side walls	m^2	319	120,596	38.47
11	Middle column	m^2	319	13,699	4.37
11	Wall and column capital	m^2	319	46,395	14.80
12	Steels fabrication				
12	Fabrication of 60grade 25 mm deformed bar	Quintal	5400	194,481	1,050.20
12	Fabrication of 60grade 16 mm deformed bar	Quintal	5400	51,950	280.53
12	Fabrication of 60grade 12 mm deformed bar	Quintal	5400	19,567	105.66
12	Fabrication of 60grade 10 mm deformed bar	Quintal	5400	26,911	145.32
13	Minimum 6mm thick cement plaster	m^2	99	487,475	48.26
14	Plastic paint for wall and ceiling	m^2	89	377,528	33.60
	TOTAL CIVIL COST OF CONSTRUCTION				**5,765.58**
15	Electrification costs	m^2	967	139,080	134.53
16	Ventilation costs (4%)				230.62
	TOTAL CONSTRUCTION COST				**6,130.65**

Stations cost estimate details for NATM and Cut and Cover method of construction

SI	Description of the Work	Units	Rate	Qty	Cost (million)
1	layout and marking	M^2	7	1,700	0.01
2	shore protection work	M^2	579	5,300	3.07
3	earthwork in excavation	M^3	32	25,650	0.82
4	extra rate for exceeding 1.5 m	M^3	7	23,150	0.16
5	extra rate for exceeding 10 m	M^3	1.06	9,100	0.01
6	extra rate for protected by palisading and dewatering	M^3	244	25,650	6.26
7	extra rate for dewatering exceeding 1.5 m	M^3	425	23,150	9.84
8	18" sand filling	M^3	652	700	0.46
9	3" soling	M^2	162	1,530	0.25
10	single layer polyethylene sheet	M^2	22	1,530	0.03
11	3" DPC	M^2	676	1,530	1.03
12	RCC Works				
i	in ground floor Concrete	M^3	6126	1,615	9.89
ii	in slab concrete (roof of 1st and 2nd flour)	M^3	6126	927	5.68
iii	Extra rate in slab concrete (roof of 1st and 2nd flour)	M^3	94	927	0.09
iv	In Side walls concrete	M^3	6195	1,274	7.89
v	Extra rate in Side walls concrete (roof of 1st and 2nd flour)	M^3	92	1,068	0.10
vi	in column concrete (roof of Ground, 1st and 2nd flour)	M^3	6195	101	0.63
vii	Extra rate in columns (GF, 1st and 2nd flour)	M^3	92	86	0.01
viii	In Beam concrete (roof, 1st and 2nd flour)	M^3	6126	1,214	7.44
ix	extra rate in Beam concrete (roof, 1st and 2nd flour)	M^3	94	910	0.09
x	In stair case concrete (GF, 1st and 2nd Floor)	M^3	6309	27	0.17
xi	Extra rate In stair case concrete (GF, 1st and 2nd Floor)	M^3	94	21	0.00
xii	in lintel(2nd floor) concrete	M^3	6101	3	0.02
xiii	Extra rate in lintel concrete(2nd floor)	M^3	94	3	0.00
13	Shuttering, Prop and necessary supports				
i	in ground floor shuttering	M^2	306	1,362	0.42
ii	in slabs shuttering (roof, 1st and 2nd floor)	M^2	488	2,438	1.19
iii	extra rate in slabs shuttering (roof, 1st and 2nd floor)	M^2	23	2,022	0.05
iv	in side walls shuttering	M^2	319	2,183	0.70
v	extra rate in side walls shuttering (2nd and 1st floor)	M^2	16	1,719	0.03
vi	In columns shuttering (2nd, 1st and)	M^2	319	539	0.17
vii	Extra ratein columns shuttering (2nd, 1st and)	M^2	16	472	0.01
viii	In Beams concrete(roof, 2nd, 1st floor)	M^2	386	500	0.19

