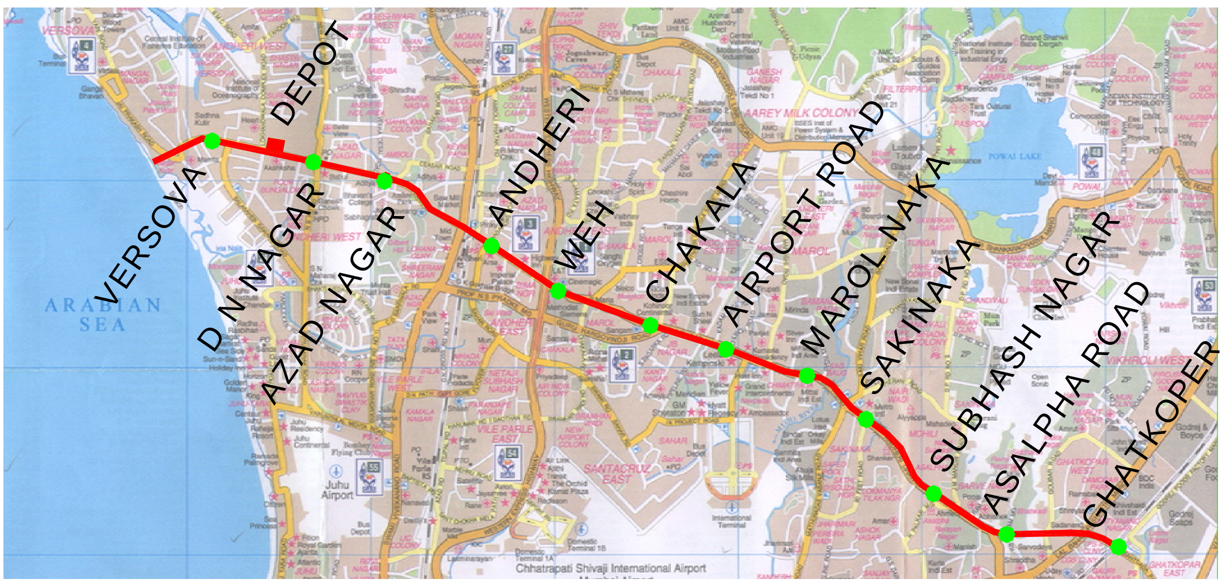
Detailed Project Report

Mumbai MRTS Project

Versova-Andheri-Ghatkopar Corridor

Client: Mumbai Metropolitan Region Development Authority



prepared by **Delhi Metro Rail Corporation Ltd.**

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SALIENT FEATURES

MUMBAI MRTS PROJECT

1. Gauge (Nominal) — 1435 mm

2. Route Length (between dead ends)

   Elevated — 11.07 Km

3. Number of stations

   Elevated — 12 Nos.

4. Traffic Forecast (Stand Alone System)

	Passenger/day (Lakh)	PHPDT
Year 2011	4.28	15,565
Year 2021	6.65	23,590
Year 2031	8.83	30,550

5. Train operation

		2011	2021	2031
a)	Designed PHPDT	14136	17670	23560
b)	Designed Train headway	3 minutes	3 minutes	3 minutes
c)	Operational Headway	5 minutes	4 minutes	3 minutes
d)	Train Composition	4 Cars	4 Cars	4 Cars
e)	Coaches required	56	64	80

6. Design speed — 80 kmph

7. Traction Power Supply

   a) Traction system voltage — 25 KV ac
   b) Current Collection — Over Head Catenary
   c) Sub Station — 2 No.

8. Rolling Stock

   a) 3.20 m wide modern rolling stock with stainless steel body.
   b) Axle load - 17 t
   c) Seating arrangement - Longitudinal
   d) Capacity of 4 coach unit - 1178 Passengers
   e) Class of accommodation - One

9. Maintenance Facilities

Maintenance Depot	**-**	**D N Nagar** **Godrej (Alternative)**

10. Signalling, Telecommunication & Train Control

a)	**Type of Signalling**		**Cab signalling and continuous automatic train control with Automatic Train Protection (ATP)**
b)	**Telecommunication**	**i)**	**Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc.**
		ii)	**Train information system, Control telephones and Centralised Clock System.**

11. Fare Collection — **Automatic Fare Collection collection system with BOM and POM, Smart card etc.**

12. Construction Methodology

Elevated viaduct consisting prestressed concrete U -shaped Girders on Single pier with pile/ Open foundations

13. Total estimated cost (at June, 2004 prices w/o taxes)	**Rs. 1488. Crores**
Inclusive of taxes	**Rs. 1670 Crores**

14. Financial Indices of MRTS Phase-I Network with this corridor

a)	**EIRR**			**21.53 %**
b)	**FIRR**			
		(i)	**Govt. Financing**	**7.56 %**
		(ii)	**PPP**	**11.06 %**

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XECUTIVE SUMMARY

0.1 INTRODUCTION

Greater Mumbai - the capital of Maharashtra, is not only the financial capital of India but the heart of commercial and trade activities of the Country as well. The Island City has experienced rapid growth in economic activity and its suburbs are growing faster than the Island City in terms of population distribution and activity location. The major challenge is in promoting growth by adequate inputs into infrastructure, which would improve quality of life of the residents. MMRDA (Mumbai Metropolitan Region Development Authority) is a nodal agency for promoting planned development in this region, which makes it automatically the nodal agency for studying and implementing transport related projects within Mumbai Metropolitan Region.

Population

The total population of Greater Mumbai in 2001 was 11.91 million (more than double of the 1971 population of 5.97 million). The population growth in the island area during 1971 ï 2001 is only 9 percent. However, the growth in suburbs (western and eastern) has been phenomenal. The suburban population has grown by almost 300 percent over the past 30 years.

Employment Scenario

As per 1998 census, the total employment in Greater Mumbai is 2.62 millions. The share of employment in Island City has fallen to 56 percent in 1991 from 72 percent in 1971. However, it has increased to 61 percent in 1998. The share of employment in western suburbs was around 25 percent of total employment in Greater Mumbai in 1998 and that of eastern suburbs was about 15 percent.

Land Use Policy

MMRDA prepared a Regional Plan for MMR for 1996 to 2011 which was approved by GOM. As per the Regional Plan, a poly-nucleated land use structure has been recommended for Mumbai Metropolitan Region (MMR). This clearly brings out MMRDAõs plan of developing alternative employment growth centres at Bandra Kurla Complex (BKC) in addition to the ones at Navi Mumbai. As per latest estimates, BKC will generate around 200,000 jobs as compared to 700,000 jobs in Navi Mumbai. In the Island City Area and the suburbs, valuable and significant land parcels have not been used since long. These areas belong to textile mills, which were shut down in the eighties. Recently, the Government of Maharashtra through MMRDA has evolved certain strategies for development of these areas and to re-develop valuable land resources.

…icles per thousand person is growing steadily, and … 2002. This clearly shows the inclination of people towards private vehicles. The trend is also influenced by the rising income level and saturation of public transport systems in Mumbai. The proportion of vehicles in island area has steadily reduced from 73 percent in 1981 to 40 percent in 2002, which is the same as the proportion of vehicles in western suburbs. The number of vehicles in eastern suburbs is only 21 percent of total vehicles in Mumbai.

Suburban Rail System

Mumbai is served by two of India's zonal railways, the Western Railway (WR) and the Central Railway (CR). The Western Railway line runs northwards from Churchgate terminus station in the Mumbai CBD parallel to the West Coast of the island towards northern and western India. Suburban operations extend for 60 kms northwards from Churchgate as far as Virar. The Central Railway runs from Chhatrapati Shivaji Terminus (CST), located on the eastern side of the CBD (approximately 1 km northeast of Churchgate) and serves a large part of Central and Eastern Mumbai. Suburban services extend from Mumbai CST as far as Kasara to the north east (120 Km) and Karjat to the south east (100 Km) . Within the Mumbai suburban system carries about 6.0 million passengers per day.

Bus Transport System

Public stage carriage bus services in the region are provided by BEST, (within BMC and up to 20 km beyond the municipal boundary), TMT in Thane and MSRTC elsewhere. With over 3,030 buses, BEST is by far the largest provider of bus services in the region. However, due to financial limitations bus replacement has been deferred in recent years. All routes within Mumbai are provided by BEST. These include radial routes to and from main centres, trunk routes linking main centres and feeder services linking to the trunk routes and to railway stations. Bus routes from Mumbai City to New Mumbai are provided by BEST and MSRTC. Routes from other points in Greater Mumbai to New Mumbai and Thane are provided by BEST, MSRTC and TMT. The dispersal of rail commuters from the main railway terminals to their final destinations in the Mumbai CBD such as Fort, Ballard Estate, Colaba or Nariman points is at present carried out primarily by the bus system. Shared taxi routes are also operated, whilst a large number of people make this final stage of their journey on foot. In the morning peak these movements involve substantial volumes running into the order of 30,000-40,000 passenger per hour from each terminus.

Road Network

The Mumbai road network has developed over many years, predominately in north-south direction radial to the CBD within the constraints of the islands. Extensive development over much of the island has led to the major traffic movements being concentrated into three main corridors; western, central and eastern. The east ï west movement is constrained by the Western and Central Railway tracks which also run for the majority of the length of the Island city.

cidents involving injury to persons reported annually in the Mumbai Metropolitan area has remained approximately constant (25000 ï 30000) over the last 30 years. The number of fatalities however has fallen by 50% since 1981 and is currently about 350 per year. As the number of vehicles in Mumbai has significantly increased, the number of accidents per vehicle kilometer has gone down. The key factors for reduction in accidents could be introduction of various traffic management measures, improved driver education and more strict police enforcement of road and traffic regulations. Lower speeds resulting from increased congestion is also a factor. However, the annual accident total of about 30000 remains high, and there is a need to ensure further reduction.

Air Pollution

In Mumbai road traffic is a major source of air pollution, which has worsened significantly in the last two decades and now poses a considerable health problem and potentially lethal hazard. Data derived from the ambient air quality monitoring by MCGB show that air pollution due to road traffic has increased by almost 400% over the last two decades. Transport (principally road traffic) now accounts for about 52% of the overall air pollution load in Greater Mumbai.

Need for Metro

Public Transport System is an efficient user of space and energy, with reduced level of air and noise pollution. As the population of the city grows, the share of public transport, road or rail-based, should increase. With Mumbai' s population crossing 12 million, the share of public transport at 88% is quite good. However, over the past decade the share has reduced from 91% to 88% and is likely to reduce further if corrective measures are not taken immediately. While upgradation of existing suburban system is underway through MUTP, it is felt that additional mass transit corridors are required to meet the expanding demand. Experience has shown that in mixed traffic conditions, comprising slow and fast moving traffic prevailing in most of our cities, road buses can optimally carry 10,000 persons per hour per direction (phpdt). Thus when on a corridor, traffic density during peak hours crosses this figure, provision of rail-based mass transport, i.e. Metro system should be considered. In any case, Metro system may become inescapable if the traffic density on a corridor reaches 20,000 phpdt.

Advantages of a Metro System

Metro systems are superior to other modes because they provide higher carrying capacity, faster, smoother and safer travel, occupy less space, are non-polluting and energy-efficient. To summarise, a Metro system:

Å Requires 1/5th energy per passenger km compared to road-based system
Å Causes no air pollution in the city
Å Causes lesser noise level

ad space if underground and only about 2 metres if elevated

ount of traffic as 7 lanes of bus traffic or 24 lanes of private motor cars (either way), if it is a medium capacity system.

Å Is more reliable, comfortable and safer than road based system

Å Reduces journey time by anything between 50% and 75% depending on road conditions.

Past Studies

A number of transportation studies were carried out in the past for Mumbai Metropolitan Region (MMR). These studies discussed travel pattern, network characteristics, and the degree of traffic saturation on the existing roads in the Study Area. The following major studies, which recommended transportation improvements in MMR, have been reviewed.

(i) **Mass Transport Study (1969):** The objective of this Study was to determine the existing conditions of available mass transportation services, future desire lines and to evolve a comprehensive, long term mass transportation plan for Greater Mumbai.

(ii) **Techno-Economic Feasibility of the 7th Rail Corridor:** Indian Railways carried out the techno-economic feasibility study of the Seventh Corridor in the year 1974. Mumbai Metropolitan region was considered as the Study Area. Detailed engineering feasibility was also carried out and the corridor alignment was fixed.

(iii) **East West Rail Corridor Study:** MMRDA got this Study done In the year 1975 for developing rail corridor connecting Bandra ï Kurla ï Mankhurd ï Panvel. The objective of this Study was to provide access to New Mumbai with a view to assisting in its development.

(iv) **Comprehensive Transport Study (CTS) for MMR:** A study was commissioned by the World Bank and MMRDA in 1993 to develop a strategy for transport development in MMR.

(v) **Mumbai Metro Study, by Mumbai Metro Planning Group:** The Study examined the feasibility of constructing and maintaining the 7th rail corridor as a heavy metro.

(vi) **MRTS Study by TEWET:** The study objective was to identify two rail based Mass Rapid Transit (MRT) Systems which are bankable, one for the CBD and one in Greater Mumbai outside the CBD, and to develop feasibility studies for the two projects.

(vii) **Sky Bus Metro Study by MMRDA:** The Konkan Railway Corporation presented to GOM(Government of Maharastra) a proposal for development of a new transport system called sky bus metro system. It envisages a system, which will be elevated and supported to central columns. The conclusion of this Study was that n has not been implemented anywhere in the world, it ...er examined on a 2 km pilot section.

0.2 EVOLUTION OF MUMBAI METRO MASTER PLAN

Transport problems of any city can be solved by integrated transport planning. While for the Mumbai city, the suburban rail system and road based transport system is being taken care of by MUIP and MUTP, the metro system proposed in the past was in a adhoc manner. Hence it was necessary to prepare a master plan for the metro system in Mumbai. The Master Plan covering entire Greater Mumbai geographical area has been prepared .

Preliminary Net Work

With a view to broadly identify the most feasible and apparently advantageous network section for possible inclusion in the final Master plan, all such possible routes were listed based on the recommendations of various studies carried out in the past. Accordingly, a primary network of about 200 km was identified.

Master plan

Based on intensive site reconnaissance surveys, alternative probable corridors were discussed with representatives of local authorities and detailed study finally a network comprising of 146.5 km was selected as Master Plan for Mumbai Metro. The Master Plan network was split in suitable corridors as under:

S. No.	Corridor	Length (Km)		
		Total	Elev.	U.G
1	Versova ï Andheri ï Ghatkopar	15.00	15.00	-
2	Coloba ï Mahim (Bandra)	18.00	8.10	9.90
	Mahim (Bandra) ï Charkop	18.00	18.00	
3	Mahim ï Kurla ï Mankhurd	12.80	10.70	2.10
4	Charkop ï Dahisar	7.50	7.50	
5	Ghatkopar ï Mulund	12.40	12.40	
6	BKC ï Kanjur Marg via Airport	19.50	11.00	8.50
7	Andheri (E) ï Dahisar (E)	18.00	18.00	
8	Hutatma Chowk ï Ghatkopar	21.80	13.30	8.50
9	Sewri ï Prabhadevi	3.50		3.50

Based on various criteria, such as ridership, availability of funds, limitation on construction and their impact on environment etc., phasing has been done for implementation of the master plan. The final approved phasing of the Master plan is as under:

		Length(Kms)			Total Cost (Rs. Cr.)
		Total	Elev.	U.G	
1	a) Versova-Andheri-Ghatkopar	63.80	51.80	12.00	8180
	b) Colaba ï Charkop				
	c) Mahim ï Mankhurd				
2	a) Ghatkopar ï Mulund	19.90	19.90	-	1990
	b) Charkop ï Dahisar				
3	a) BKC ï Airport - Kanjur Marg	62.80	42.30	20.50	9355
	b) Andheri (E) ï Dahisar (E)				
	c) Hutatma Chowk ï Ghatkopar				
	d) Sewri ï Prabhadevi				
	Total	**146.50**	**114.00**	**32.50**	**19525**

0.3 TRAFFIC STUDY

The traffic forecasting for all the corridors has been done while preparing the Master Plan for Mumbai Metro. However at present corridor is being implemented separately, the traffic forecasting has also been done for stand alone corridor with suitable assumptions. The traffic forecast for stand alone corridor has been used for train operation plan and depot design. However the station design takes care of traffic demand in case of complete phase I is commissioned.

The projected traffic demand in 2011, 2021 and 2031 is given below.

Proposed Peak Hour Link loadings on Versova- Andheri – Ghatkopar

Station	Station	2011		2021		2031	
		To Versova	To Ghatkopar	To Versova	To Ghatkopar	To Versova	To Ghatkopar
Ghatkopar	Asalpha	9755	12225	14890	17160	20485	23025
Asalpha	Subhash Nagar	10115	12390	15390	17410	15300	23485
Subhash Nagar	Saki Naka	10120	12390	15390	17410	21310	23485
Saki Naka	Marol Naka	10440	12905	16165	18225	22360	24525
Marol Naka	Airport	11860	14615	18945	21760	25385	27970
Airport	Chakala	11860	14610	18950	21755	25385	27960
Chakala	W E H	12155	15240	20050	23215	26745	30050
W E H	Andheri	12210	15565	20070	23590	26880	30550
Andheri	Azad Nagar	6480	7415	10605	11340	12710	13525
Azad Nagar	D N Nagar	2025	1670	3250	2640	4285	3350
D N Nagar	Versova	150	185	365	365	415	430

ak Hour Boarding and Alighting

	1		2021		2031	
Station Name	**Boarding**	**Alighting**	**Boarding**	**Alighting**	**Boarding**	**Alighting**
Versova	183	152	237	198	317	264
D N Nagar	1492	1874	1941	2439	2591	3256
Azad Nagar	5958	4670	7753	6081	10347	8116
Andheri Metro	9476	7059	12330	9191	16456	12267
WEH	1592	1858	2072	2419	2765	3228
Chakala	2077	2415	2703	3145	3607	4197
Airport Road	4	0	5	0	7	0
Marol Naka	1891	2191	2460	2852	3283	3807
Saki Naka	1502	2010	1954	2617	2609	3493
Subhash Nagar	4	0	5	0	7	0
Asalpha	365	168	474	219	633	292
Ghatkopar Metro	9756	12223	12694	15916	16942.4904	21243
	34298	**34618**	**44628**	**45076**	**59565**	**60163**

0.4 System Selection

A. Permanent Way

Choice of Gauge

Standard Gauge (1435mm) is invariably used for metro railways world over due to its unlimited advantages. During the last decade, 20 new metros have been constructed in various cities of the world. All these metros have gone in for Standard Gauge even though the national gauge for mainline railways in some of these countries was different from Standard Gauge. In India the national gauge is Broad Gauge (1676mm). The reasons for selection of gauge is described in the report.

Track Structure

Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus it is imperative that the track structure selected for Metro Systems should be long lasting and should require minimum or no maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. Ballastless track with long welded head hardened rails has been proposed as mainline track. In depot also ballastless track has been proposed as the same is on elevated deck. However at Godrej depot the track structure shall be ballasted similar to Indian railways track structure for depot and workshops.

Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened as per IRS-T- 12-96. As these rails are not manufactured in India at present, these are to be imported. For

rade of rails should be 880, which can be easily
usly.