ix	extra rate in Beams concrete(roof, 2nd, 1st floor)	M^2	39	375	0.01
x	in staircase shuttering (2nd, 1st and GF)	M^2	390	100	0.04
xi	Extra rate in stair case shuttering (2nd, 1st and GF)	M^2	39	75	0.00
14	fabrication of 60 grade 25 mm deformed bar	Quintal	5400	2,177	11.76
15	fabrication of 60 grade 16 mm deformed bar	Quintal	5400	1,141	6.16
16	fabricating of 60 grade12 mm deformed bar	Quintal	5400	302	1.63
17	fabrication of 60 grade 10 mm deformed bar	Quintal	5400	499	2.69
18	125 mm thick brick wall	M^2	423	13,005	5.50
19	minimum 12 mm thick cement plaster	M^2	109	305	0.03
20	minimum 6 mm thick cement plaster	M^2	99	6,718	0.67
21	10 mm thick color situ mosaic	M^2	921	2,884	2.66
22	plastic emulsion paint to inner wall and ceiling	M^2	89	5,170	0.46
23	cement paint to outer walls	M^2	62	305	0.02
24	supply, fitting and fixing of stairs rails	M^2	3710	35	0.13
25	supply, fitting and fixing collapsible	M^2	2892	13	0.04
26	supplying, fitting and fixing of windows grills	M^2	1167	168	0.20
27	supplying, fitting and fixing of Steel glazed window shutter	M^2	3297	168	0.55
28	supplying, fitting and fixing of M.S door shutters	M^2	3400	65	0.22
29	painting of doors and windows shutter	M^2	101	110	0.01
30	provision of drip course	Rm	47	116	0.01
31	roof top parapet	M^2	953	92	0.09
	TOTAL CONSTRUCTION COST				**89.56**
32	Lightings and Escalators	station			30
33	Air-condition and ventilations	station			64.4
	TOTAL COST FOR ONE STATION CONSTRUCTION				**183.96**

APPENDIX C

PICTURES OF TEHRAN TOHID TUNNEL CONSTRUCTION

Figure C1: South Ramp

Figure C2: Gallery 1

Figure C3: Portal Entrance

Figure C4: Mid piles Construction

Figure C5: Galley One Constructed

Figure C6: Half Section of the Tunnel

Figure C7: Jomhoori Shaft under Construction

Figure C8: Jomhoori Shaft Constructed

Figure C9: Opening Gallery 3

Image C10: Arch Construction

Figure C11: Gallery 5 before and after Removing

Figure C12: King Pile Decoration

Figure C13: Side Wall Construction

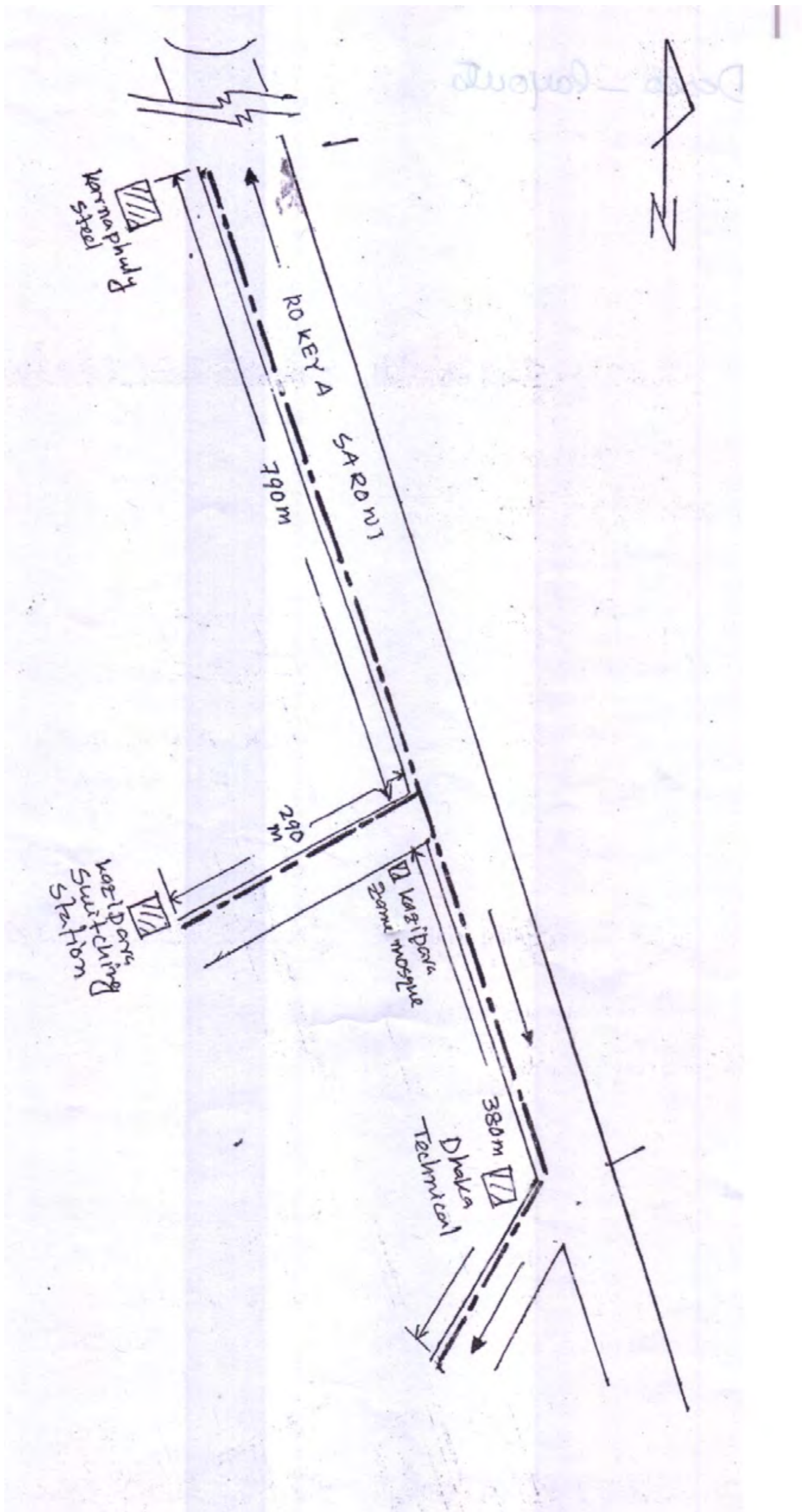
Figure C14: Pavement Construction

Figure C15: Pavement Construction

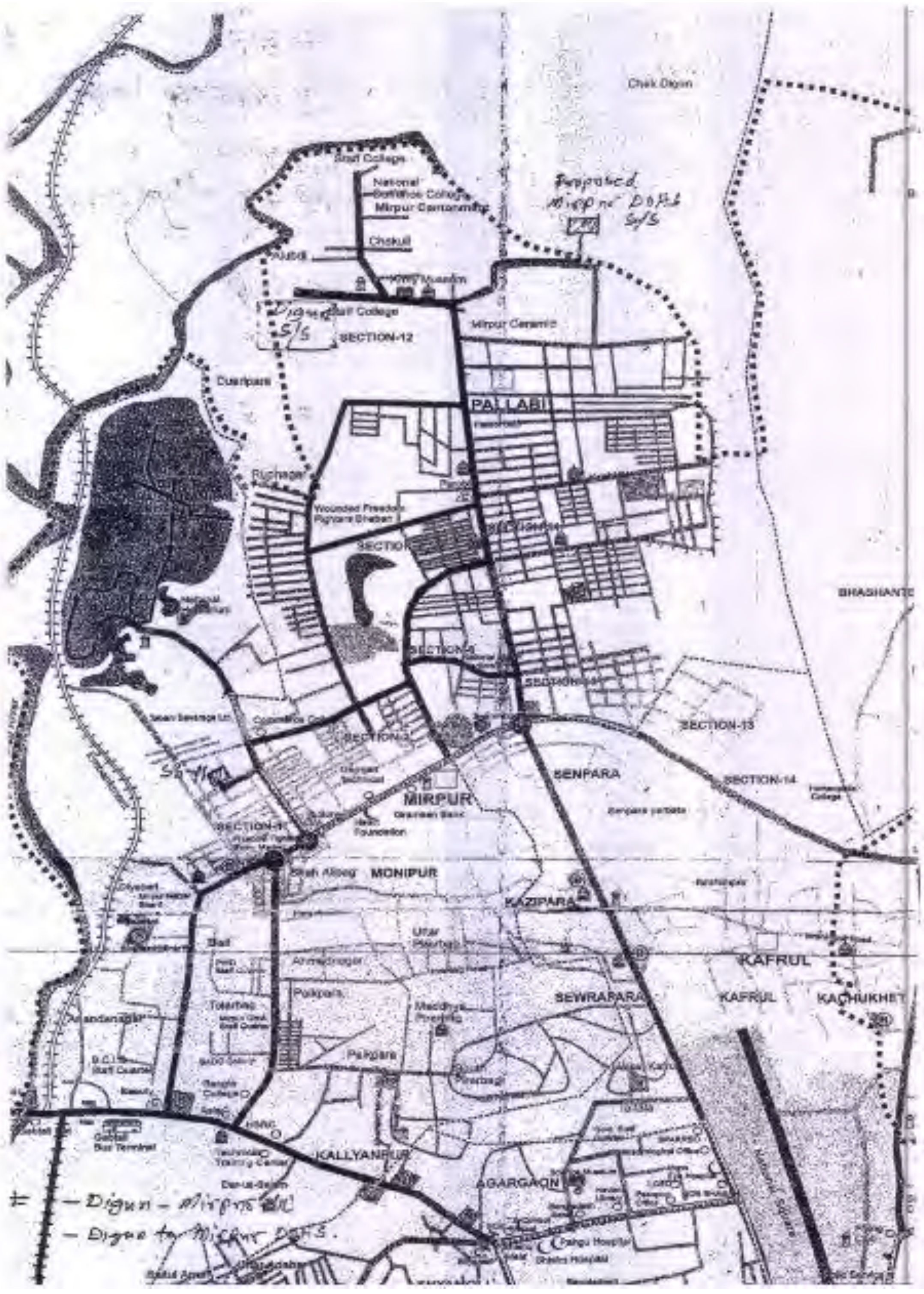
Figure C16: Finished Pavement and Section of tunnel