Turnouts

- From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:

  i) On main lines, 1 in 9 type turnout with a lead radius of 300 metres and permissible speed on divergent track as 40 km/h .

  ii) On Depot lines, 1 in 7 type turnout with a lead radius of 140 metres and permissible speed on divergent track as 25 km/h.

- The Scissors cross-overs on Main Lines (1 in 9 type) will be with a minimum track centre of 4.5 m .

B. Traction System

Traditionally, electric traction is used in Metro systems for requirement of high acceleration and pollution-free services in urban areas. There are three standard and proven systems of electric traction for use in suburban and metro lines, viz.: - 750V dc third rail, 1500V dc overhead catenary and 25kV ac overhead catenary system. All the three systems are presently in use in India (750 V DC third rail in Kolkatta Metro, 1500V dc catenary in Mumbai suburban of Central & Western Railways and 25kV ac catenary in Delhi Metro & Indian Railways

Out of the three system mentioned above, 25kV ac traction has the economical advantages of minimal number of traction sub-stations and potential to carry large traffic (60,000-90,000 PHPDT).

Keeping in view the ultimate traffic requirements, standardisation, commonality of traction system with Western & Central Railway and other techno-economic considerations, 25kV ac Catenary traction system is considered to be the best trade-off and hence, proposed for adoption on Mumbai Metro System.

C. Signalling and Train Control

Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. These requirements of the metro are planned to be achieved by adopting a automatic signaling in the section and balise based Automatic Train Protection (ATP), State of Art automatic train supervision system.

The telecommunication system acts as the communication backbone for Signalling systems and other systems such as SCADA, AFC etc and provides telecommunication services to meet operational and administrative requirements of metro network.

The telecommunication facilities proposed are helpful in meeting the requirements for

1. Supplementing the Signalling system for efficient train operation.
2. Exchange of managerial information
3. Crisis management during emergencies
4. Passenger information system

The proposed telecom system will cater to the following requirements:

- Train Traffic Control
- Assistance to Train Traffic Control
- Maintenance Control
- Emergency Control
- Station to station dedicated communication
- Exchange Telephone
- Passenger Announcement System within the station and from Central Control to each station.
- Centralised Clock System
- Train Destination Indicator
- Instant on line Radio Communication between Central Control and Moving Cars and maintenance personnel.
- Data Channels for Signalling, SCADA, Automatic Fare Collection etc.

E. Automatic Fare Collection

Mass Rapid Transit Systems handle large number of passengers. Ticket issual and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based automatic fare collection system is proposed.

AFC system proves to be cheaper than semi-automatic (manual system) in long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines, overall less cost of

...art Card/Token) in comparison to paper tickets and ... of revenue.

Integration of AFC with Suburban/Bus System

Common Smart Card based ticketing for both Suburban and Bus systems is not proposed at this stage as this will require installation of AFC system at all suburban stations and in buses also. A Clearing House system will also be required for separation of revenue among various operators. However, the proposed system has multioperator capability and in future this will be possible to integrate various transport providers and other agencies.

F. ROLLING STOCK

Rolling stock for Mumbai Metro is similar to the one adopted for Delhi Metro. Rolling Stock has been selected based on the following criteria:

- Proven equipment with high reliability;
- Passenger safety features, including fire resistance;
- Energy efficiency;
- Light weight equipment and coach body;
- Optimised scheduled speed;
- Aesthetically pleasing Interior and Exterior;
- Low life cycle cost; and
- Flexibility to meet increase in traffic demand.

The controlling criteria are reliability, low energy consumption, light weight and high efficiency leading to lower annualized cost of service. The coach should have high rate of acceleration and deceleration.

Keeping the above features in mind, 3.2 m wide stainless steel light weight coaches are proposed for the Mumbai Metro, with length of 22.24 m for trailer coach and 22.46 m for motor coach (including couple buffers). Height of coach is 3.9 m. Train length for 4 coach train is 89.5 m while that of 6 - coach train is 134 m. The Axle load is about 17 t for which the structures are to be designed.

Traction motors are 220 KW and propulsion system is 3-phase drive with variable voltage and variable frequency (VVVF) control. Trains will have regenerative braking system to save energy cost. Current collection is through overhead catenary from 25 kV ac. Trains will be air-conditioned and provided with automatic door closing and opening system with 4 wide doors per coach on each side. The trains will have state of the art cab signalling with continuous automatic train control and automatic train protection system. The trains will have passenger information and announcement system.

Coaches have longitudinal seats with a seating capacity of 43 and 239 standees per motor coach and 50 seating and 257 standees per trailer coach thus total dense crush capacity of 282 (MC) to 307 (TC), at 6 persons/sqm.

ed shall have design speed of 90 kmph and maximum ph. Maximum acceleration and decleration is 0.8 m/s^2 ergency braking the deceleration shall be 1.3 m/s^2.

0.5 Civil Engineering

Geometric Design Norms

The design parameters related to the Metro system described herewith have been worked out based on a detailed evaluation, experience and internationally accepted practices. Various alternatives were considered for most of these parameters but the best-suited ones have been adopted for the system as a whole. The design parameters as suggested in the earlier studies for Andheri - Ghatkopar section have also been modified so as the same parameters are applicable for all metro corridors in Mumbai.

Horizontal curves are provided with mimimum radius of curve as 100 m which will have permissible speed of 40 kmph. All the curves are transistioned for comfort and safety. Vertical curves are provided at each change of gradient with a radius of 2500 m except in certain cases the radius is kept as 1500 m.

The viaducts carrying the tracks will have a vertical clearance of minimum 5.5 m above road level. For meeting this requirement with the ‘U’ shaped pre-stressed concrete girders, the rail level will be about 8.5 m above the road level. However, at stations which are located above central median, the rail level will be 12 m above road level. These levels will, however, vary marginally depending upon where the stations are located.

Gradients

Normally the stations shall be on level stretch. In limiting cases station may be on a grade of 0.1 %. Between stations, generally the grades may not be steeper than 2.0 %. However, Where existing road gradients are steeper than 2 %, gradients upto 4% (compensated) can be provided in short stretches on the main line.

Design Speed

The maximum sectional speed will be 80 km/h. However, the applied cant, and length of transition will be decided in relation to normal speeds at various locations, as determined by simulation studies (to be done at detailed design stage) of alignment, vertical profile and station locations.

Description of Alignment

Project Area

The project area has two distinct sections viz.Versova-Andheri (western segment) and Andheri-Ghatkopar (Eastern segment). Versova is the old fishermen village located in the west cost. The Versova-Andheri area has developed in the last 20 years and has mixed land use predominantly residential and education institutions .Whereas, Andheri-Ghatkopar (upto

...er development, Andheri is the most important sub ...ern Railway and Ghatkopar is the most important ...way. This area serves the Marol industrial area of MIDC, Sahar International airport and nearby developing office/commercial complexes. The section Saki Naka to Ghatkopar is mainly residential and do not have proper road access.

Alignment

The corridor is proposed as elevated system and will traverse through the center of the existing arterial roads of Jai Prakash Road and Mathuradas Vasanji Road (Andheri-Kurla Road). A small length of the road near Asalpha is not existing but is taken up for development by MMRDA as a part of MUIP. The total length of the corridor is 11.07km. A maintenance depot will be located on Jai Prakash Road near D.N. Nagar in about 12.25 Hectares of, land which is almost vacant. The key alignment is shown in **index plan** and **index section.**

It is suggested that the longitudinal section of the proposed DP road in Asalpha area be reviewd so as to reduce the pier height of the Metro Alignment in Asalpha and Golibar road – Ghatkopar stretch.

It was indicated by MMRDA, that road widening /construction activity will be taken up prior to Metro construction and the roads with their full ROW will be available for Metro construction and existin median shall remain median of widened road. Hence, the alignment planning, station planning, assessment of land requirement for the Metro system and other associated facilities etc. have been done accordingly.

Viaduct Structure

The proposed viaduct structure for the Mumbai Metro is a 'U' shape deck carrying two tracks on single pier located on the median of the road. The width of the deck is 9.1 m and the pier will be 1.45 m to1.6 m diameter. A road clearance of 5.5 m is ensured below the viaduct structure. The foundation shall be pile foundation at most of the locations though pile foundation socketed in rock or open foundations may be necessary at certain isolated locations. The superstructure shall be pre-cast segmental construction which will cause minimal inconvenience to the road users.

Station Locations & Planning

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport. However effort has also been made to propose station locations, such that inter station distances are as uniform as possible. The average spacing of stations is kept close to one km.

ATIONS (VERSOVA - GHATKOPER)			
		CHAINAGE	**INT.-DIST(M)**
	DEAD END	**W 3733.66**	**-**
1	**VERSOVA**	**W 3139.6**	**-**
2	**D N NAGAR**	**W 2139.24**	**1000.36**
3	**AZAD NAGAR**	**W 1344**	**795.24**
4	**ANDHERI**	**0**	**1344**
5	**WEH**	**E 995.9**	**995.9**
6	**CHAKALA**	**E 2279.09**	**1283.19**
7	**AIR PORT ROAD**	**E 3014.28**	**735.19**
8	**MAROL NAKA**	**E 3660.12**	**645.84**
9	**SAKINAKA**	**E 4696.02**	**1035.9**
10	**SUBHASH NAGAR**	**E 6046.49**	**1350.47**
11	**ASALPHA ROAD**	**E 6788.51**	**742.02**
12	**GHATKOPER**	**E 7786.31**	**997.8**
	DEAD END	**E 8253.33**	**-**
	AVG.INT.STN DITANCE		**993.26**

Twelve stations are planned on the Versova- Andheri ï Ghatkopar corridor. All the stations on the corridor are elevated. Stations are located on the middle of the road and designed with elevated concourse with access from both sides of the road.

All the elevated stations are provided with side platforms. This has been planned to avoid reverse curves on approach of the stations. This arrangement also provides the flexibility of constructing viaduct through the stations and constructing the stations enveloping the viaduct or combined structural arrangement for stations including the track carrying structure.

An interchange station with the North - South corridor is planned at D.N.Nagar. The second corridor `Colaba- Bandra- Charkopô(North ï South) flies over the first corridor as double elevated. The station has a common concourse at ground level. A link line between the two corridors through depot is also provided near this station for transfer of rakes for operational purpose only.

Stations have been divided into two distinct areas, namely public and non-public (technical areas). The public area is further sub divided into unpaid and paid area. Provision for escalators are made at all stations in paid area for future. However at a few important stations escalators shall be provided from the beginning itself. Lifts for disabled passengers are provided at all stations.

Traffic integration facilities are provided at following locations:-

- Andheri Metro Station with Andheri Suburban Railway Station.
- Ghatkopr Metro Station with Ghatkopar Suburban Railway Station

rsova Bus Depot.

In addition facilities are also proposed for integration with city buses at importanat stations.

Geo Technical Investigation

Geotechnical investigations were carried out along both the corridors upto a depth of 30 m in soil, 10 m in soft rock and 5 m in hard rock. Soil and rock samples were collected and tested in laboratory.

The sub-soil strata at proposed site comprises of various types of layers such as, Silty Sand, Sandy Clay, Silty Sandy Clay with gravel , Slightly weathered to fresh BRECCIA/ SHALE/ LIMESTONE, Highly to moderately weathered SANDSTONE/ BRECCIA/ BASALT Completely weathered rock.

For the elevated section pile foundation with 1.2m dia piles socketed in rock is recommended. The bearing capacity of soil is not likely to cause any problem for the foundations.

Utilities

The proposed Metro alignment is passing along major arterial roads of the city road network, which are serving Institutional, commercial and residential areas. A large number of surface and sub-surface utility services viz. sewers, water mains, storm water drains, telephone cables, electric poles, traffic signals etc. are existing along the proposed alignment. Details of the existing utility services along the proposed alignment have been collected from the concerned authorities, i.e. Municipal Corporation of Greater Mumbai(MCGM), Public Works Deptt. (PWD), Irrigation and Flood Department, MCGM, BEST (Bombay Electric Supply & Transportation), Mumbai Traffic Police, BSES(Bombay Sub-urb Electric Supply)/Reliance Energy, TATA Power, Mahanagar Gas Ltd., MMRDA & MAHADA, TATA Tele Services, Reliance Info. Ltd, Western & Central Railway etc. The affected portions of the services with reference to the proposed alignment were identified and temporary diversion & relocation proposals of the affected services have been indicated.

Land Requirement

Since land is a scarce commodity especially in metropolitan areas, every effort has been made to keep land requirement to the barest minimum and acquisition of private property is minimal. Land is mainly required for Depot and route alignment on sharp bends, station buildings, platforms, entry/exit structures, traffic integration, power sub-stations, administrative buildings and temporary construction depots / work sites etc.

Land requirement on the Versova- Andheri ï Ghatkopar corridor is about 12.64 hectares out which 0.031 hectares belongs to government while balance 12.61 hectare is private land.

ative site located at Godrej area (Exhibition Ground), is required for all facilities including Test Track.

0.6 MAINTENANCE DEPOTS

On the Versova- Andheri ï Ghatkopar corridor a maintenance depot along with minmum repairing facilities has been proposed at D.N.Nagar. The depot is partly elevated due to site constraints. A transfer link between this corridor and the North- South corridor (Colaba- Bandra- Charkop) has also been proposed from this depot. The area of the Depot being planned on the corridor is about 12.25 Hectares. The site has a road approach from the J.P Road. A washing plant is also proposed here.

Alternatively depot at Godrej land (exhibition ground) is also suitable though it requires a link line of 1.625 km. for approach. It is suggested that the land be reserved for future use as depot with full net work of Mumbai Metro.

Holding capacity of the Depot has been planned to be 45 rakes of 6 coach each for inspection purposes. Daily tests and checks shall be done at stabling sidings. 7 day, 15 day and 45 day inspection shall be done inside the Inspection Shed. The facilities shall be provided in phases and augmented as the train frequency and formation increases due to growth in traffic. Overhauling of the rakes is not planned at this depot.

0.7 Train Operation Plan

Any public transport system, particularly a Metro system, is made attractive by providing high frequency service both during peak and off-peak hours. For this purpose short trains (4 coach consist) are proposed initially at 5 minutes frequency during peak periods. The frequency can be brought down to 3 minutes in future depending upon the demand.

Salient features of the proposed train operation plan are:

- ♦ Running of services for about 19 hours of the day (4.30 AM to midnight) with a station dwell time of 30 seconds.
- ♦ Make up time of 5-10%, with 8-12% coasting.
- ♦ Average speed of 32 kmph.

Each 4-coach train will consist of two motor cars(MC) and two Driving Trailer Cars (TC), (DTC-MC-MC-DTC). while 6 coach train will consist of two Motor Cars(MC) , two Driving Trailer Cars (DTC) and two Trailer Cars(TC). The capacity of each coach and trains is given below:

DTC : 282 passengers, MC and TC : 307 passengers

4-Car Train : 1178 passengers , 6 Car Train : 1792 passengers headway and train composition) for the year 2011, he peak hours is given below.

- **Year 2011**
  The operation on Varsova ï Andheri - Ghatkopar Corridor is planned with **4-car trains at 5 minutes headway** in the first year of operation with Peak Hour Peak Direction Capacity of **14136** . The capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on few inter station section, but will avoid excessive under loading on most of the sections.

- **Year 2021**
  The operation on - Varsova ï Andheri - Ghatkopar Corridor is planned with **4-car trains at 4 minutes** headway for the year of operation i.e. **2021** to meet the Peak Hour Peak Direction demand of **23590** . The capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on three inter station sections, but will avoid excessive under loading on most of the sections.

- **Year 2031**
  The operation on Line 1- Varsova ï Andheri - Ghatkopar Corridor is planned with **4 - car trains at 3 minutes** headway for the year of operation i.e. **2031** to meet the Peak Hour Peak Direction Demand of **30547** . The normal capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on some inter station sections, but will avoid excessive under loading on most of the balance sections.

  Details of capacity provided is summarised below:

Versova – Andheri – Ghatkopar Corridor

Year	**2011**	**2021**	**2031**
Cars/trains	**4**	**4**	**4**
Head way (Minutes)	**5**	**4**	**3**
PHPDT Demand	**15565**	**23590**	**30550**
PHPDT Capacity Available	**14136**	**17670**	**23560**

6 car trains can be introduced in case demand picks up, particularly if the other corridors are commissioned.

No. of Coaches required
The of coaches required in the year 2011, 2021, 2031 are also given below. These includes operation and maintenance reserve.

	2011	**2021**	**2031**
Total	56	64	80

Power supply is required for operation of Metro system ï for running trains, for station services, workshops, depots & other maintenance infrastructure. Broad estimation of auxiliary and traction power demand is made based on the following requirements: -

(i) Specific energy consumption of rolling stock ï 70KWh/1000 GTKM
(ii) Regeneration by rolling stock ï 30%
(iii) Elevated/at ï grade station load ï initially 250KW, which will increase to 350 KW in the year 2031
(iv) Depot auxiliary load - initially 2000KW, which will increase to 2500 KW in the year 2031.

Power requirements have been assessed for the year 2011, 2021 and 2031, which are briefly summarized below:-

Power Demand Estimation (MVA)

Corridor	**Use**	**2011**	**2021**	
Versova – Andheri-Ghatkopar Corridor	Traction	7	9	
	Auxiliary	6	8	
	Total	**13**	**17**	

Keeping in view the reliability requirements, two 33/25kV Receiving Sub-stations (one as stand by) are proposed to be set up (one at depot and other at Marol Naka). This is an economical solution without compromising reliability. Based on the discussions with Reliance Energy Ltd., it is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations at 33kV voltage through cable feeders as indicated below.

Sources of Power Supply

No	**Corridor**	**Grid sub-station of Reliance Energy Ltd. (Input voltage)**	**Location of RSS of Metro Authority**	**Approx. length of 33kV cables**
1.	Versova - Ghatkopar section	Versova Receiving sub-station (220/33kV)	Depot	1km. (Double circuit)
2.		Arrey Receiving sub-station (220/33kV)	Marol Naka	3km. (Double circuit)

Further transmission of electric power will be done through 33kV cables, which will be laid along the alignment on viaduct for catering to traction and auxiliary power requirements.

s (33/0.415kV):- Auxiliary sub-stations (ASS) are to ation. A separate ASS is required at depot. The ASS anine or platform level inside a room. The auxiliary load requirements have been assessed at 350 kW for elevated stations. Accordingly, two dry type cast resin transformers (33/0.415kV) of 400 kVA capacity are proposed to be installed at the stations (one transformer as standby). Depot ASS will also be provided with 2x2000 kVA auxiliary transformers.

Supervisory Control and Data Acquisition (SCADA) system:-
The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system.

Standby Diesel Generator (DG) sets:- In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide a standby DG set of 100 KVA capacity at the stations to cater to the following essential services:

(i) Essential lighting
(ii) Signaling & telecommunications
(iii) Fire fighting system
(iv) Lift operation
(v) Fare collection system

Silent type DG sets with low noise levels are proposed.