APPENDIX D

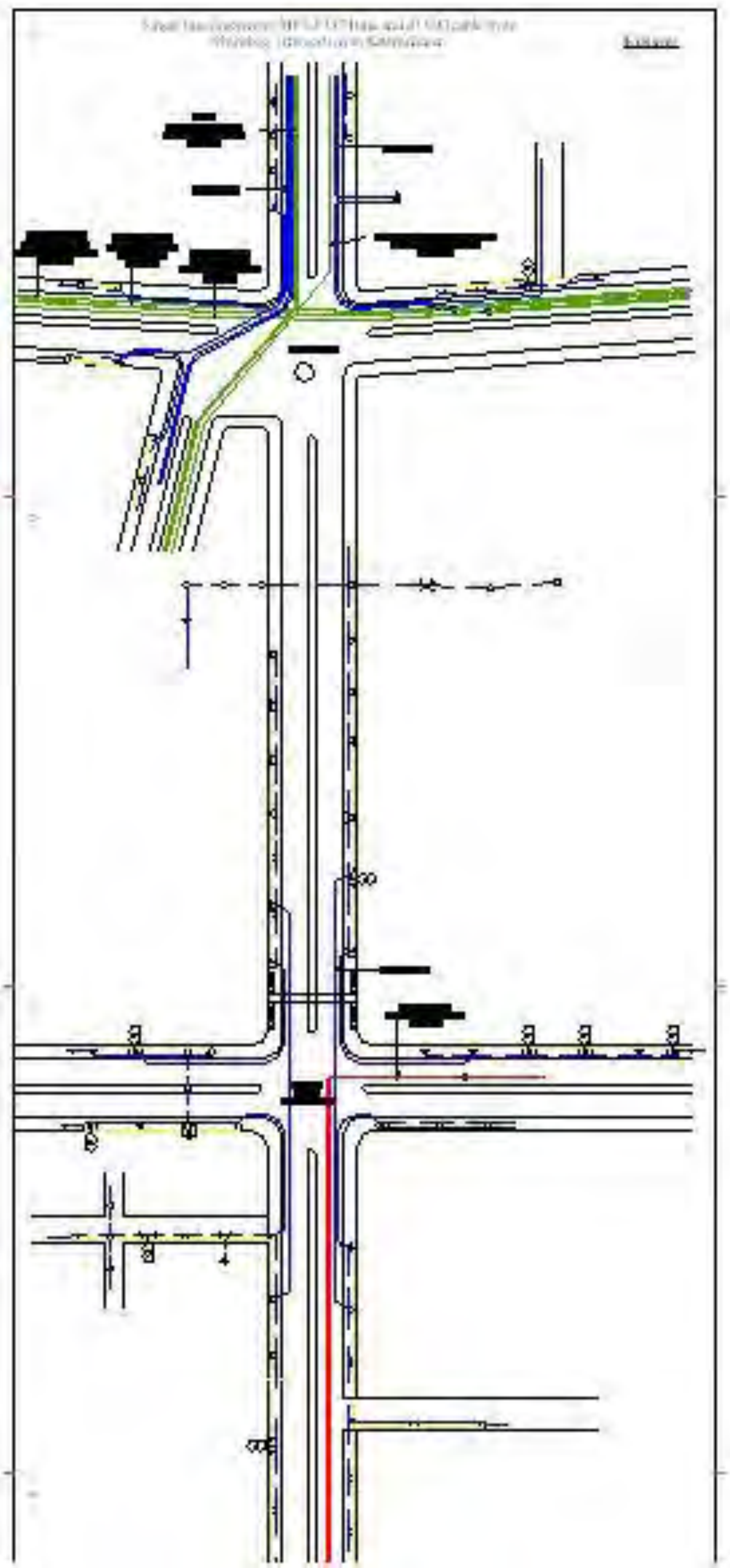
PLANS PROVIDED BY UTILITY PROVIDERS IN DHAKA



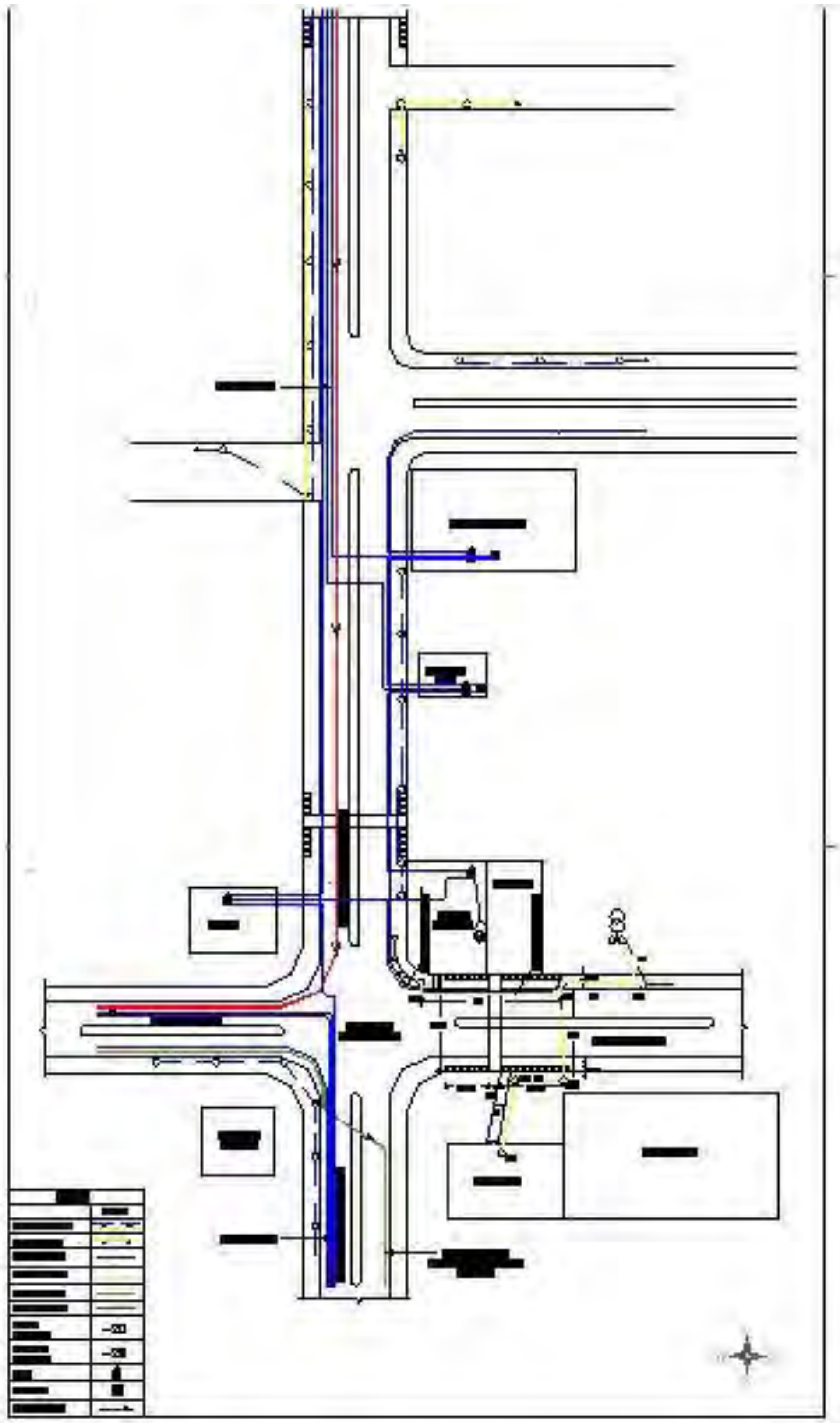
Plan D-1: DESCO Rokeya Sarani Arterials Network