Energy Saving Measures
Energy charges of any metro system constitute a substantial portion of its operation & maintenance (O & M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement during initial years of operation. Subsequently, traction power consumption increases with increase in train frequency/composition in order to cater more traffic.
Following Energy saving measures are recommended:

- Light weight, modern rolling stock with 3 phase VVVF drive
- Regenerative Braking
- Use of natural light at stations and sectioning of load
- Machine room less lifts
- Energy efficient, auto sensor escalators
- Energy efficient equipments
- SCADA for energy control

Electric Power Tariff
The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25-35% of

...st. Therefore, it is the key element for the financial ... The annual energy consumption is assessed to be ... in initial years (2011), which will double by horizon year 2031. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff be kept at a minimum in order to contain the O& M costs. Therefore, the power tariff for Mumbai Metro should be at effective rate of purchase price (at 33kV voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. This is expected to be in the range of Rs. 2.50-2.75 per unit. It is proposed that Government of Maharashtra takes necessary steps to fix power tariff for Mumbai Metro at ―No Profit No Loss‖ basis. However financial analysis has been done with tariff as Rs.2.75 per unit and Rs.4.50 per unit (present day tarriff)

0.9 Environmental Impact Assessment

A detailed Environmental Impact Assessment Study has been carried out along the proposed alignment. As a part of this Study, comprehensive environmental baseline data was collected. Both positive and negative impacts of the project were assessed in detail. An important environmental consideration of this project is that neither any forest area nor any plants / trees of endangered species exist along the proposed alignment, though few Jhuggi clusters / unauthorised constructions and residential / commercial properties are affected. To minimise the negative environmental impacts, a comprehensive Environment Management Plan needs to be drawn up based on the recommendations of the environment report, both for construction and operational phases, outlining necessary remedial measures.

0.10 COST ESTIMATES

Preliminary Cost Estimates for the corridor has been prepared at June‘2004 prices.The estimated cost at June‘2004 prices is Rs.1488 crores without taxes but including land cost. The cost including taxes and duties is Rs. 1670 Crores. The completion cost with project completion in the year 2010 is Rs 1936 crores including escalation, but excluding IDC.

ABSTRACT CAPITAL COST ESTIMATES (costs at June, 2004 price level)

S. No.	Description	Amount (Rs. in crores)
1.	**Land**	**304.65**
2.	**Civil Engineering Works**	
2.1	Alignment and Formation	
2.1.1	Elevated	243.54
2.1.2	Utilities (Civil Works) including Road Restoration	33.21
2.1.3	Rehabilitation & Resettlement	7.00
2.1.4	Station Buildings (elevated)	127.00
2.2	Permanent Way	54.80
	Sub-total (1 & 2)	**777.2**
3.	**Electrical Works**	
3.1	**Traction & Power Supply including Lifts, Escalators, etc.**	**116.38**

		Amount (Rs. in crores)
	Sub-total (Item 3)	**116.38**
4.	**Signaling & Telecommunications Works**	
4.1	Signalling & Telecommunication including Cable Diversions	127.31
4.2	AFC Installations at Stations	30.00
	Sub-total (Item 4)	**157.31**
5.	**Depot Elevated**	**130.00**
6.	**Rolling Stock (in 2011)**	**238.00**
7.	**General Charges @ 3% on all items except 1**	**33.21**
8.	**Contingency (3% on all items from 1 to 7)**	**43.35**
	Grand Total:	**1488.45**
	Say Rs. 1488 crores	

The overall capital cost estimates with Duties and Taxes is given below: the cost details of Airport Link is also shown:

			Taxes and duties					
		Total cost without Taxes & duties	**custom duty**	**works tax**	**excise duty**	**sale tax**	**total**	**Total cost with tax & Duties**
	Overall Capital cost excluding Aiport link	**1488.46**	**80.20**	**31.74**	**48.78**	**20.93**	**181.66**	**1670.12**
	Aiport link	**88.88**	**7.23**	**1.11**	**3.01**	**1.49**	**12.84**	**101.72**
Overall capital cost excluding Airport link								**Rs. 1670 cr**
***Overall capital cost including Airport link**								**Rs.1772 cr.**

- The consultants have recommended not to include the Airport port link connection, as there is no improvement in the revenues due to itõs addition. In fact, it would be resulting in capacity reduction on Versova ï Andheri ï Ghatkopar corridor and would increase the operation cost. However, the study review committee recommended that the Airport link to be provided. Therefore, the cost estimates have been shown separately.

0.11 ECONOMIC ANALYSIS

Economic

The proposed system will provide a variety of benefits to the city and society, viz. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. Economic analysis has been carried out for the proposed Metro network by comparing **"with"** and **"without"** project scenario. The **'with'** project scenario takes into account, estimated total costs that the local economy would be called upon to bear. The **'without'** project scenario envisages a situation wherein the existing infrastructure continues to be utilized taking into account increased estimated costs due to higher projected traffic.

s a result of project implementation are

- savings in vehicle operating cost
- reduction in congestion
- saving in passenger travel time
- reduced pollution and fuel consumption.

The cost and benefit streams arising under the above situations have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices.

The Economic Internal Rate of Return **(EIRR)** has been worked out using Discounted Cash Flow technique to the net benefit stream at economic prices and its value is estimated as **21.53 % .** This falls to 20.00 and 21.04 respectively in case of increase in cost by 10% or decrease in traffic materialization by 10% respectively.

0.12 FINANCIAL ANALYSIS

Costs

The project cost at June 2004 prices is Rs. 1488 crore including the land cost of 305 crores. The completion cost including the escalation is Rs. 1720 crore. Year wise investment plan is given below. The expenditure spills over to 2009-10 and 2010-11 though the commissioning of the corridor is planned in 2009 end.

Year –wise Investment

Figs in Rs. Cr.

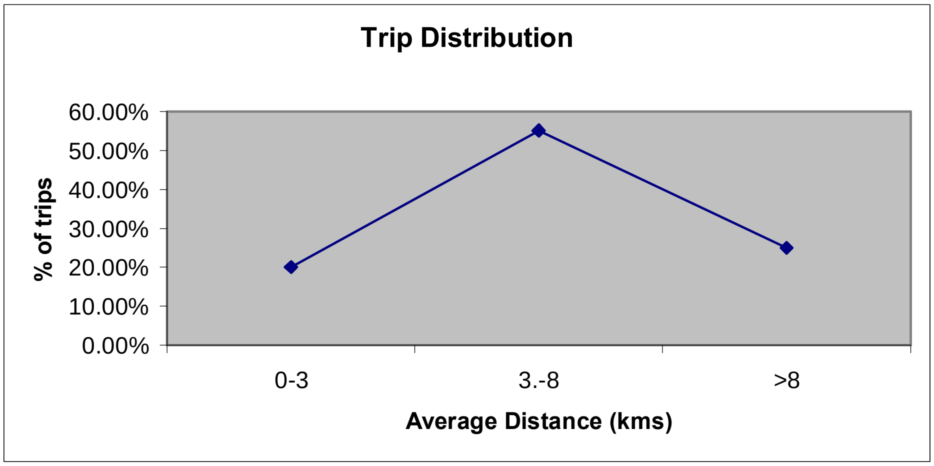
Year	Construction Cost (Fixed)	Land Cost	Completion Cost
2006-07	59	152.50	217
2007-08	414	152.50	628
2008-09	473		571
2009-10	177		225
2010-11	59		79
Total	1183	305	1720

The total O&M cost in the year 2009 is expected to be Rs. 75.39 crores. For the purpose of financial analysis the depreciation cost (3% on project cost excluding land cost) and the replacement cost (20 year life for signalling equipments and 30 years for traction and rolling stock) has been taken into account in addition to the capital cost in the year 2024 and 2034 for additional rolling stock.

The trip generation and trip distribution for various years for the stand alone system is as follows

Year	Trips per day @ 60% of full network traffic
2009	3.91
2011	4.28 (50%)
2021	6.65
2031	8.83

Trip Distribution



The fare structure has been estimated @ 1.5 times of the ordinary bus fare prevalent in the year 2009. The bus fares for the year 2009 have been obtained by escalating the existing BEST fares by an overall factor of 10%. These fares have been escalated once every two years @ 5% per annum. The proposed fare structure in the year of commissioning is given below:

Fare Structure in 2009 (in Rs.)

Distance in kms	Bus Fare - 2004	Bus Fare - 2009	1.5 times bus fare	Metro fare - 2009
0-3	3	3.3	4.95	5
3.-8	5	5.5	8.25	8
> 8	7.5	8.25	12.38	12

roperty Development and advertisement have been ıe fare box revenues. Apart from development of tions and depot it is possible to raise resources through leasing of parking rights at stations, advertisement on trains and tickets, advertisements within stations and parking lots, advertisements on viaducts, columns and other metro structures, co-branding rights to corporates, film shootings and special events on metro premises.

Financial Internal Rate of Return (FIRR)

The Financial Internal Rate of Return (FIRR) obtained with the above revenues and costs is 7.56 % over a horizon period of 30 years of operation (2009-2039). The various sensitivities with regard increase/decrease in capital costs, O&M costs and revenues are as shown below:

FIRR Sensitivity

	CAPITAL COSTS			
	20% Increase	**10% Increase**	**10% decrease**	**5% Decrease**
FIRR	6.02%	6.77%	8.43%	7.99%
	REVENUES			
	5% Increase	**10% Increase**	**10% Decrease**	**20% Decrease**
FIRR	8.33%	9.04%	5.73%	3.12%
	O&M COSTS			
	10% Increase	**10% Decrease**		
FIRR	6.75%	8.31%		

Financing Options

A wide variety of models can be theoretically considered for financing of metros ranging from completely government owned to totally privatised. There are certain benefits and drawbacks of both. Whereas completely government owned lack transparency and are shackled by bureaucracy the completely privately owned ones would not serve the social sector but be lured by the objective of profit maximisation. The social purpose of such projects can never be ignored, however, at the same time it is of utmost importance to run these systems with efficiency comparable to the private sector. These purposes can be served by creating an SPV independent of the bureaucratic controls and vested with sufficient powers to run the system independently or be evolving some form of Public ï Private partnership which would bring together the strengths of both the public and private sectors. The Delhi metro model is the SPV model which has been able to construct and run the system efficiently without compromising the social objective.

nvolves the formation of a special purpose vehicle ent and also to operate the project. There is a possibility/potential of involving some private sector entity as equity holder. The financial structure of the project can then be determined in such a way that a part of the capital cost is contributed as equity and the remaining is borrowed as senior or subordinate debt from the government, financial institutions, banks or bilateral / multilateral funding agencies. Another source of funding which has been extensively used in Hong Kong is funds from real estate development for financing capital expenditure. In this case upfront contribution required from the equity holders is much less than the project cost. The debt and the interest there on are repaid by the SPV from its net revenue streams. Long time debt is normally possible only when government guarantees are made available for repayment of loan as well as for the interest charges there on. Because of the need for high volume of debts, the project viability depends to a large extent on the rate of interest and the tenure of the debt. The SPV, being a corporate body, has flexibility in implementation and operation of the project. It can be responsive to customer requirement and can attempt various ways of revenue augmentation. SPV being a corporate body is liable to pay corporate tax and other taxes if applicable. The above model can be further improved upon if after construction the SPV hands over the operations and maintenance of the same to a private body.

PUBLIC-PRIVATE PARTNERSHIPS

The various forms Public-private partnerships can take are *Supply and service contracts, Management contracts, Leases*, *Concessions, Joint ventures and Divestiture.* Supply and service contracts and management contracts are in the nature of contracts awarded to a private party as out sourced jobs or management of the operations. Concessions not only give the private operator the responsibility of O&M of utility asset but also for investment. The ownership remains with the government but full use rights vest with the operator. Concessions are a form of lease in which the contractor agrees to make certain fixed investments and retains the use of the assets for a longer contract period. In this approach, the state (or municipality or other public entity) delegates the right to provide a service to the private sector and yet retains some control over the sector by incorporating a concession contract or license defining the terms and conditions (including the rights and obligations of the service provider) that will govern the infrastructure project or company. This type of arrangement is most suited to sectors with monopolistic characteristics. This may take the form of lease and operate (or affermage) contract, under which the private contractor is responsible at his own risk for providing the service, including operation and maintenance of the infrastructure against payment of a lease fee. The other forms of concession could be BOOT/BOT/BOO. These are used generally for Greenfield projects. The concessionare in such projects is also responsible for building and financing new investments. At the end of the concession term the sector assets are returned to the state. BOO (build own operate) is a similar scheme but it does not involve transfer of assets.

ncession stipulate transferring of the right and the n infrastructure service to a private company. This sponsibility for the operations and at least for a part of the commercial risk of service provision. The concessionaire is, by and large, held responsible for achieving specified results in service delivery and is given some freedom to choose the means for meeting those targets.

The success of this type of contracts depends on their duration which reflects the number of years the investors need to recoup their investment. In the French style concessions (affermage) the assets return to the state at the end of the period free of charge or for a nominal amount. The public authority remains responsible for financing most investments; hence, affermage are shorter (10-15 years) than Greenfield BOTs or concessions requiring major upfront capital expenditures. In the latter cases these can exceed 30 years.

The concessionaire approach has not been adopted in the rail based urban transit system in India because the project construction costs are very high. This naturally involves requirement of huge amount of debt to be raised from the market sources to undertake such a project. The highway sector has been quite successful in the country in developing Highway projects through the BOT .Power sector has a very limited experience of project development under BOO route.
It is important to understand that project beyond the size of Rs 300 cr have not been successful in attracting debt in the Indian market. Recent experience of road sector suggests that projects in the size of Rs 50 to Rs 200 cr could only be developed under BOT mechanism, with majority of projects in the lower end category. The success of these projects was solely dependent on the assurance of traffic or revenue. These projects were based on a clearly defined risk mitigation mechanism.

There is no available history to justify the development of mega transport projects under BOT route in India except in the case of Konkan Railway Corporation. KRCL was the first effort by the Indian Railways in the form of a corporate enterprise for the construction of a railway track. The finances for KRCL came from the promoters ï the Ministry of Railways and the State governments of Goa, Maharashtra, Karnataka and Kerala- and the issue of tax-free bonds. The funds could be secured at an average cost of 11%. This emerges from the inability of the major debt market players to provide resources for large projects. The other, and the most important factor responsible for the inability of raise resources from the market is the inability of project developer to come out with a risk mitigation mechanism acceptable to the lenders.

The project costs are excluding taxes and duties which presumes that exemption from payment of taxes and duties would be available to the project.

In case if PPP route is adopted for implementation, the land would be made available to the concessionaire and the government would invest 26% of the t is also presumed that the additional capital required 2034 would be shared in the same proportion as the reover, the replacement of the rolling stock would not be to the concessionaireõs account. However, the return on (Pre Tax) equity with a debt-equity ratio of 1.5:1 would be 7.81% and with debt : equity ratio of 2:1would be 7.62. The rate of interest for the debt is assumed as 11% p.a.

In this option Mumbai Metro Rail Corporationõs (MMRC) role would be limited to that of a regulatory authority. Thus MMRC would monitor the implementation of the project and on its commissioning perform the tasks such as laying down passenger fares, targets for the minimum number of services to be run by the Concessionaire, their frequency, punctuality, reliability and safety, etc. MMRC, in this option, will have to enter into an agreement with the Concessionaire clearly listing out obligations and rights of the Concessionaire and the client. Following are the important terms, which are usually included in the agreement.

- Land required for the project and 26% of equity shall be made available to the Concessionaire. The balance project cost is to be mobilised by the Concessionaire himself.
- Implementation of the project and its subsequent operation and maintenance is to be the responsibility of the Concessionaire. The concession is for a period of 30 years of operation plus the period of construction.
- A guarantee for the minimum level of ridership would be required to be given to the concessionaire. If this level of ridership does not materialize for any reason, the Concessionaire will have to be compensated for the shortfall.
- Operation and maintenance expenditure for the project shall be borne by the Concessionaire. All revenues generated shall go to the Concessionaire including revenues from property development, advertisements, etc.
- Standards to which the assets of the project are required to be maintained and the quality of the assets at the time of transfer of these assets to the Client at the end of the concession period should be clearly spelt out.
- Normally a metro system will require addition of assets like rolling stock, etc. over a period of time due to increase in traffic. The source of funding of the same is explicitly spelt out in the agreement ð the Concessionaire or the Client. Similarly, the responsibility of replacement of assets on completion of their life, if due during the period of Concession, is clearly spelt out ð whether by the client or the Concessionaire.
- A mechanism for quick resolution of disputes between the Concessionaire and the Client is provided for.
- Insurance liability of the Concessionaire is indicated.
- The Concessionaire transfers all the assets to the Client at the end of the concession period at a nominal residual value or free of cost.

P model, certain risks are to be shared between the concessionaire. The details of risks and mitigation d in the report.

0.13 IMPLEMENTATION PLAN

On receipt of the Detailed Project Report, following action will require to be taken for implementing the Versova - Andheri - Ghatkopar section of Mumbai Metro project:

- Approval of the Detailed Project Report by Maharashtra State Government and the Central Government, both the Governments committing to an investment decision.
- Signing of an MOU between Maharashtra State Government and the Central Government for firming up arrangements for equity and other related items pertaining to this project.
- Providing legal cover for construction as well as operation and maintenance stages of the project.
- In case the project cann't be implemented through PPP, the two Governments to agree to financing of the debt portion of the project through an SPV and also to the time frame for completing the project.

Institutional Arrangement

It is recommended to form an SPV for implementation of the project. As the SPV needs to be vested with adequate powers to implement and operate the system, it is recommended to form the SPV on the lines of Delhi Metro Rail Corporation (DMRC). The SPV can be named as Mumbai Metro Rail Corporation (MMRC). It is proposed that the State Government and the Central Government, each will have total equity of 40% shared equally. State govt. shall provide the land cost as an interest free subordinate debt to the SPV. As the SPV formed on the lines of DMRC will have equal equity from Central and State Governments, the number of Directors from the State and the Central Government will also be equal. While the Managing Director will be a nominee of the State Government, the Chairman should be the Secretary, Ministry of Urban Development and Poverty Alleviation of the Central Government. The Board of Directors (BOD) are to be vested with full powers to implement the project with adequate delegation of power to the Managing Director for day to day working.

It is also recommended that a 'High Power Committee' headed by Chief Secretary, Maharashtra Government and comprising secretaries of the concerned departments of the State Government and heads of civic agencies be constituted to sort out the problems connected with implementation of the project.

ROGRAMME

entation schedule for implementing the project on w

Suggested Implementation Schedule on BOT

S. No.	Item of Work	Completion Date
1	Approval of DPR	31.10.2004
2	Obtain Government Clearances	28.02.2005
3	Arranging Consultant for selection of concessionaire	Completed
4	Calling for Tender on BOT (Based on Feasibility Report)	In progress
5	Finalising Suitable Concessionaire	30.05.2005
6	Financial closer	30.11.2005
7	Execution of work and Procurement of equipments, coaches and installations	01.12.2005 - 30.11.2008
8	Testing and Commissioning	01.12.2008 - 31.12.2008
9	Revenue Operation	31.03.2009

The land acquisition process can start immediately after approval of DPR so that land is available before construction works take off.
It is also recommended to appoint an independent engineering consultant to monitor and advise MMRDA during the execution phase.

IMPLEMENTATION THROUGH SPV
In case the PPP approach is not successful, the project can be implemented through public sector as in case of Delhi. In such a case a SPV is to be formed on the pattern of Delhi Metro Rail Corporation (DMRC) and can be named as MMRC (Mumbai Metro Rail Corporation). Once the SPV formed, it has to take action for appointment of General Consultants for project management including preparation of tender documents. Till the General Consultants are in position, MMRC should appoint an interim Consultant for all preliminary and enabling jobs such as land acquisition, detailed design of civil structures, utility diversions, etc.

A suggested project implementation schedule is given below. The proposed date of commissioning of the section with suggested dates of important milestones is given below

ntation Schedule through SPV

	k	**Completion Date**
1	Approval of DPR	31.01.2005
2	Obtain Government Clearances	28.02.2005
3	Attempt to fix Concessionaire	30.05.2005
4	Fix interim Consultant for preliminary works	30.06.2005
5	Fix General Consultant	31.12.2005
6	Tender Finalisation for Civil Works for Viaduct	30.06.2006
7	Execution of works and Procurement of equipments, coaches and installations	01.07.2006 - 31.06.2009
8	Testing and Commissioning	01.07.2009 - 30.09.2009
9	Revenue Operation	01.10.2009

LEGAL FRAME WORK

Construction of Mumbai Metro phase I is expected to commence soon. Out of its three corridors in phase I, the first corridor may be ready for commissioning in about three years and other corridors may be ready for commissioning after a further period of two years. Thus there is immediate need to have a legislation to provide legal cover to the construction stage of Mumbai Metro. Enactment of any new legislation is a time-consuming exercise. Experience has shown that it takes a minimum of two to three years from conceptualisation stage for a new legislation to be enacted. To enable construction of Mumbai Metro to commence in the year 2005-06, it has, therefore, become necessary to extend the Metro Railways (Construction of Works) Act, 1978 to Mumbai.

As for the legal cover to the operation and maintenance stage of Mumbai Metro, it is high time to go in for a comprehensive legislation which will cater to both construction as well as operation and maintenance stages of Metro Railways in all million plus cities. After that Act is enacted, the existing Acts, namely, Metro Railways (Construction of Works) Act, 1978 and Delhi Metro (Operation and Maintenance) Act, 2002 and the Calcutta Metro Railway (Operation and Maintenance) Temporary Provisions Act, 1985 can be repealed. The comprehensive legislation should, inter-alia, contain provisions for the following:

- Functions and powers of the organisation to be entrusted with the tasks of implementing a metro system and its subsequent operation and maintenance. This organisation should be conferred adequate powers to enable it to expeditiously implement the metro system and later to operate and maintain it without any problem.
- Acquisition of land for construction of a metro railway, including acquisition of rights to use underground space below privately owned buildings for laying a metro line.

ion for certifying safety of a metro line before it is c carriage of passengers. This organization should ed with the role of enquiring into the causes of accidents involving metro trains and suggesting remedial measures for avoiding recurrence of such accidents.

- Statutory authority for deciding the compensation payable for losses, injuries, casualties, etc. arising out of accidents involving metro trains.
- Penalty for offences committed in metro trains or metro premises.

a maintenance depot along with minmum repairing facilities has been proposed at D.N.Nagar in about 12.25 Hectares of land.

A transfer link between this corridor and the North- South corridor (Colaba- Bandra- Charkop) has also been proposed from this depot.

A washing plant is also proposed here.
Alternatively depot at Godrej land (exhibition ground) is also suitable though it requires a link line of 1.625 km
On the Versova- Andheri ï Ghatkopar corridor. The depot is partly elevated due to site constraints. The area of the Depot being planned on the corridor is about. The site has a road approach from the J.P Road.

. For approach. It is suggested that the land be reserved for future use as depot with full net work of Mumbai Metro.

Holding capacity of the Depot has been planned to be 45 rakes of 6 coach each for inspection purposes. Daily tests and checks shall be done at stabling sidings. 7 day, 15 day and 45 day inspection shall be done inside the Inspection Shed. The facilities shall be provided in phases and augmented as the train frequency and formation increases due to growth in traffic. Overhauling of the rakes is not planned at this depot.

Chapter 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Greater Mumbai - the capital of Maharashtra, is not only the financial capital of India but the heart of commercial and trade activities of the Country as well. The Island City has experienced rapid growth in economic activity and its suburbs are growing faster than the Island City in terms of population distribution and activity location. The major challenge is in promoting growth by adequate inputs into infrastructure, which would improve quality of life of the residents.

1.1.2 Mumbai has become a victim of its own success. The employment opportunities it offers have served as a major attraction for immigration from rural hinterland as well as from all parts of the Country. Four-fold growth of population since 1951 has been largely accommodated in the suburbs while highest concentration of jobs has remained in the Island City. Moreover, the physical characteristics of the City are such that the suburbs have been constrained to spread northwards only, and all transport facilities are concentrated within three narrow corridors. This has put great stress on all modes operating in these corridors.

1.1.3 The City with its present population of over 12 million generates about 14 million trips in a day, with about 88 percent of the total trips catered by the suburban railway and the public transport bus services provided by BEST. The ever growing vehicular and passenger demands coupled with constraints on capacity augmentation of the existing network have resulted in chaotic condition during peak hours of the day.

1.1.4 The Government of Maharashtra has adopted a number of policies to alleviate this situation by decentralising the City. Most notables of these include the development of Navi Mumbai and Bandra – Kurla Complex. Navi Mumbai has attracted close to one million people and provided about 2 lakh jobs outside Greater Mumbai. The gradual relocation of city's wholesale markets to Navi Mumbai and establishment of new container port at Nava Sheva have helped in re-distributing commercial vehicle trips and reducing the demand for road space in the Island City.

1.2 DEMOGRAPHIC PROFILE

1.2.1 The total population of Greater Mumbai in 2001 was 119.14 lakh (double of the 1971 population of 59.7 lakh). The rise in population during 1971-81 was around 38 percent and has remained around 20 percent during 1981-91 and 1991-2001 respectively. (refer **Table 1.1**)

Table 1.1
Population Growth in Greater Mumbai (in Millions)

Year	Island City	Western Suburbs	Eastern Suburbs	Greater Mumbai
1971	3.07	1.71	1.19	5.97
1981	3.28	2.86	2.10	8.24
1991	3.17	3.95	2.80	9.93
2001	3.35	5.10	3.46	11.91

1.2.2 The population growth in the island area during 1971 – 2001 is only 9 percent. However, the growth in suburbs (western and eastern) has been phenomenal. The suburban population has grown to almost 300 percent over the past 30 years.

As is evident, the share of island population has been declining continuously. The proportion of population in island area has declined to 28 percent in 2001 from 51 percent in 1971. The share of suburbs has gone up to almost 72 percent of the total population of Mumbai. Also, in 2001, the proportion of population in Western suburbs is almost 43 percent of the total population of Mumbai while that in eastern suburbs is 29 percent only.

1.3 EMPLOYMENT SCENARIO

1.3.1 The employment data of Greater Mumbai collected from the *National Economic Census* for 1971, 1981, 1991 and 1998 is classified in 10 categories as given below:

1. Agriculture, Forestry and Fishing
2. Mining and Quarrying
3. Manufacturing and Repair services
4. Electricity, Gas and Water
5. Construction
6. Wholesale & Retail trade and Restaurants & Hotels
7. Transport, Storage and Communication
8. Financing, Insurance, Real estate and Business services
9. Community, Social and Personal services
10. Others

1.3.2 The employment growth during 1971-1998 in different areas of Greater Mumbai is shown in **Table 1.2**. The share of employment in Island City has fallen to 56 percent in 1991 from 72 percent in 1971. However, it has increased to 61 percent in 1998. The share of employment in western suburbs was around 25 percent of total employment in Greater Mumbai in 1998 and that of eastern suburbs was about 15 percent.

Table 1.2
Employment in Different Areas of Greater Mumbai (in Millions)

Year	Island City	Western Suburbs	Eastern Suburbs	Greater Mumbai
1971	1.09 (71.90)	0.24 (15.38)	0.19 (12.71)	1.53 (100.00)
1981	1.39 (63.62)	0.51 (23.03)	0.29 (13.35)	2.19 (100.00)
1991	1.34 (55.62)	0.64 (26.30)	0.44 (18.08)	2.42 (100.00)
1998	1.59 (60.51)	0.65 (24.91)	0.38 (14.58)	2.62 (100.00)

Note : Figures in brackets indicate the proportion of total employment

The change in employment in Greater Mumbai is presented in **Table 1.3**. It may be seen that during 1991-98, the growth of employment in Island area was 18 percent, while in western suburbs it was only 2 - 3 percent. In the eastern suburbs, this figure has reduced by about 13 percent during 1991-98.

Table 1.3
Decadal Change in Employment in Greater Mumbai(in %)

Decade	Island City	Western suburbs	Eastern Suburbs	Greater Mumbai
1971-81	27.34	115.41	51.12	43.92
1981-91	-3.57	25.97	49.34	10.30
1991-98	17.74	2.53	-12.69	8.24

1.4 LAND USE POLICY

MMRDA prepared a Regional Plan 1996 – 2011, for MMR as required under the Maharashtra Regional & Town Planning Act 1966, which was approved by GOM.

1.4.1 Major recommendations of the Regional Plan are as follows:

- A new Industrial Growth Policy should be framed with specific economic, environmental and urban development objectives. Unlike the past, it should also promote modern, technologically advanced, environment friendly industries in Mumbai Municipal limits, and encourage changes in Mumbai's industrial structure, by facilitating revival of sick and obsolete industries.
- The policy should minimise the adverse impact of new industrial growth on environmental and civic infrastructure.
- The policy should facilitate direct industrial growth in the underdeveloped part of the Region to achieve balanced regional development.
- The policy should help generate new employment opportunities.

1.4.2 As per the Regional Plan, a poly-nucleated land use structure has been recommended for Mumbai Metropolitan Region (MMR). This clearly brings out

MMRDA's plan of developing alternative employment growth centres at Bandra Kurla Complex (BKC) in addition to the ones at Navi Mumbai. As per latest estimates, BKC will generate around 200,000 jobs as compared to 700,000 jobs in Navi Mumbai.

1.4.3 In the Island City Area and the suburbs, valuable and significant land parcels have not been used since long. These areas belong to textile mills, which were shut down in the eighties. Recently, the Government of Maharashtra through MMRDA has evolved certain strategies for development of these areas and to re-develop valuable land resources. **Table 1.4** presents the total land area, which belongs to textile mills, and the envisaged uses of the land area:

Table 1.4
Proposed Redevelopment of Textile Mill Land Area

S. No.	Land Uses	Area Sq. m.
1	BMC : Open Space / Community Facilities	313291
2	MHADA : Low Income Housing	313291
3	Commercial Use	313291
	Total	**939,874**

1.5 VEHICLE REGISTRATION

1.5.1 The data on private vehicles in Greater Mumbai is available for three regions, namely, the Island City, the Western and Eastern suburbs. The number of private vehicles registered in Greater Mumbai is given in **Table 1.5**. The ratio of private vehicles per thousand population is growing steadily, and has reached 68.30 in 2002. This clearly shows the inclination of people towards private vehicles. The trend is also influenced by the rising income level and saturation of public transport systems in Mumbai.

Table 1.5
Greater Mumbai Motor Vehicle Statistics

Year	Private Vehicle Registration	Population	Private Vehicle per 1000 population
1971	108146	5970575	18.11
1981	229185	8243405	27.80
1986	365190	8958013	40.76
1991	506959	9925891	51.07
1995	516640	10678015	48.38
1997	604503	11075187	54.58
1998	649654	11279279	57.60
2000	736852	11698814	62.99
2002	828769	12133955*	68.30

Note
***** Estimated Population

1.5.2 The proportion of vehicles in island area has steadily reduced from 73 percent in 1981 to 40 percent in 2002, which is the same as the proportion of vehicles in western suburbs. The number of vehicles in eastern suburbs is only 21 percent of total vehicles in Mumbai. Distribution of vehicles in Island and Suburbs is shown in **table 1.6.**

Table 1.6
Distribution and Growth of Vehicles in Island and Suburbs

Year	Island	Western suburbs	Eastern Suburbs	Total
1981	73%	16%	11%	100%
1991	58%	27%	15%	100%
1996	44%	37%	20%	100%
1998	41%	38%	20%	100%
2000	40%	39%	20%	100%
2002	40%	40%	21%	100%

1.6 SUBURBAN RAIL SYSTEM

1.6.1 The main skeleton of the rail network in Mumbai was laid down over 100 years ago, initially to link Mumbai and adjacent townships. Electric suburban rail services were started in 1923 in Mumbai by the Grand Indian Peninsula Railway (forebearer of the Central Railway in Mumbai).

1.6.2 Today Mumbai is served by two of India's zonal railways, the Western Railway (WR) and the Central Railway (CR). The Western Railway line runs northwards from Churchgate terminus station in the Mumbai CBD parallel to the West Coast of the island towards northern and western India and Delhi. Suburban operations extend for 60 kms northwards from Churchgate as far as Virar. The Central Railway runs from Chhatrapati Shivaji Terminus (CST), located on the eastern side of the CBD (approximately 1 km northeast of Churchgate) and serves a large part of Central India. Suburban services extend from Mumbai CST as far as Kasara to the northeast (120-Km) and Karjat to the southeast (100-Km)

1.6.3 The CR is also responsible for services on the "Harbour Line" which runs from CST station along the East Side of Mumbai Island to Rawli junction where the line splits. One branch runs north west to join the Western Railway main line at Bandra, with the other line continuing northwards to Kurla, before turning eastwards to serve Chembur and Mankhurd and cross the new Thane Creek bridge to access Navi Mumbai. At Wadala, the Mumbai port rail lines join the Harbour line and north of Wadala, the harbour lines are shared with freight traffic to and from Mumbai docks.

1.6.4 Within the Mumbai area both zonal railways carry a combination of suburban, long distance passenger and freight traffic. Daily passenger volumes are about 6.0 million mostly commuter trips within the Metropolitan Region and approximately 2.0 lakh long distance travellers.

1.6.5 Within Mumbai many suburban stations are less than 1.5 km apart and in some cases less than 1 km. Such close stations are characteristic of a metropolitan urban railway rather than a suburban system. In addition to the lines radiating from Mumbai there is also a double line track connection between Vasai Road on the Western Railway and Diva / Dombivli on the Central Railway. This allows long distance north-south trains to bypass Mumbai.

1.6.6 All Western and Central railway lines within the Mumbai suburban area are Indian Broad Gauge (1.676 m) and electrified using the 1500 volt d.c. overhead system. The traction system is planned for conversion to 25 kV a.c. In some areas tracks are prone to flooding during the monsoon season due to drainage system shortcomings on adjacent land or to inadequate or partially blocked storm water outlets.

1.6.7 Suburban services operate electric multiple units (EMU's) predominantly formed as 9 car rakes (being upgraded to 12 car rakes). A multiple aspect colour light signalling system is used. EMU's are fitted with an Auxiliary Warning System (AWS) which prevents motormen from exceeding 38 km/h when running under single yellow (caution) signals and makes an emergency brake application if a red (danger) signal is passed.

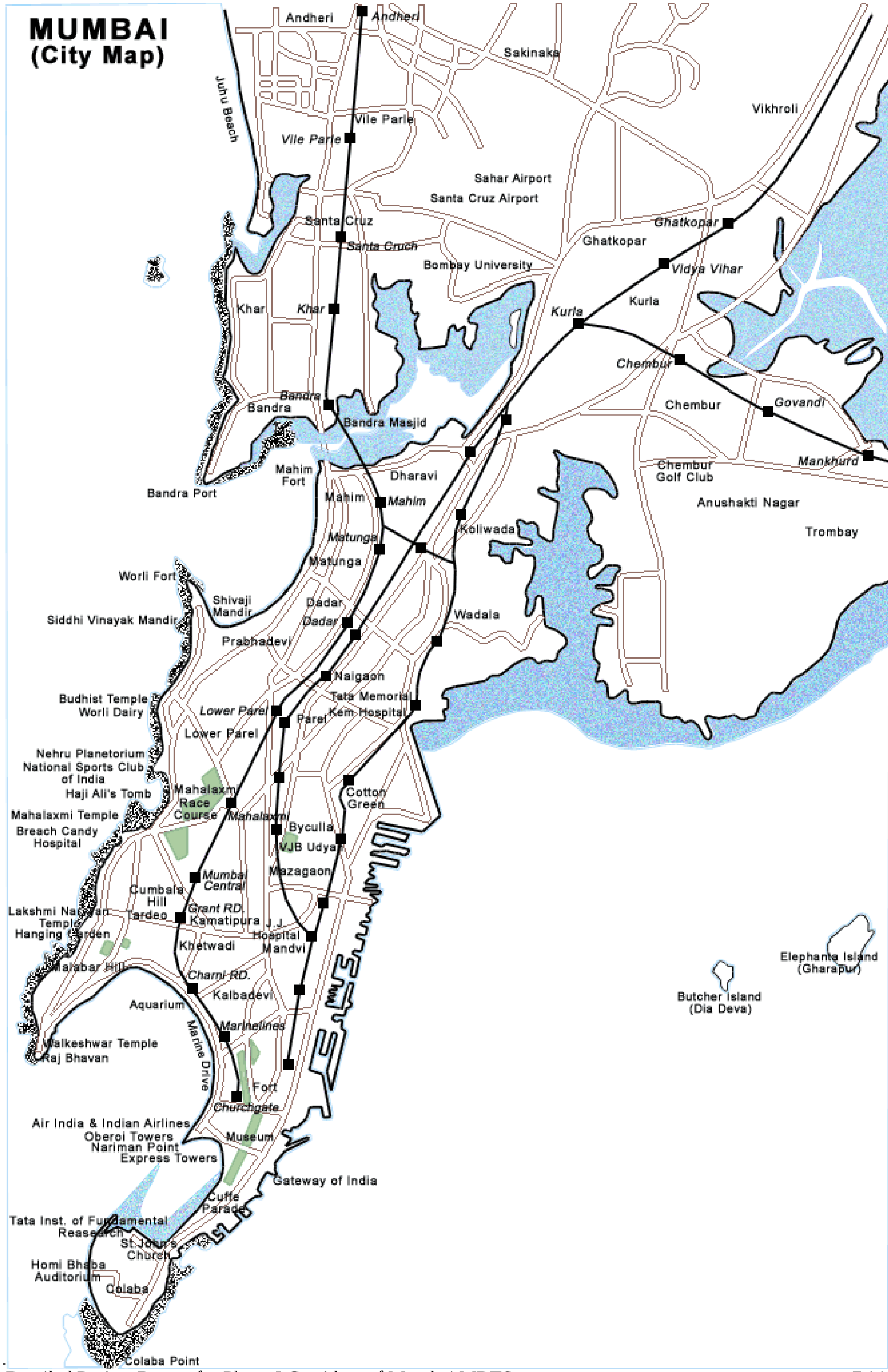
1.7 THE ROAD NETWORK

1.7.1 The road network has developed over many years, predominately in north-south direction radial to the CBD within the constraints of the islands. There are very few cross links with any continuity across all radials. Extensive development over much of the island has led to the major traffic movements being concentrated into three main corridors; western, central and eastern. The western corridor generally provides a higher level of service than the central and eastern corridors. The central corridor, especially in the south Island area, is severely congested with high pedestrian movements and bus traffic. The eastern corridor, which runs adjacent to the port, carries large volume of truck traffic and suffers badly from long term parking and informal roadside vehicle maintenance activities. The network is shown in **Figure 1.1**.