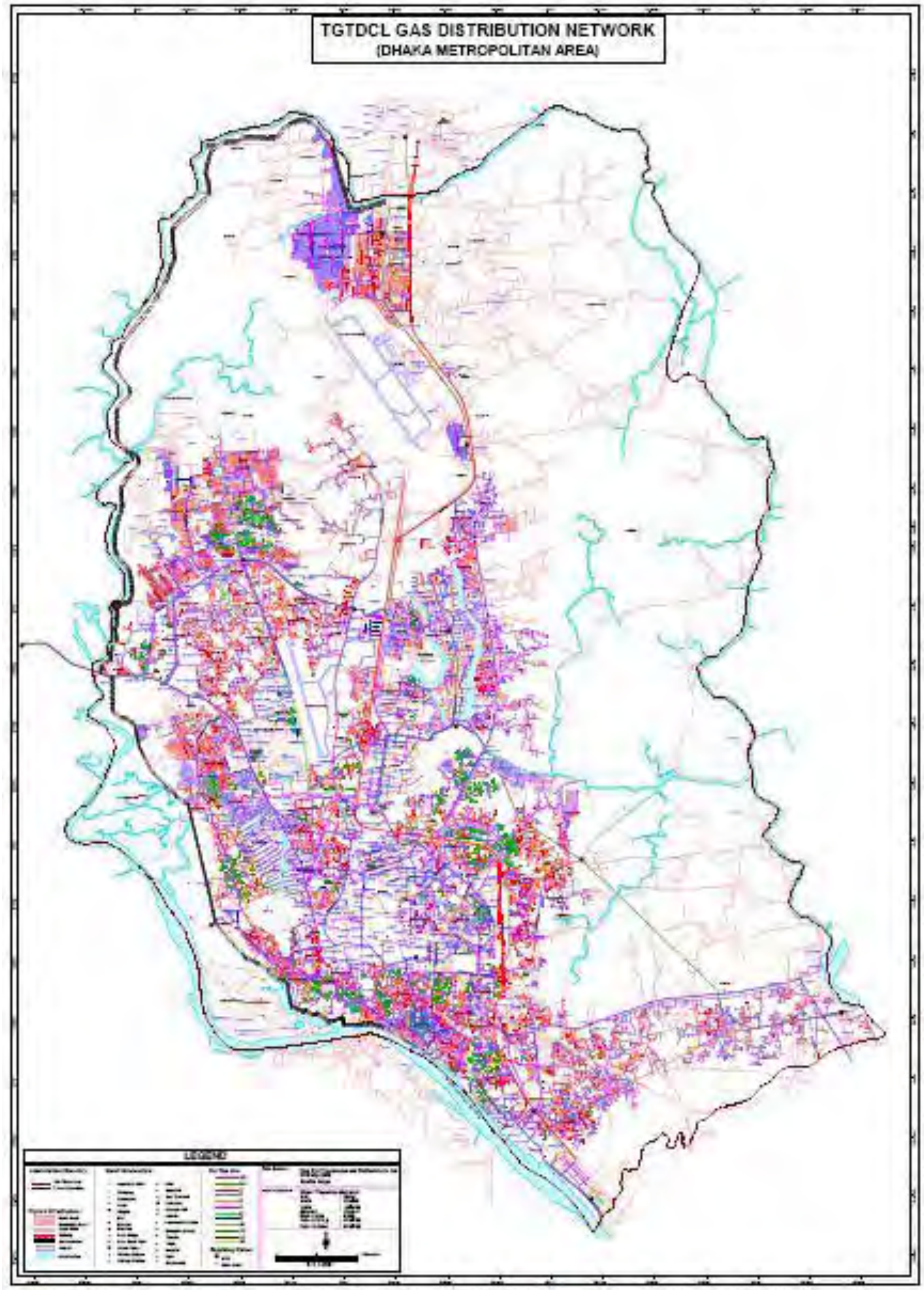
Plan D-2: DESCO Mirpur Section 10 Arterials