1.7.2 The east – west movement is constrained by the Western and Central Railway tracks which also run for the majority of the length of the Island city. Consequently major traffic movements are concentrated on relatively few roads, resulting in major points of congestion where east-west movements intersect the north-south corridor at such points as Khodadad Circle, Gadkare Chowk and Sion intersection.

1.7.3 To the north of Mumbai Island, the east – west movements are further restricted by the limited number of crossing points of the River Mithi. The lack of a good link between places such as Santa Cruz and Chembur or Vashi often results in considerable detours via Sion and the Western and Eastern Express Highways.

1.7.4 The roads of Mumbai serve not only as a means of transport provision but also function as parking areas for vehicles, sites for hawkers and other commercial activities, and extended footways. In some places, notably on the Western Express Highway, part of the right of way (though not the carriageway) has also been encroached upon by slums. These other functions, together with frequent


MUMBAI
(City Map)
Andheri
Andheri
Sakinaka
Juhu Beach
Vile Parle
Vile Parle
Vikhroli
Sahar Airport
Santa Cruz Airport
Santa Cruz
Santa Cruch
Ghatkopar
Ghatkopar
Bombay University
Vidya Vihar
Khar
Khar
Kurla
Kurla
Chembur
Bandra
Bandra
Bandra Masjid
Chembur
Govandi
Mahim Fort
Dharavi
Chembur Golf Club
Mankhurd
Bandra Port
Mahim
Mahim
Anushakti Nagar
Koliwada
Trombay
Matunga
Matunga
Worli Fort
Shivaji Mandir
Dadar
Dadar
Wadala
Siddhi Vinayak Mandir
Prabhadevi
Naigaon
Budhist Temple
Worli Dairy
Lower Parel
Tata Memorial
Kem Hospital
Parel
Lower Parel
Nehru Planetorium
National Sports Club of India
Haji Ali's Tomb
Mahalaxmi Race Course
Cotton Green
Mahalaxmi Temple
Mahalaxmi
Breach Candy Hospital
Byculla
VJB Udyan
Mazagaon
Mumbai Central
Cumbala Hill
Lakshmi Narayan Temple
Tardeo
Grant RD.
Kamatipura
J.J. Hospital
Hanging Garden
Khetwadi
Mandvi
Malabar Hill
Charni RD.
Elephanta Island (Gharapuri)
Kalbadevi
Butcher Island (Dia Deva)
Aquarium
Marine Drive
Marinelines
Walkeshwar Temple
Raj Bhavan
Fort
Churchgate
Air India & Indian Airlines
Oberoi Towers
Nariman Point
Express Towers
Museum
Gateway of India
Cuffe Parade
Tata Inst. of Fundamental Reasearch
St.John's Church
Homi Bhaba Auditorium
Colaba
Colaba Point

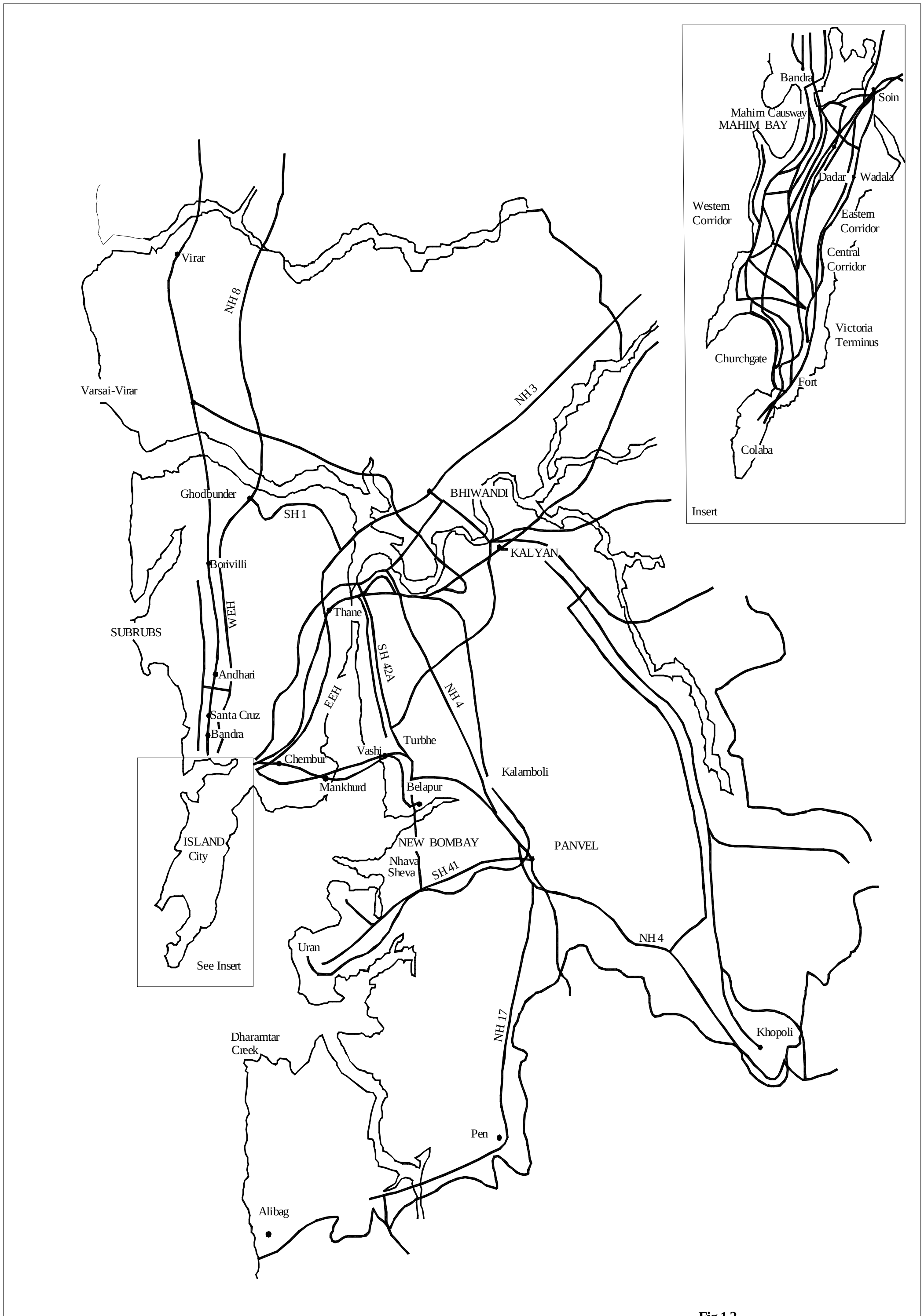


Fig 1.2

Existing Strategic road Network

disruption due to service provision and maintenance, severely reduce the traffic capacity of the highways.

1.8 BUS TRANSPORT SYSTEM

1.8.1 Public stage carriage bus services in the region are provided by BEST, (within BMC and up to 20 km beyond the municipal boundary), TMT in Thane and MSRTC elsewhere.

1.8.2 With over 3,030 buses, BEST is by far the largest provider of bus services in the region. However, due to financial limitations bus replacement has been deferred in recent years and some 25% of this fleet is now more than 10 years old which is the company's preferred limit to bus life.

1.8.3 All routes within Mumbai are provided by BEST. These include radial routes to and from main centres, trunk routes linking main centres and feeder services linking to the trunk routes and to railway stations. Additionally, some routes operate on a limited stop basis providing slightly faster journey times on the trunk routes between the Mumbai City area and outlying parts of Greater Mumbai. However, the improvement in journey time in many cases is marginal due to the traffic congestion and the retention of too many stops on the routes due to public demand.

1.8.4 Bus routes from Mumbai City to Navi Mumbai are provided by BEST and MSRTC. Routes from other points in Greater Mumbai to Navi Mumbai and Thane are provided by BEST, MSRTC and TMT.

1.8.5 The dispersal of rail commuters from the main railway terminals to their final destinations in the Mumbai CBD such as Fort, Ballard Estate, Colaba or Nariman points is at present carried out primarily by the bus system. Shared taxi routes are also operated, whilst a large number of people make this final stage of their journey on foot. In the morning peak these movements involve substantial volumes running into the order of 30,000-40,000 passenger per hour from each terminus.

1.8.6 BEST operates an "on demand" feeder service during the morning peak hour between Churchgate or CST and Nariman Point or Colaba. This entails constantly having buses queued up at the rail terminus to take passengers so as to avoid any build up of waiting time for the passengers.

1.9 ACCIDENTS

1.9.1 The number of personal injury accidents, reported annually in the Mumbai Metropolitan area has remained approximately constant (25000 – 30000) over the last 30 years. The number of fatalities however has fallen by 50% since 1981 and is currently about 350 per year. As the number of vehicles in Mumbai has significantly increased, the number of accidents per vehicle kilometer has gone down.

1.9.2 The reduction in accident rate and fatalities may be due to the introduction of various traffic management measures, improved driver education and more strict police enforcement of road and traffic regulations. Lower speeds resulting from increased congestion is also a factor. However, the annual accident total of about 30000 remains high, and there is a need to ensure further reduction.

1.10 AIR POLLUTION

1.10.1 In Mumbai road traffic is a major source of air pollution, which has worsened significantly in the last two decades and now poses a considerable health problem and potentially lethal hazard.

1.10.2 Data derived from the ambient air quality monitoring by MCGB show that air pollution due to road traffic has increased by almost 400% over the last two decades. Transport (principally road traffic) now accounts for about 52% of the overall air pollution load in Greater Mumbai. The air pollution from traffic is principally carbon monoxide (CO), Nitrous Oxide (NOx) and hydrocarbons (HC) whereas industrial pollution takes the form of suspended particulates (SPM), sulphur dioxide (SO_2) and to a lesser degree NOx.

1.10.3 Within the traffic stream the large numbers of motor cycles, motor scooters and autorickshaws are estimated to produce 34.5% of total pollutants, this is more than trucks and buses (33.2%) or cars (32.3%). Carbon monoxide and hydrocarbons are the main pollutants from two and three wheelers. Since auto rickshaws are concentrated in the suburbs (they are banned from operations in the Island City), they are an important source of air pollution in the suburban centres of Mumbai and in the principal towns of the region. The GOI Central Motor Vehicle Rules lay down emission standards for new two and three wheeler vehicles and for “light duty vehicle” in respect of CO and HC for current application, with tighter standards for application after 1995 and 2000. These future higher standards aim to reduce emissions to less than 20% of the currently permitted levels.

1.10.4 Many people in Mumbai would appear to have a high tolerance to traffic noise, which is at present not seen as a widespread problem, although levels of noise near the main highways are high by Western standards. It is likely that noise will become more of a perceived problem as traffic volumes increase and if increased traffic flows take to filtering through residential areas. Traffic engineering and environmental traffic management measures will be necessary to control this in future.

1.11 NEED FOR METRO

Public Transport System is an efficient user of space and energy, with reduced level of air and noise pollution. As the population of the city grows, the share of public transport, road or rail-based, should increase. For a city with population of 1.0 million, the share of public transport should be about 40 - 45%. The percentage share of public transport should progressively increase with further growth in the population of the city, reaching a value of about 75% when the population of the city touches 5 million mark. With Mumbai' s population crossing 12 million, the share of public transport at 88% is quite good. However, over the past decade the share has reduced from 91% to 88% and is likely to reduce further if corrective measures are not taken immediately. While upgradation of existing suburban system is underway through MUTP, it is felt that additional mass transit corridors are required to meet the expanding demand.

Whether the public transport system on a corridor in the city should be road-based or rail-based will depend primarily on the traffic density during peak hours on the corridor. Experience has shown that in mixed traffic conditions, comprising slow and fast moving traffic prevailing in most of our cities, road buses can optimally carry 10,000 persons per hour per direction (phpdt). When traffic density on a corridor exceeds 10,000 phpdt, the average speed of buses comes down, journey time increases, air pollution goes up, and commuters are put to increased level of inconvenience.

Thus when on a corridor, traffic density during peak hours crosses this figure, provision of rail-based mass transport, i.e. Metro system should be considered. In any case, Metro system may become inescapable if the traffic density on a corridor reaches 20,000 phpdt.

1.12 TYPES OF METROS AND THEIR CAPACITY

Rail based mass transport in cities can be brought mainly under three categories:-
Since, the number of commuters to be dealt is relatively less in LRTS, its trains consist of 2 to 3 coaches and other related infrastructure is also of a smaller size. For medium capacity Metro systems, the train generally comprises 3 to 6 coaches with ultimate train headway of about 3 minutes. The other related infrastructure e.g. civil works, stations, passenger handling equipment etc. are also planned accordingly.

Heavy capacity metro systems have to deal with large traffic densities ranging from 50,000 to 80,000 phpdt. Accordingly, the trains have 6 to 9 coaches and other related infrastructure is also of large size. Beyond the traffic level of 80,000 phpdt, additional parallel lines are normally planned. The metro system being constructed in Delhi is heavy capacity system.

1.13 ADVANTAGES OF A METRO SYSTEM

Metro systems are superior to other modes because they provide higher carrying capacity, faster, smoother and safer travel, occupy less space, are non-polluting and energy-efficient. To summarise, a Metro system:

- Requires 1/5th energy per passenger km compared to road-based system
- Causes no air pollution in the city
- Causes lesser noise level
- Occupies no road space if underground and only about 2 meter width of the road if elevated
- Carries same amount of traffic as 7 lanes of bus traffic or 24 lanes of private motor cars (either way), if it is a medium capacity system.
- Is more reliable, comfortable and safer than road based system

- Reduces journey time by anything between 50% and 75% depending on road conditions.

1.14. REVIEW OF PAST STUDIES

A number of transportation studies were carried out in the past for Mumbai Metropolitan Region (MMR). These studies discussed travel pattern, network characteristics, and the degree of traffic saturation on the existing roads in the Study Area. The following major studies, which recommended transportation improvements in MMR, have been reviewed.

(i) **Mass Transport Study (1969):** The objective of this Study was to determine the existing conditions of available mass transportation services, future desire lines and to evolve a comprehensive, long term mass transportation plan for Greater Mumbai. Travel projections were made upto the year 1981. These projections formed the basis for identifying the 6^{th} and 7^{th} Rail Corridors.

(ii) **Techno-Economic Feasibility of the 7^{th} Rail Corridor:** Indian Railways carried out the techno-economic feasibility study of the Seventh Corridor in the year 1974. Mumbai Metropolitan region was considered as the Study Area. Passenger traffic of 1.78 million per day was estimated to be carried by the 7^{th} Corridor in 1981.

Detailed engineering feasibility was also carried out and the corridor alignment was fixed. The corridor runs underground (South to North) from Colaba to Bandra (17.38 km) and East to West from Bandra to Kurla elevated (4.90km) and a spur to the airport (4.1 km).

(iii) **East West Rail Corridor Study:** MMRDA got this Study done In the year 1975 for developing rail corridor connecting Bandra – Kurla – Mankhurd – Panvel. The objective of this Study was to provide access to Navi Mumbai with a view to assisting in its development.

Out of the proposed corridor, Mankhurd – Vashi – Panvel section has been completed. The Bandra-Kurla section of this corridor has not been developed so far.

(iv) **Comprehensive Transport Study (CTS) for MMR:** A study was commissioned by the World Bank and MMRDA in 1993 to develop a strategy for transport development in MMR.

The Study focused on the strategies for transport development, institutional strengthening for effective implementation of the proposed strategies and suggesting an investment program with appropriate prioritization.

The recommended strategy covers investments worth a total of Rs. 11,300 crore, including rail system investment of Rs. 7000 crore, bus and ferry system investments of Rs. 570 crore and a highway programme of Rs. 3730 crore including a substantial traffic engineering and management component.

(v) Mumbai Metro Study, by Mumbai Metro Planning Group: The Study examined the feasibility of constructing and maintaining the 7th rail corridor as a heavy metro, and covers a detailed techno-economic study, market survey, estimates of ridership on the new corridors, cost estimates of capital investments and operation, revenue expected and financial aspects.

(vi) MRTS Study by TEWET: The study objective was to identify two rail based Mass Rapid Transit (MRT) Systems which are bankable, one for the CBD and one in Greater Mumbai outside the CBD, and to develop feasibility studies for the two projects.

The TEWET study also identified total network for Greater Mumbai after examining 3 alternatives. The recommended Network is of 57 km length with an estimated cost of Rs. 12,000 crore and in Island city it follows the 7th Corridor alignment. In the suburbs, the line is extended North upto Andheri with two branches; one going upto Charkop in west suburbs & other leading to Mulund via Ghatkopar.

The detailed feasibility study was done for part of the Master Plan namely Andheri – Ghatkopar section with a spur to Sahar Airport. Total length was about 10 km and estimated cost Rs. 800 crore. Most of the alignment was elevated except small underground stretch of 1.5 km below flyover at Andheri MMR.

(vii) Sky Bus Metro Study by MMRDA: The Konkan Railway Corporation presented to GOM a proposal for development of a new transport system called sky bus metro system. It envisages a system, which will be elevated and supported to central columns. MMRDA carried out a techno-economic feasibility study of this system for Andheri – Ghatkopar section. The conclusion of this Study was that since this system has not been implemented anywhere in the world, it needs to be further examined on a 2 km pilot section.

Chapter 2

EVOLUTION OF MUMBAI METRO MASTER PLAN

2.0 BACKGROUND

Mumbai's transport problems can be solved by integrated transport planning. While suburban rail system and road based transport system is being taken care of by MUIP and MUTP, the metro system had been proposed in the past in adhoc manner. Hence it was necessary to prepare a master plan for the metro system in Mumbai. The procedure followed and rigorous exercise and consultation done in evolving an acceptable Master Plan covering entire Greater Mumbai geographical area has been described in Detail in the Report on phase I of this study. The same is summarized below:

2.1 PRELIMINARY NET WORK

With a view to broadly identify the most feasible and apparently advantageous network section for possible inclusion in the final Master plan all such possible routes were listed based on the following inputs:

i) Recommendation of the earlier studies for various rail based systems such as $6^{th}/7^{th}$ corridor, SMART study, MMG study.

ii) Existing and future land use plans including Regional plan for MMR which indicate the locations and intensity of population and employment growth and development pf alternate City centers.

iii) Suburban Rail Improvement Plans arising out of Department budgetary schemes and MUTP (phase I & II).

iv) Availability of suitable lands for depot to minimize dead running and land cost.

v) Arterial road network expansion programme envisaged under the sanctioned projects of MUTP and MUIP.

vi) The suggestion of the members of the study review committee.

Accordingly, a preliminary network of about 200 km was identified.

2.2 MASTER PLAN

Thereafter intensive site reconnaissance surveys were carried out. The alternative probable corridors were discussed with representatives of local authorities and finally a network comprising of 146.5 km was selected as Master Plan for Mumbai Metro. The most important criteria in finalizing the Master plan were

- Feasibility of the minimum values for system parameters in terms of vertical curves, horizontal curves and gradients.
- Maximum intermodal integration with existing and committed suburban rail network.
- To serve areas of population and employment concentration not served here to.
- Easy connectivity to Depot sites.
- To ensure regional linkages and connectivity to rail system proposed in adjoining regions like Thane and Navi Mumbai.

The Master Plan network was split in suitable corridors as under:

S. No.	Corridor	Length (Km)		
		Total	Elev.	U.G
1	Versova – Andheri – Ghatkopar	15.00	15.00	-
2	Coloba – Mahim (Bandra)	18.00	8.10	9.90
	Mahim (Bandra) – Charkop	18.00	18.00	
3	Mahim – Kurla – Mankhurd	12.80	10.70	2.10
4	Charkop – Dahisar	7.50	7.50	
5	Ghatkopar – Mulund	12.40	12.40	
6	BKC – Kanjur Marg via Airport	19.50	11.00	8.50
7	Andheri (E) – Dahisar (E)	18.00	18.00	
8	Hutatma Chowk – Ghatkopar	21.80	13.30	8.50
9	Sewri – Prabhadevi	3.50		3.50

2.3 PHASING OF MASTER PLAN

The Master Plan of Metro finalized for Greater Mumbai consists of approximately 146.50 km of Rail network. It is practically not feasible to develop the entire network at one go for many reasons like (i) Availability of sufficient funds (ii) limitation on civil work construction (iii) The environmental and traffic impacts during construction (iv) difficulties in acquisition of open lands as well as built up structures (v) resettlement of project affected families.

The Master Plan Network was therefore grouped into different phases. The criteria adopted in finalizing the phases were

i) Ridership per unit length of the corridor.
ii) Ridership per unit investment on the corridor.
iii) Sectional traffic loads, and
iv) Environmental Impact

After detailed deliberation with the study review committee suitable weightages were assigned to these four criteria as under

i) Ridership per unit length = 40 %
ii) Ridership per unit investment = 25 %

iii) Sectional traffic loads = 25 %
iv) Environmental Impact = 10 %

The preliminary results of phasing exercise were discussed in the meeting of the Executive Committee of MMRDA, chaired by the Chief Secretary, GOM and later in the meeting of the Authority of MMRDA chaired by the Chief Minister of GOM. The final approved phasing of the Master plan is as under:

Phase	Corridors	Length(Kms)			Total Cost (Rs. Cr.)
		Total	Elev.	U.G	
1	a) Versova-Andheri-Ghatkopar	63.80	51.80	12.00	8180
	b) Colaba – Charkop				
	c) Mahim – Mankhurd				
2	a) Ghatkopar – Mulund	19.90	19.90	-	1990
	b) Charkop – Dahisar				
3	a) BKC – Airport - Kanjur Marg	62.80	42.30	20.50	9355
	b) Andheri (E) – Dahisar (E)				
	c) Hutatma Chowk – Ghatkopar				
	d) Sewri – Prabhadevi				
	Total	**146.50**	**114.00**	**32.50**	**19525**

Chapter 3

TRAFFIC FORECAST

3.0 BACKGROUND

The methodology adopted for forecasting commuter rider-ship in Greater Mumbai and on the Metro corridors is discussed in detail in the phase 1 Report. It is emphasized here that most vigorous & in-depth exercise was undertaken at Master Plan preparation level itself by utilizing the "TRIPS model" and with the help of expert from TCS & IIT, Mumbai. Same is described in brief here under.

3.1 STUDY AREA, TRAFFIC ZONING AND PLANNING PERIOD

3.1.1 The Study Area includes the geographical limits of Greater Mumbai (upto Dahisar in the North, Mulund in the North – East and Airoli and Vashi in the East).

3.1.2 The traffic zone system of the Study has been designed with the help of 88 census sections, based on following criteria:

- Conformance with ward boundaries
- Conformance with census section boundaries (as far as possible)
- Regular shape of the zone
- Un-skewed land use distribution
- Conformance with natural and artificial boundaries such as creek, river, major roads, rail corridors etc.

3.1.3 The zoning system of the Study Area (Greater Mumbai) for development of Metro Master Plan comprises of 105 zones (46 in the island area and 59 in the suburbs). These 105 zones in Greater Mumbai are the same for the prior base year (1996), the base year (2003) and all future base years (upto 2031). The traffic zones in the island and suburbs are shown in **Figure 3.1** and **Figure 3.2** respectively. In addition to the 105 internal zones, three external zones have been considered for the prior base year (1996). For the base year (2003) and the horizon year (2031), the three external zones are split into four to account for the change in the pattern of external traffic.

3.2 METHODOLOGY FOR RIDERSHIP FORECAST

The Study methodology followed for the ridership forecasting on the Mumbai Metro consists of the following five stages.

1. Database Preparation
2. Prior Base Year Analysis
3. Base Year O-D Validation
4. Base year Model Development
5. Ridership forecasting and Sensitivity Analysis

The following sub-sections briefly describe each stage.

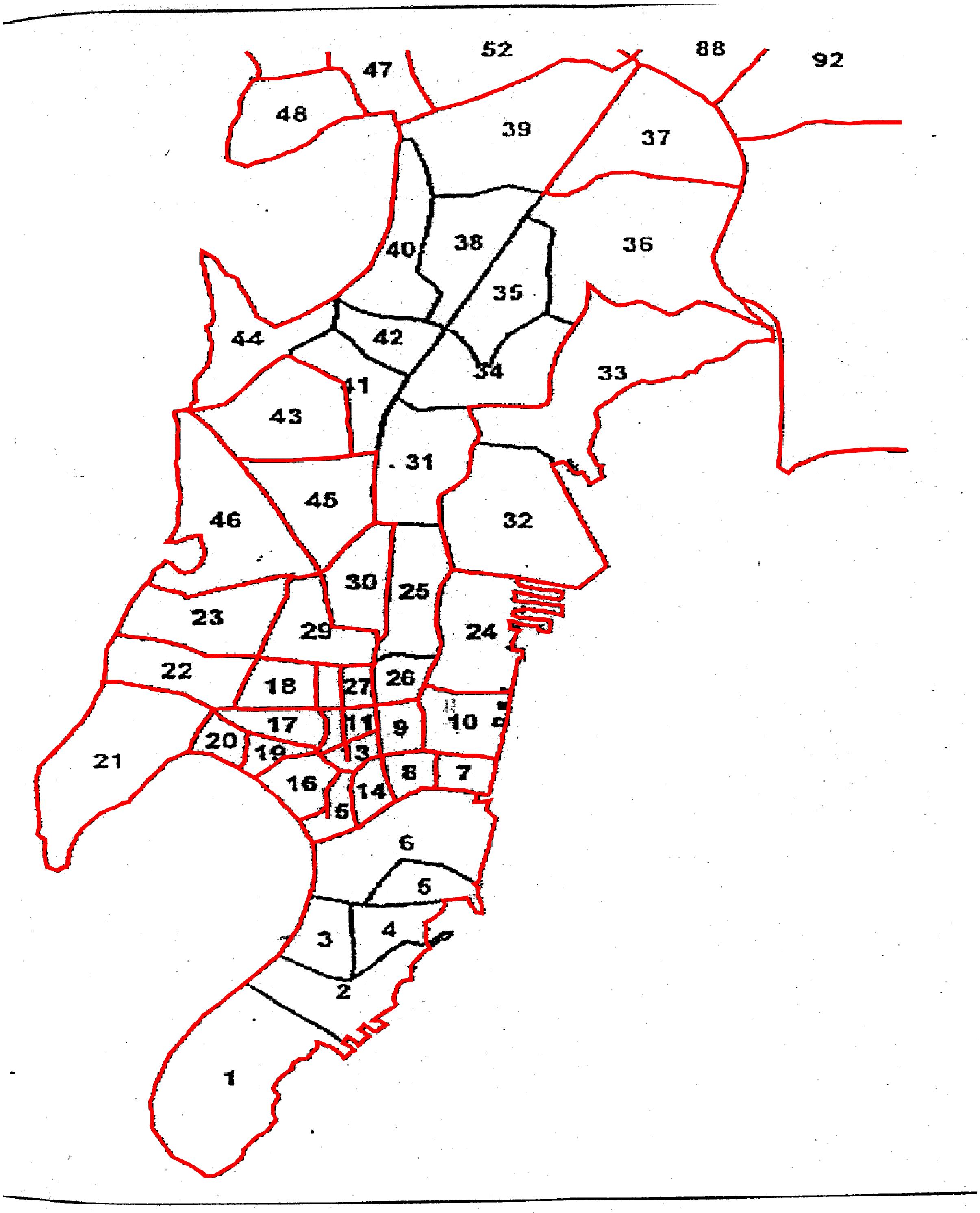


Figure 3.1: Mumbai Island: Traffic Zoning System

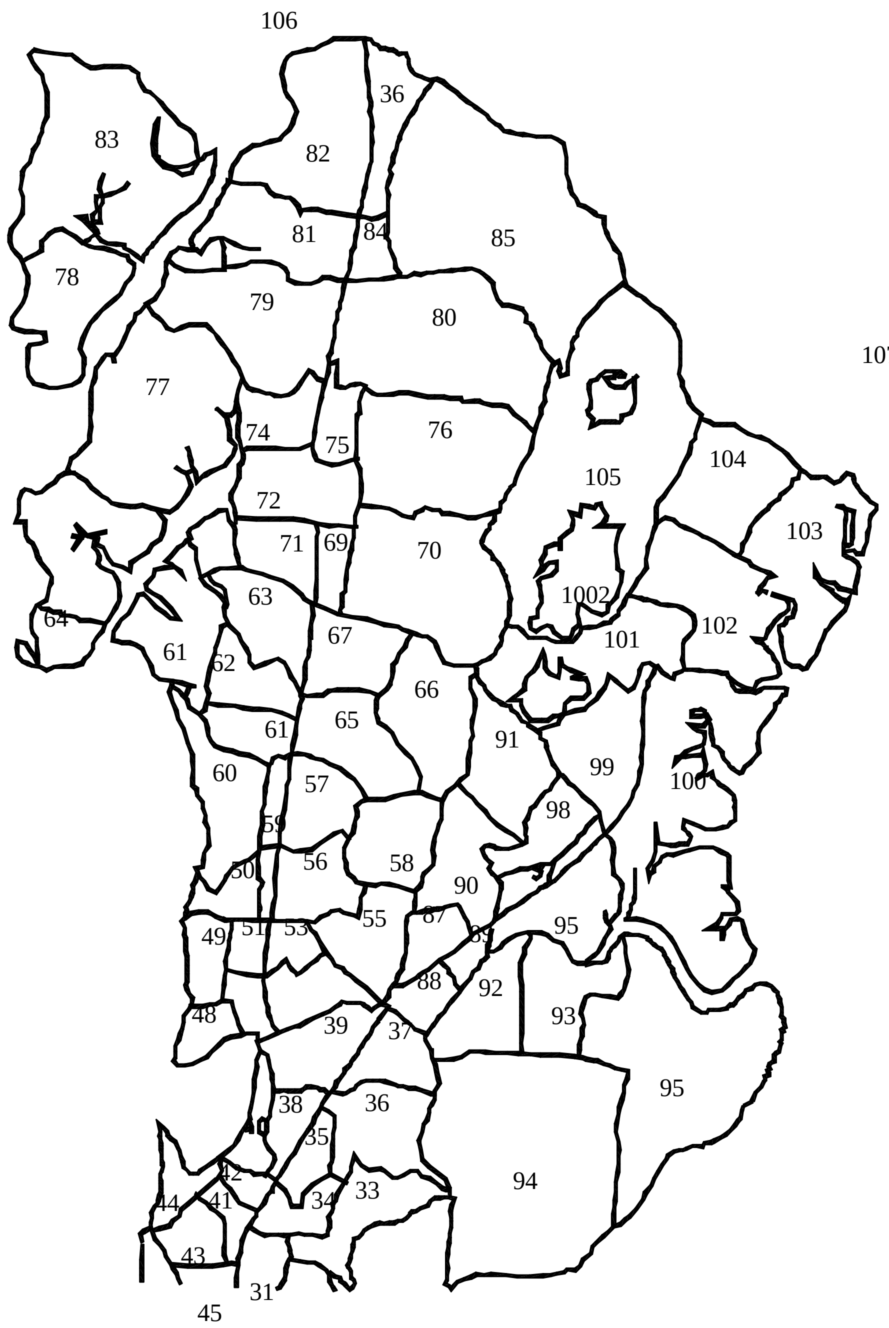


Figure 3.2 : Mumbai Subrubs : Traffic Zoning System

Stage – 1 Database Preparation

This stage involved preparation of database required for the development of demand forecasting model. The activities under this stage include collecting data required for the Study from primary and secondary sources, and analyzing and compiling the results in the required format.
This stage results in generation of the following information:

- Adjusted traffic zone-wise demographic and socio-economic data for previous (1996) and current (2003) base years
- Projected planning variables for the horizon years
- Transport (Public Transport and Highway) network for the prior base year and all horizon years
- Mode-wise external OD matrices
- Growth factors for projecting external and commercial vehicle trips

Stage – 2 Prior Base Year Analysis

The mode-wise (Public Transport - PT, Private Vehicle - PV, Taxi - TX) internal O-D matrices of 1996 were adopted from the Study directly, as these matrices have been thoroughly validated (Mumbai Metro Study Final Report, 1996). The Mode-wise daily internal trip end and Gravity models were calibrated for the prior base year (1996) using adjusted planning variables (mode-wise O-D matrices and travel time skims). Travel time skims were obtained by simple assignment of O-D matrices on 1996 network. The process is shown in **Figure 3.3**.

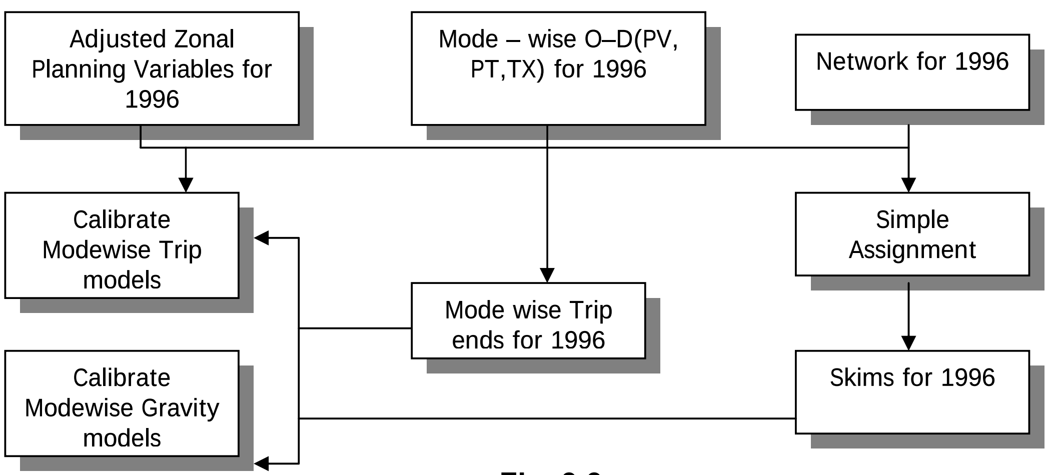


Fig. 3.3

Stage – 3 Base year O-D Validation

The main objective of this stage was to develop thoroughly validated mode-wise O -D matrices for the base year (2003). Calibrated trip end and distribution models (obtained from stage – 2), together with the base year planning variables and network data, were used to update the base year travel pattern. The internal commercial vehicle matrix of 1996 was updated to the base year, by using the appropriate zonal growth factors, and by using the *Furness technique* for

distribution. The external travel pattern for the base year was obtained from the O-D survey conducted at external cordon stations.
The mode-wise trip matrices obtained were further adjusted for trip rates and assigned on the base year network. This helps in obtaining the link flows. These modelled link flows were validated against the observed link flows across the screen lines. If the deviation exceeds specified limits, the trip matrices were estimated using the *Maximum likelihood* method from the link volumes, and by assigning confidence levels to the O-D data.

The O-D matrices obtained were thoroughly validated and used for model development. Base year OD matrix validation is depicted in **Figure 3.4**.

Stage – 4 Base Year Model Development

Using the planning variables and validated total O-D matrix for base year (2003), trip end models were calibrated for the total internal passenger travel. A single gravity model was calibrated using the validated trip ends and skims (generalized cost) obtained from Stage 3 assignment process as the seed values. The revised skims obtained after successive modal split and traffic assignments were used to calibrate the gravity model.

A binomial Logit it modal split model was devised, to determine the share of public transport and private vehicles. The modal was based on the generalized cost functions developed using stated preference data. The Public transport matrix includes the person trip performed by bus, rail, auto and taxi, while the Private vehicle matrix include person trips by car and two-wheeler. The cost skims that were obtained from the assignments were used to calibrate the mode choice model.

The daily public transport passenger matrix was assigned to the public transport network, which includes a) Bus network (prepared by coding all the BEST bus routes), b) Intermediate Public Transport (IPT) routes on the road network and c) Rail Network with all the existing suburban rail links. The public transport assignment was based on generalized time, which was a combination of In-Vehicle Travel Time (IVTT), Waiting Time (WT), Transfer Time (TR), Fare in time units and Discomfort.

There are two important steps in public transport assignment. These are ***path building*** and ***loading trips*** on these paths. The purpose of path building is to identify all reasonable paths between zones and provide associated travel information in generalized time, so that the proportion of trips using each path may be calculated at the loading stage. Between any pair of zones, the maximum number of trips were loaded on to the best path. The other paths with longer generalized times were loaded with fewer trips. The proportion of trips to be loaded were calculated on the basis of a logistic choice function based on generalised time.