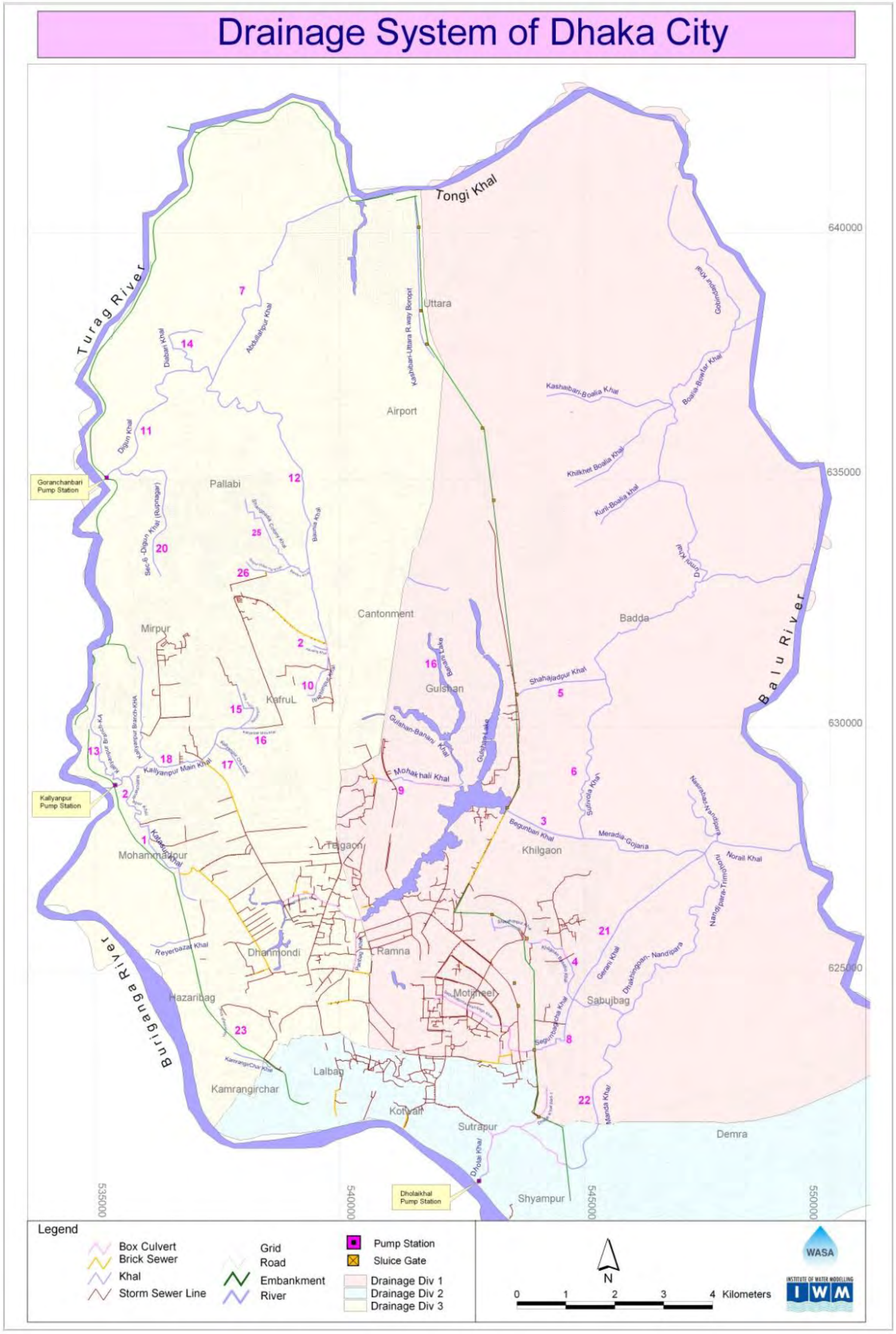
Plan D-3: DPDC Saarc Fuara Arterials



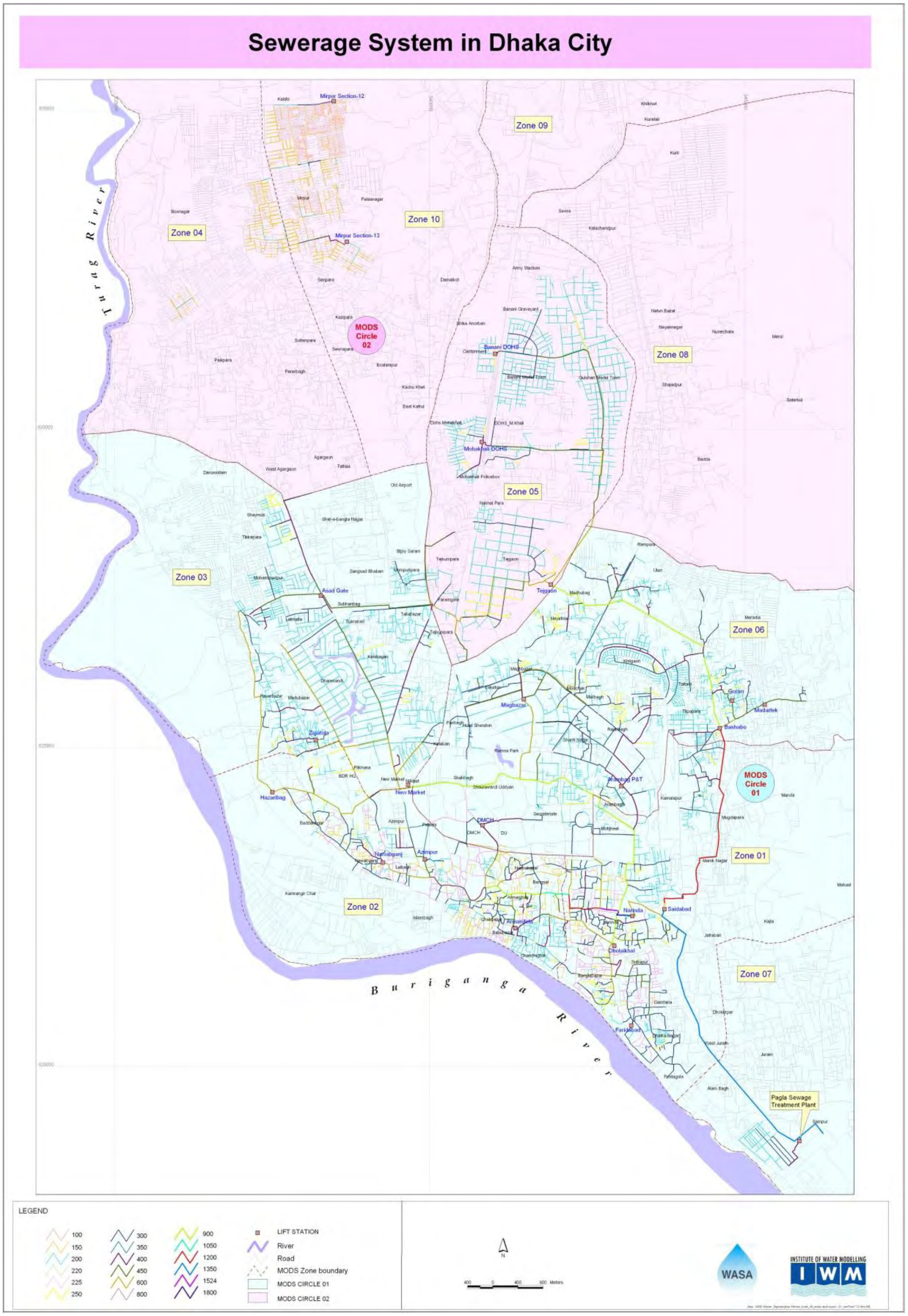
Plan D-4: DPDC Bangla Motor Intersection Arterials