The public transport assignment was also required to assign the trips as per the observed modal shares. In order to achieve this, the parameters of the generalised time were fixed based on the values obtained from the analysis of

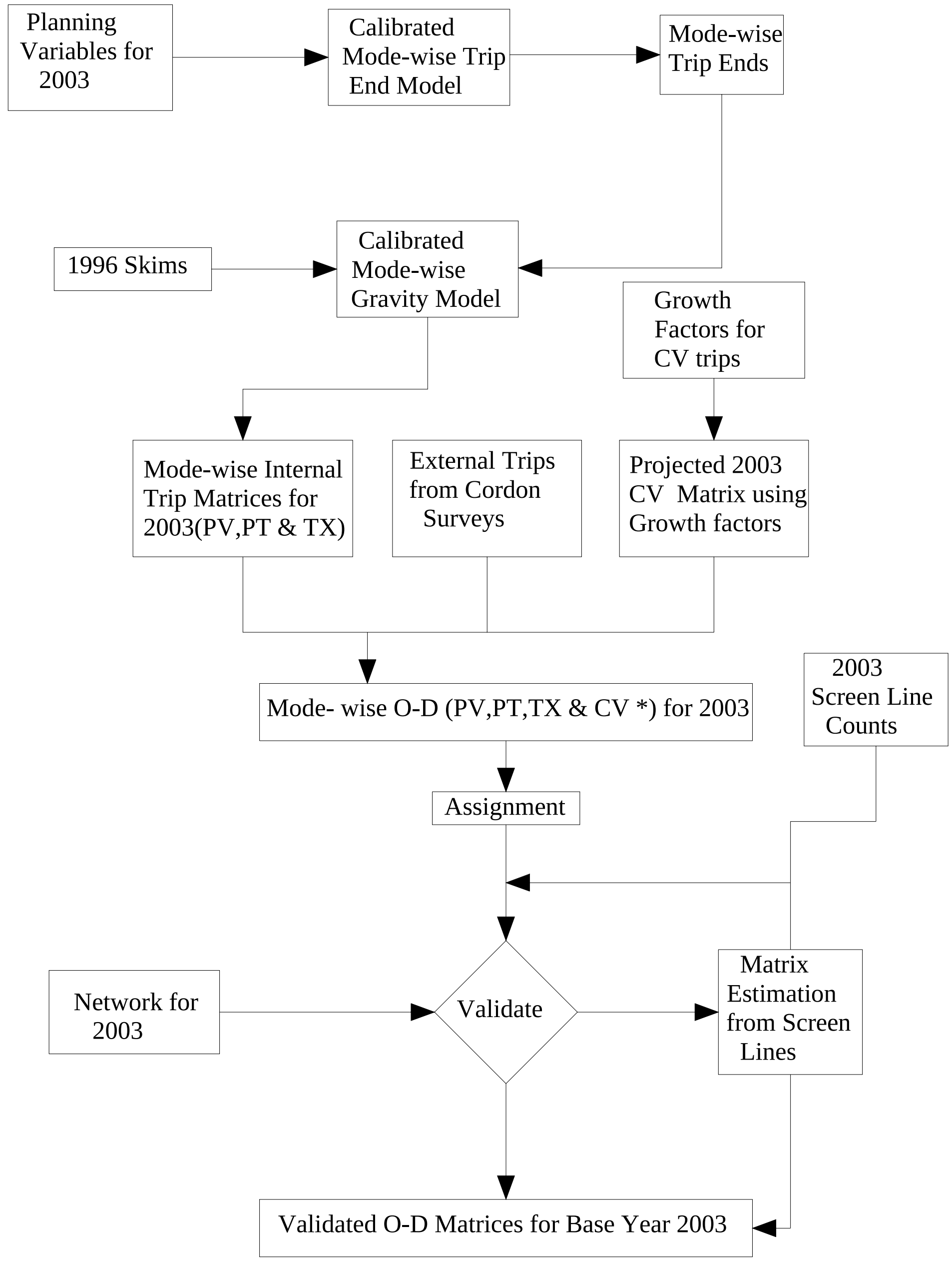


Figure 3.4 Validation of Matrices for Base Year 2003

stated preference surveys. After performing the public transport assignment, the assigned flows across the screen lines were compared with the observed flows.

Highway assignment was carried out for peak hour, preloading the highway network with peak hour public transport and commercial vehicle flows. The daily public transport loadings are factored by the peak hour flow to daily flow ratios to obtain the peak hour public transport flows. These peak-hour public transport (bus and IPT) and commercial vehicle flows in terms of PCU's were preloaded on to the highway network before loading the private vehicle passenger O-D matrices. The private vehicle passenger matrices were converted into peak hour PCU units, by using appropriate regional peak hour ratios and passenger – PCU conversion factors, based on observed occupancies at screen lines. An incremental capacity restraint procedure based on generalised cost was used in loading private vehicle matrices.

The public transport network was revised with the speeds obtained after assigning the private trips. The assignment of public transport trips was performed on the revised network, and the next iteration of private traffic assignment was carried out by taking the bus, taxi, auto and truck flows as preloads. This iterative process between public and private vehicles traffic assignment was repeated until there was no appreciable change in the link loadings and link costs.

Two skims namely the highway time and highway travel costs were obtained from the loaded network. The skims obtained were used for calibrating the gravity model and the modal split-modal. The process of distribution, modal split and assignment was repeated till the OD matrices become stable. The complete model development process is graphically represented in **Figure 3.5.**

Stage – 5 Ridership Forecasting

The calibrated base year trip end models along with the projected planning variables and horizon year networks were used to forecast the future daily internal passenger trip ends for the horizon years (2011, 2021 and 2031).

These future year trip ends were distributed by applying the calibrated gravity distribution model with the previous cost skims available for the initial run (the base year cost skims were used for estimating travel pattern of 2011). The OD matrix of total daily passenger trips obtained for the horizon year under consideration were split into public transport and private vehicle total daily OD matrices using the ***calibrated mode choice*** model. Truck OD matrix and mode-wise external trips (inter-city trips) were forecast using zonal growth factors and by Furnessing. The cost skims used in gravity distribution model and mode choice models were revised using the ones obtained by assigning the public transport trips and highway trips on to their respective networks. The cost/time skims obtained using the final stabilized link costs were used to get the final mode wise daily passenger O-D matrices.

The ridership estimates for various corridors have been made presuming that the entire Master Plan network exists as well as separately for phase I scenario. However, for Versova - Andheri - Ghatkopar section, it is presumed to carry 60%

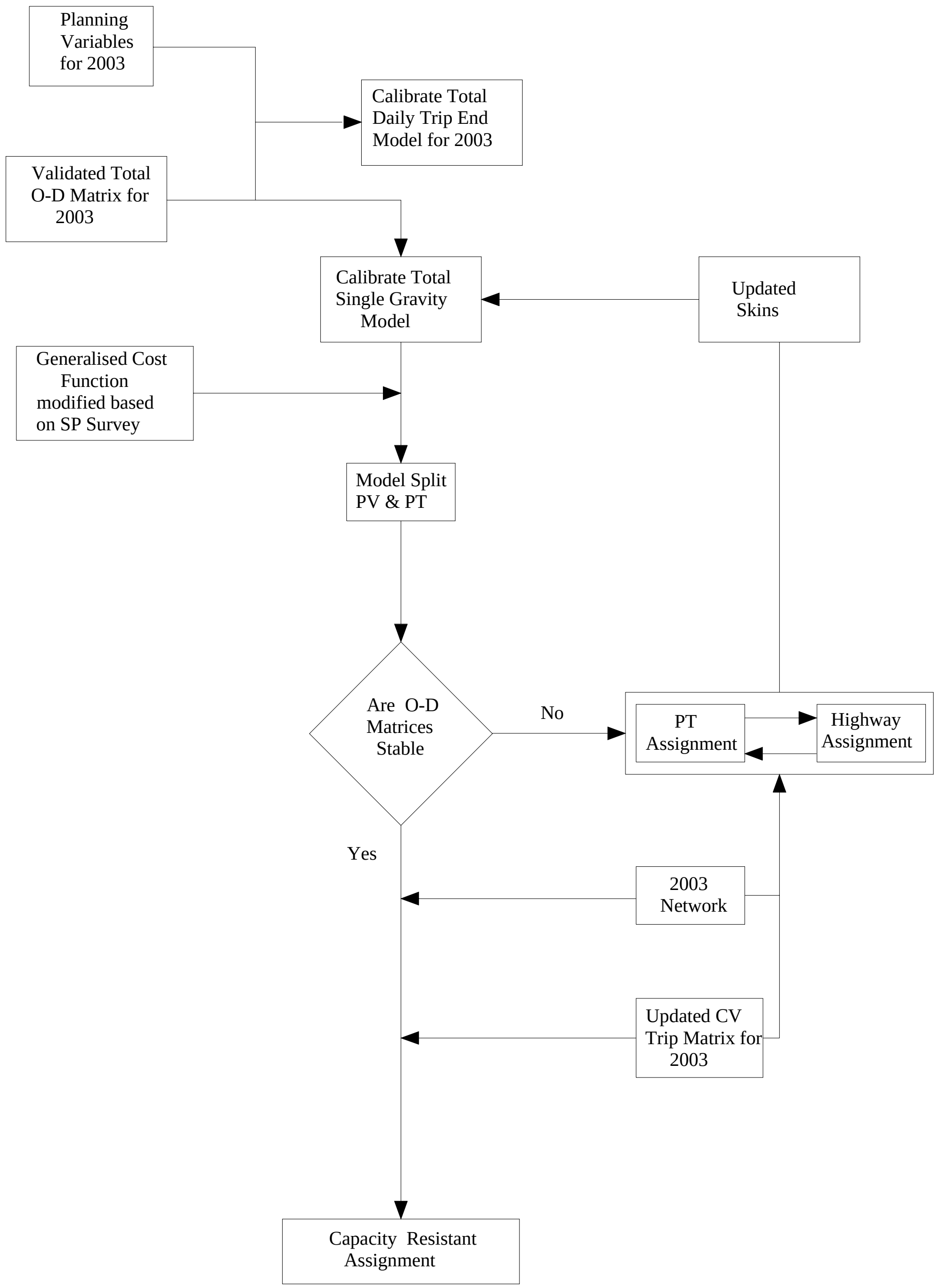


Fig 3.5 Base Year Model Displacement

of the ridership as "stand alone" section as compared to estimated ridership for phase I on this Corridor.

3.3 LAND-USE POLICY

The MMRDA has prepared a Regional Plan (1996-2011) for Mumbai Metropolitan Region, which has recommended a poly-nucleated land-use structure with alternate growth centers at Bandra-Kurla Complex and Navi Mumbai. In the Island City large parcels of land belonging to the Textile Mills which became redundant since 80's are potential source for intensive development.

3.4 STATED PREFERENCE SURVEY

With a view to determine commuter behavior with respect to mode of travel, commuter preferences and willingness to shift to the proposed metro, limited SPS was carried out. The subjective values of time obtained from SP survey are presented below:

Mode	WT (Rs./hr.)	TT (Rs./hr.)	DC (Rs./hr. per unit shift in a DC)
TW	44.00	36.50	27.00
CAR	*	79.00	65.00
BUS	22.50	20.00	1.90
II Rail	15.00	13.00	1.50
I Rail	24.00	20.00	2.80

* This variable has not found significant for car mode.

3.5 PLANNING PARAMETERS

3.5.1 Population

The population projections of Island city, Western Suburbs and Eastern Suburbs of Greater Mumbai as given by the planning division of MMRDA are as shown in **Table 3.1**. The corresponding annual growth rates of population are given in **Table 3.2**.

Table 3.1
Areawise Population Projection for Greater Mumbai

Name of the Area	2001		2011		2021		2031	
	Population	Share	Population	Share	Population	Share	Population	Share
Greater Mumbai	**11,914,398**	**100.00**	**13,504,324**	**100.00**	**15,166,615**	**100.0**	**16,675,115**	**100.0**
Island City	3,326,837	27.92	3,360,255	24.88	3,394,009	22.38	3,411,017	20.46
Western Suburbs	5,095,685	42.77	6,031,316	44.66	6,999,588	46.15	7,886,378	47.29
Eastern Suburb	3,491,876	29.31	4,112,753	30.46	4,773,018	31.47	5,377,720	32.25

Table 3.2
Annual Growth Rates: Greater Mumbai

Name of the Area	1991-2001	2001-2011	2011-2021	2021-2031
Greater Mumbai	1.92	1.26	1.17	0.95
Island City	0.60	0.10	0.10	0.05
Western Suburb	2.58	1.70	1.50	1.20
Eastern Suburb	2.35	1.65	1.50	1.20

Using the aggregate estimates and following the guidelines of the Committee, the census sectionwise population was worked out.

Table 3.3
Population Growth in MMR

(Population in Lakh)

Region	2001	% Gr	2011	% Gr	2021	% Gr	2031
Gr. Mumbai	119.1	1.26	135.0	1.17	151.7	0.95	166.7
Western Region	11.9	4.40	18.3	3.79	26.6	3.05	35.9
North East Region	41.9	2.86	55.7	2.47	71.1	1.85	85.5
Navi Mumbai Region	10.5	5.62	17.4	4.11	25.9	3.46	36.5
Neral Karjat Region	1.9	1.65	2.3	1.61	2.7	1.55	3.2
Pavvel-Urban Reg. (Ourside Navi Mumbai	2.6	4.06	3.9	4.63	6.1	4.89	9.9
Pen Region	0.9	1.05	1.1	1.29	1.2	1.74	1.4
Alibag Region	1.2	0.92	1.3	0.85	1.4	0.75	1.5
TOTAL	190.0		235.0		286.7		340.6

3.5.2 Employment

The employment projections of Island City, Western Suburbs and Eastern suburbs of Greater Mumbai as provided by the planning department of MMRDA (based on national economic census data) are as shown in **Table 3.4**. The corresponding annual growth rates of employment are given in **Table 3.5**.

Table 3.4
Areawise Employment Projections for Greater Mumbai

(Employment in lakh)

Year	Greater Mumbai	Island City	Western Suburb	Eastern Suburb
1980	22.0	14.0	5.1	2.9
1990	24.3	13.5	6.4	4.4
1998	26.3	15.9	6.5	3.8
2001	27.1	16.0	7.1	4.1
2011	29.3	16.1	8.4	4.8
2021	31.6	16.3	9.7	5.6
2031	33.6	16.4	10.9	6.3

Table 3.5
Annual Growth Rates of Employment for Greater Mumbai

Period	Greater Mumbai	Island City	Western Suburb	Eastern Suburb
1980-1990	0.99	-0.36	2.34	4.09
1990-1998	0.99	2.06	0.31	-1.68
1998-2001	1.09	0.17	2.60	2.23
2001-201	0.78	0.10	1.70	1.65
2011-2021	0.75	0.10	1.50	1.50
2021-2031	0.62	0.05	120	1.20

Using the aggregate estimates and following the guidelines of the Committee, the employment distribution was worked out considering the following development scenarios.

Scenario 1.

The following development aspects form this scenario.

1. There will be additional employment of 88,011 by 2011 due to mill land development in Island city. This has been worked out assuming 10 sqm built area per employee. The corresponding shift of assumed employment from Western and Eastern Suburbs to Island City has been in the proportionate manner.

2. In addition, the growth of Bandra – Kurla complex (i.e. census section 48) has been considered by increasing the employment figures to 75,000 in 2006, 1,000,00 in 2011 and 2,00,000 in 2031.

3. Also the growth in Andheri (E) i.e. MIDC & SEEPZ (i.e. census section 55) has been considered by increasing the employment to 190,000 by 2031 and implementing a reduction of 16,000 in Mahul, Trombay, Govandi, Vadavali Borla Mankhurd & Mandala (i.e. census section 80).

Scenario 2

The following development aspects form this scenario.

1. There will be additional employment of 88,011 by 2011 due to mill land development in island city. This is considered as new employment adding to the total employment of Greater Mumbai.

2. In addition, the rapid growth of Bandra – Kurla Complex (i.e. census section 48) has been considered by increasing the employment figures to 75,000 in 2006, 1,00,000 in 2011 and 2,00,000 in 2031.

3. Also the growth in Andheri (E) i.e. MIDC & SEEPZ (i.e. census section 55) has been considered by increasing the employment to 190,000 by 2031

and implementing a reduction of about 26,000 in Mahul, Trombay, Govandi, Vadavali Borla Mankhurd & Mandala (i.e. census section 80).

3.5.3 Vehicle Ownership

In order to design the vehicle ownership variable and to use it in modeling of the trip ends of the base year (2003), the vehicle ownership data for Greater Mumbai was used. **Table 3.6** presents this data from 1981 to 2002 for Greater Mumbai.

Table 3.6
Private Vehicle Ownership in Greater Mumbai

Year	Pvt Vehicle Population	Population	Pvt Vehicle per 1000 population
1981	229185	8243405	27.80
1986	365190	8958013	40.76
1991	506959	9925891	51.07
1995	516640	10678015	48.38
1998	649654	11279279	57.60
2002	828769	12133955	68.30

A logistic model of the form

Y = S/ (1 + a e – bt)

Where

Y = Vehicles owned per thousand population
S = Saturation level
T = time in year
a and b = parameters to be estimated

was used for the vehicle ownership data. The analysis was based on the assumption that the vehicle ownership would reach a saturation level of 150 veh/1000 population eventually. The estimates of vehicle ownership obtained for the years, 2011, 2021 and 2031 are given in **Table 3.7**.

Table 3.7
Projected Vehicle Ownership in Greater Mumbai

Year	Vehicles per 1000 population	Population	No. of Vehicles
2011	86	13504324	1161415
2021	106	15166615	1608210
2031	120	16675115	1996032

For estimation of the number of vehicles in each zone, the projected number of private vehicles of each region were distributed to the zones of that region, proportionately, based on the population and projected vehicles per 1000 population in that year.

3.6 TRAFFIC DEMAND FORECASTING

3.6.1 Updating of Travel pattern from prior base year (1996)

Separate trip and models were developed for public Transport, Private Vehicles and IPT passenger using connected planning variables. Trip end models were developed using stepwise multiple regression technique. The network for 1996 was further strengthened and incorporated in TRIPS.

3.6.2 Conversion of Daily O-D Matrix to Peak Hour Matrix

The peak hour O D Matrix was obtained by applying appropriate daily to ph conversion factors using area specific factors and separately for each mode.

3.6.3 Assignment of Base Year O-D Matrices and validation

The O D matrices for 2003 were thoroughly validated by comparing the interchange of assigned trips across seven lines with the volume counts.

The public transport assignment is done based on generalized time. The components of generalized time are in-vehicles travel time, waiting time, transfer time, fare and discomfort in time units.

3.6.4 Highway Assignment

The highway assignment has been carried out for peak hour preloading the highway network with P H public transport flows. An equilibrium procedure based on generalized cost was used in loading these matrices.

3.6.5 Validation with Link flows across screen lines

The rail flows assigned across the screen lines were compared with rail flows projected by MRVC. In the case of road-based flows the assigned link flows for all the screen lines were found to match within reasonable degrees of accuracy with observed flows.

3.6.6 Base Year (2003) Model

Trip Ends of internal passenger trips by all modes for the base year (2003) were calculated from validated O-D matrices. These were developed using stepwise linear regression technique for Trip production and Trip attraction. A Gravity Trip Distribution model was calibrated for distributing the total passenger trips. The Modal split parameters for Public Transport and private vehicle split were estimated using the skims obtained from P T and Highway assignment.

3.7 FORECASTING OF O D MATRICES

The calibrated trip end equations were for the daily internal person trips were applied on the projected planning variables for 2011, 2021 and 2031 to get the future trip ends of internal daily person trips.

The O-D matrix of daily person trips thus obtained for the future was split into public transport matrix (passenger trips) and daily private vehicle passenger trips, using calibrated mode choice model.

3.8 ASSIGNMENT OF O-D MATRICES ON THE NETWORK

The peak hour O-D matrix P T passenger trips was assigned to public transport network, for BEST bus, suburban train and Metro plan. Similarly daily matrices of private vehicle person trips were converted to Peak Hour O-D matrix in passenger car units by applying appropriate factors. The truck peak hour PCU matrix was loaded on to the preloaded network. The appropriate speed flow relationships were used for this purpose.