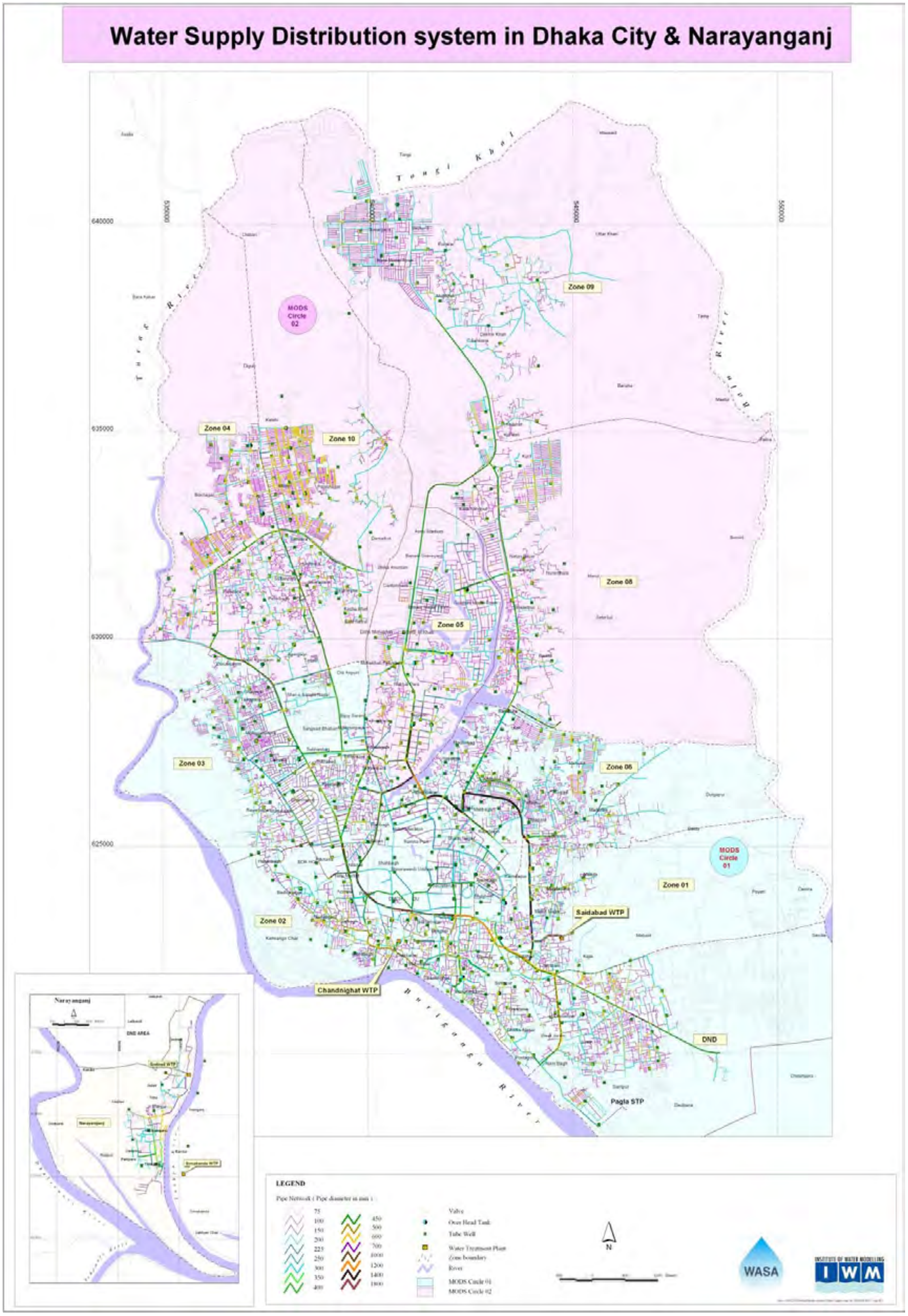
Plan D-5: Titas Arterials



Plan D-6: WASA Drainage Distribution Layout



Plan D-7: WASA Sewerage Collection Layout



Plan D-8: WASA Water Distribution Layout

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INTRODUCTION

Chapter 2

LITRATURE REVIEW

Chapter 3

METHODOLOGY

Chapter 4

DATA COLLECTION AND ANALYSIS

Chapter 5

PROPOSED METRO FOR DHAKA CITY

Chapter 6

COST ANALYSIS

Chapter 7

CONCLUSIONS AND RECOMENDAITONS