3.9 RIDERSHIP ON VERSOVA – ANDHERI – GHATKOPAR CORRIDOR

The station to station link loading in both directions during peak hour for the years 2011, 2021 and 2031 are given in the **Table 3.8** , below as per the traffic forecast made at the time of preparation of Mumbai Metro Master Plan:

Table 3.8
Station – station Link Loads

Station	Station	2011		2021		2031	
		To Versova	To Ghatkopar	To Versova	To Ghatkopar	To Versova	To Ghatkopar
Ghatkopar	Asalpha	19511	24446	24816	28602	34144	38376
Asalpha	Subhash Nagar	20235	24778	25646	29016	25501	39144
Subhash Nagar	Saki Naka	20243	24778	25653	29016	35515	39144
Saki Naka	Marol Naka	20889	25809	26944	30374	37264	40872
Marol Naka	Airport Road	23716	29225	31578	36270	42306	46615
Airport	Chakala	23718	29219	31580	36256	42309	46600
Chakala	W E H	24307	30484	33420	38691	44574	50085
W E H	Andheri Metro	24418	31126	33449	39316	44799	50912
Andheri Metro	Azad Nagar	12957	14831	17672	18904	21186	22542
Azad Nagar	D N Nagar	4051	3341	5419	4403	7138	5580
D N Nagar	Versova	304	365	609	609	694	716

3.10 THE TRAFFIC FORECAST FOR "STAND ALONE" SCENARIO

The traffic forecast on the Versova- Andheri – Ghatkopar corridor has been described in the earlier paragraphs. As the MMRDA was of the view that it is likely that this corridor alone will be functional at least in the year 2011 it is necessary to forecast the traffic on the corridor on stand alone basis.

The Master Plan estimates are slightly higher than those of the earlier studies of SMART (1997) and CES update (2003). The main reason is that in our methodology taking into account the element of "Discomfort in time units" as part of generalized time. The discomfort values are based on the stated preference surveys. The other governing factors for ridership forecast are population and employment growth and distribution. These factors are largely dependant upon the Government policies, attractiveness of Mumbai in general and growth of surrounding influence / catchment areas around Versova _ Andheri – Ghatkopar corridor. Also, there are other competing modes like BEST bus Service, Auto rickshaws and Taxies, whose services offer greater penetration and accessibility (almost door-to-door) as compared to fixed route and station controlled MRTS system. Therefore the shift expected from these modes to Metro system may not reach the values as assumed theoretically. Besides, any new system introduced in existing urban scenario will require some time to settle and win commuter confidence and entice them to reorganize their travel behavior.

Keeping in view the above uncertainty it is expected that ridership estimates will be less than the model results. Such conservative estimates will also project realistic economic / financial benefit and help to generate confidence in the BOOT operators. For the purpose of DPR the loadings and PHPD flows are assumed to be 50 % of the Master plan estimates in the year 2011 and 60% in the year 2021 and beyond. It is estimated that about 40% of reduction is because of discomfort element , shift from competing modes, population and employment projection short fall and initial time required to build up confidence in the users.

Another 10% reduction in the year 2011 is because of the fact that in that year entire master plan corridors will not be in place. The traffic for intermediate years have been estimated by interpolation. The peak hour link loading and Boarding/Alighting figures are shown in **Table 3.9 and 3.10** respectively.

Table 3.9
Proposed Peak Hour Link loadings on Versova- Andheri – Ghatkopar adopted for Economic analysis & Station Planning

Station	Station	2011		2021		2031	
		To Versova	To Ghatkopar	To Versova	To Ghatkopar	To Versova	To Ghatkopar
Ghatkopar	Asalpha	9755	12225	14890	17160	20485	23025
Asalpha	Subhash Nagar	10115	12390	15390	17410	15300	23485
Subhash Nagar	Saki Naka	10120	12390	15390	17410	21310	23485
Saki Naka	Marol Naka	10440	12905	16165	18225	22360	24525
Marol Naka	Airport	11860	14615	18945	21760	25385	27970
Airport	Chakala	11860	14610	18950	21755	25385	27960
Chakala	W E H	12155	15240	20050	23215	26745	30050
W E H	Andheri Metro	12210	15565	20070	23590	26880	30550
Andheri Metro	Azad Nagar	6480	7415	10605	11340	12710	13525
Azad Nagar	D N Nagar	2025	1670	3250	2640	4285	3350
D N Nagar	Versova	150	185	365	365	415	430

Table 3.10
Peak Hour Boarding and Alighting

	2011		2021		2031	
Station Name	**Boarding**	**Alighting**	**Boarding**	**Alighting**	**Boarding**	**Alighting**
Versova	183	152	237	198	317	264
D N Nagar	1492	1874	1941	2439	2591	3256
Azad Nagar	5958	4670	7753	6081	10347	8116
Andheri Metro	9476	7059	12330	9191	16456	12267
WEH	1592	1858	2072	2419	2765	3228
Chakala	2077	2415	2703	3145	3607	4197
Airport Road	4	0	5	0	7	0
Marol Naka	1891	2191	2460	2852	3283	3807
Saki Naka	1502	2010	1954	2617	2609	3493
Subhash Nagar	4	0	5	0	7	0
Asalpha	365	168	474	219	633	292
Ghatkopar Metro	9756	12223	12694	15916	16942	21243
	34298	**34618**	**44628**	**45076**	**59565**	**60163**

CHAPTER 4

SYSTEM SELECTION

4.0 PERMANENT WAY

4.1 CHOICE OF GAUGE

Standard Gauge (1435mm) is invariably used for metro railways world over. During the last decade, many metros such as Cairo, Madrid, Bangkok, Manila, Beijing etc. have been constructed in various cities of the world. All these metros have gone in for Standard Gauge even though the national gauge for mainline railways in some of these countries was different from Standard Gauge. In India the national gauge is Broad Gauge (1676mm). The question whether Mumbai Metro should go in for Broad Gauge or Standard Gauge has, therefore, been examined with following important parameters.

(i) Metro alignments in a city have to pass through heavily built-up areas for optimal passenger utilisation and this imposes severe restrictions on the selection of curves. As in most of the cities in India no 'right of way' has been reserved for metro systems, the alignments have to follow the major arterial roads. These roads may often have sharp curves and right-angle bends. In such a situation adoption of Standard Gauge is advantageous since it permits adoption of sharper curves compared to Broad Gauge to minimise property acquisition along the alignments.

(ii) In Standard Gauge 1 in 7 and 1 in 9 turn-outs, which occupy lesser length, are feasible compared to 1 in 8 ½ and 1 in 12 turn-outs required for Broad Gauge. Length of cross-overs for Standard Gauge is thus lesser than for Broad Gauge. Land requirement for depots where a large number of lines connected together in the shape of ladder is also reduced. Standard Gauge is, therefore, more suited for use in built up environment where land availability is scarce.

(iii) For Standard Gauge, optimised state-of-the-art rolling stock designs are available ‘off-the-shelf’. This is not so for Broad Gauge where new designs for rolling stock have to be specially developed which entails extra time and cost.

(iv) Because of the availability of a very large market, constant up-gradation of technology takes place for Standard Gauge coaches. Thus upgraded technology is available on a continued basis in case of Standard Gauge. This is not so in case of Broad Gauge.

(v) For the same capacity gross weight of a metro coach is lower for Standard Gauge than for Broad Gauge. Standard Gauge rolling stock thus results in recurring saving in energy consumption during operation.

(vi) Once technology for Standard Gauge coaches get absorbed and a manufacturing base for them is set up in India, there will be considerable export potential for the coaches, since almost all the countries use Standard Gauge for their metros. This is not so in case of Broad Gauge.

(vii) It is some time argued that adoption of Broad Gauge for metros would enable inter-running of metro trains with Indian Railways since the latter uses Broad Gauge. Inter-running is, however, technically and / or operationally not feasible as the two systems have different:

- Rolling Stock characteristics,
- Signalling Systems,
- Headways,
- Tariffs,
- Moving dimensions, and
- Loading standards.

(viii) Track gauge is not a technical parameter for any metro rail system. It is a planning parameter. This issue was also examined in January 2000 by the Ministry of Law and Justice who had opined that the choice of gauge is a matter which lies within the jurisdiction of the metro rail organisation entrusted with the responsibility of implementing and operating the metro systems.

Since inter-running is not feasible, choice of Gauge for a metro system should be based solely on technical and economic considerations on which Standard Gauge turns out to be superior.

From the above, it is seen that Standard Gauge will be cost-effective and at the same time enable Mumbai Metro to be at par with world-class metros and enable it to remain technically up-dated in future. Standard Gauge will also enable setting up a manufacturing base for coaches required for metros in other cities of the country as well create an export potential for such coaches. Adoption of Standard Gauge is, therefore, recommended for Mumbai Metro. A wider gauge is not justified for 3.2 m wide coach and axle loads are as low as 17 ton for Standard Gauge Metro.

Further a note on selection of gauge and use of 3.20m wide coaches instead of 3.66m wide coaches as Annexure 1 at end of this chapter.

4.2 TRACK STRUCTURE

Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus it is imperative that the track structure selected for Metro Systems should be long lasting and should require minimum or no maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy in view.

4.2.1 General

Two types of track structures are proposed for any Metro. The normal ballasted track is suitable for At-Grade (surface) portion of Main Lines and in Depot (except inside the Workshops, inspection lines and washing plant lines. The ballastless track is recommended on Viaducts and inside tunnels as the regular cleaning and replacement of ballast at such location will not be possible. In case of Versova - Andheri - Ghatkopar corridor even the depot is elevated, hence ballastless track is proposed for adoption throughout.

From considerations of maintainability, riding comfort and also to contain vibrations and noise levels, the complete track is proposed to be joint less and for this purpose even the turnouts will have to be incorporated in LWR/CWR.

The track will be laid with 1 in 20 canted rails and the wheel profile of Rolling Stock should be compatible with the rail cant and rail profile.

4.2.2 Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened as per IRS-T- 12-96. As these rails are not manufactured in India at present, these are to be imported. For the Depot lines, the grade of rails should be 880, which can be easily manufactured indigenously.

4.2.3 Ballastless Track on Main Lines (Viaducts)

On the viaducts, it is proposed to adopt plinth type ballastless track structure with RCC derailment guards integrated with the plinths (shown in **Fig.1**). Further, it is proposed to adopt Vossloh-336 Fastenings System (shown in **Fig.2**) or any other suitable system on both types of ballastless track structures, with a base-plate to base-plate spacing of 65 cm. on viaducts. Most of the components of Vossloh-336 fastening system are now indigenously available. The toe load design for the clips is to be finalised at the detail design stage.

4.2.4 Ballastless Track in Depot

The ballastless track in Depot may be of the following types:

- Discretely supported on concrete/steel pedestal for inspection lines.
- Embedded rail type inside the Workshop.
- Plinth type for Washing Plant line.
- Normal Ballastless (as on viaduct) for Stabling and other running lines.

4.2.5 Turnouts

- From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:

  i) On main lines, 1 in 9 type turnout with a lead radius of 300 metres and permissible speed on divergent track as 40 km/h (shown in **Fig.3**).

  ii) On Depot lines, 1 in 7 type turnout with a lead radius of 400 metres and permissible speed on divergent track as 25 km/h (shown in **Fig.4**).

- The Scissors cross-overs on Main Lines (1 in 9 type) will be with a minimum track centre of 4.5 m (shown in **Fig.5**).

- The proposed specifications for turnouts are given below: -

  i) The turnouts should have fan-shaped layout throughout the turnout so as to have same sleepers/base-plates and slide chairs for both LH and RH turnouts.

  ii) The switches and crossings should be interchangeable between ballasted and ballastless turnouts (if required).

- The switch rail should be with thick web sections, having forged end near heel of switch for easy connection with lead rails, behind the heel of switch. The switches should have anti creep device at heel of switch for minimising the additional LWR forces transmitted from tongue rail to stock rail.

- The crossings should be made of cast manganese steel and with welded leg extensions. These crossings should be explosive hardened type for main lines and without surface hardening for Depot lines.

- The check rails should be with UIC-33 rail section without being directly connected to the running rails.

4.2.6 BUFFER STOPS

On main lines and Depot lines, friction buffer stops with mechanical impact absorption (non-hydraulic type) need to be provided. On elevated section the spans on which friction buffer stops are to be installed are to be designed for an additional longitudinal force of 85 T, which is likely to be transmitted in case of Rolling Stock impacting the friction Buffer Stops.

4.3 RAIL STRUCTURE INTERACTION

For continuing the LWR/CWR on Viaducts, the elevated structures are to be adequately designed for the additional longitudinal forces likely to be transmitted as a result of Rail-Structure interaction. Rail structure interaction study will determine the need and locations of Rail Expansion Joints (REJ) also. REJ in ballasted track will be for a maximum gap of 120 mm, whereas on ballastless track for a maximum gap of 180 mm.

4.4 WELDING

Flash Butt Welding Technique is to be used for welding of rails. Alumino-Thermic Welding is to be done only for those joints which cannot be welded by Flash Butt Welding Technique, such as joints at destressing locations and approach welds of switches & crossings. For minimising the population of Thermit welds, mobile (rail-cum-road or portable) Flash Butt Welding Plant will have to be deployed.

4.5 TRACTION SYSTEM

Traditionally, electric traction is used in Metro systems for requirement of high acceleration and pollution-free services in urban areas. There are three standard and proven systems of electric traction for use in suburban and metro lines, viz.: - 750V dc third rail, 1500V dc overhead catenary and 25kV ac overhead catenary system. All the three systems are presently in use in India (750 V DC third rail in Kolkatta Metro, 1500V dc catenary in Mumbai suburban of Central & Western Railways and 25kV ac catenary in Delhi Metro & Indian Railways). However, conversion of 1500 V dc to 25kV ac is currently in progress in Mumbai suburban areas of Central and Western Railways.

750V dc third rail system has been extensively used in metros and more than 60% of existing metro systems in the world utilise 600-750V dc third rail system. The system does not negate the aesthetics of the city as it is laid alongside the track and also requires smaller tunnel diameter for underground section compared to other systems. This system has a technical limitation beyond a traffic level of 60,000 PHPDT on account of requirement of large number of traction sub-stations and difficulty in differentiation between over-current and short-circuit currents. Few recently commissioned Metro systems with 750V dc third rail are Bangkok Transit System (1999), Athens Metro (2000), Istanbul Metro (2001) and Tehran Metro (2000). All these are medium capacity Metro systems designed for a traffic level up to 45000 PHPDT.

1500V dc catenary system has been adopted by some of heavy metros to overcome the limitation imposed by 750V dc system for catering to traffic level of 60,000-80,000 PHPDT (e.g. Singapore, Hong Kong, Guangzhou etc.). This system requires use of catenary masts and messenger wires on elevated viaducts thereby affecting aesthetics of the city.

Stray current corrosion is often encountered in dc-electrified railways and therefore, suitable measures are required for protection against corrosion of metallic structures, reinforcement and utility pipes caused by dc stray current. Some of the old Metros are spending heavily on corrosion repairs caused by dc stray currents.

25kV ac traction has the economical advantages of minimal number of traction sub-stations and potential to carry large traffic (60,000-90,000 PHPDT). The system requires catenary masts on surface/elevated section, thereby affecting aesthetics and skyline of the city. Suitable measures are required for mitigation of electro-magnetic interference (EMI) caused by single-phase 25kV ac traction currents. EMI mitigation measures are simple and well known compared to dc stray current corrosion protection.

Typical 25kV AC Catenary Arrangement

Traffic requirements of the Mumbai Metro have been projected in the range of 50,000-60,000 PHPDT in horizon year 2031. The alignment of proposed corridor is on elevated viaducts and future extensions are also mostly on elevated sections. Keeping in view the ultimate traffic requirements, standardisation, commonality of traction system with Western & Central Railway and other techno-economic considerations, 25kV ac Catenary traction system is considered to be the best trade-off and hence, proposed for adoption on Mumbai Metro System. Since the route is on elevated viaducts with wide roads, it would not be prone to safety hazards to public and residents of nearby buildings as well. However, suitable measures will have to be implemented for mitigation of EMI & EMC caused by 25 kV single-phase traction currents.

4.6 SIGNALLING

4.6.1 Introduction

The signaling system shall provide the means for an efficient train control, ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on the network.

4.6.2 Signalling and Train Control

4.6.2.1 Overview

Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. These requirements of the metro are planned to be achieved by adopting a automatic signaling in the section and balise based ATP, State of Art automatic train supervision system. This will:

- Provide high level of safety with trains running at close headway (3 minutes), ensuring continuous safe train separation.
- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
- Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed / Distance to Go status in his cab enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather.
- Increased productivity of rolling stock by increasing line capacity and train speeds, and enabling train to arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock.

- Improve maintenance of Signalling and telecommunication equipments by monitoring system status of trackside and train born equipments and enabling preventive maintenance.

A Signalling and control system shall be provided on all running tracks of the metro including car shed except for lines used mainly for local shunting. At all stations with points and crossings, computer based interlocking will be provided for operation of points and crossings/setting of routes including track of adjacent station. The control of train operation will be done from computer based operation control centre (OCC) and will be supervised by Traffic Controller. Facilities for setting of the route and clearing of the signals will also be provided from workstation/CCIP located at stations with points and crossings. The depot shall be interlocked and equipments with a workstation / CCIP to control and supervise the movements within its yards.
To ensure safety with close headway of train services (3 minutes headway) and for optimization of heavy investment in the infrastructure and rolling stock, the metro shall be provided with an automatic train protection and supervision system. This will enable running of optimum train services meeting traffic requirements in the most efficient and cost effective way.

4.6.2.2 Selection of System

The Signalling and Train Control system shall be as below:

a. Interlocking System:

At all stations with points and crossings, Solid State Interlocking (SSI) will be provided for operation of points and crossings and setting of routes.

The setting of the route and clearing of the signals will be done by work station which can be either locally (at station) operated or operated remotely from the Operation control Centre (OCC). All the sections on the corridor is automatic signaling.

b. Train Depot : Signalling

The depot for Versova - Ghatkopar corridor is situated at Versova. All depot lines except the ones used for shunting and in workshop shall be interlocked. A workstation each shall be provided in the Depot Control Centre for electrical operation of the points, signals and routes of the depot yard.

c. Automatic Train Protection

To ensure safety in train operation and to provide optimum train services on the section the train control on the metro shall be provided with Automatic Train Protection (ATP) system. For this the transmission from track to train will be intermittent through balise based ATP. Facilities for automatic enforcement of temporary / permanent speed restrictions shall also be built in to enhance safety during maintenance work.

d. Train supervision and Control Office

A train supervision system will be installed to facilitate the monitoring of train operation and also remote control of the stations .The train supervision will log each train movement and display it on the workstations with each Traffic Controller at the OCC and on one workstation placed in the Station Control room (SCR) with each Station Controller.

4.6.2.3 Standards

The following standards will be adopted with regard to the Signalling system.

Description	Standards
▪ Interlocking	Solid State Interlocking adopted for station having switches and crossing. All related equipment as far as possible will be centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for shunting, workshop/inspection shed areas.
▪ Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
▪ Track Circuit	Audio frequency Track circuits on running section, test track and in depot.
▪ Signals at Stations	Line Side signals to protect the points (switches).
▪ UPS (uninterrupted power at stations as well as for OCC)	For Signalling and Telecommunications
▪ Signalling along the line.	Automatic signalling (Three aspect) . LED type signals for reliability and reduced maintenance cost.
▪ Train protection systems	Automatic train control with over speed protection and protection against signal passing at danger.
▪ Train Describer System	Movement of all trains to be logged on to a central computer and displayed on workstations in the Operational Control Centre and at the SCR. Remote control of stations from the OCC.

▪ Redundancy for TP/Train Describer.	Future space provision for redundancy for Train born equipments. Redundancy to be provided for ATS at OCC.
▪ Cables	Cables will be steel armoured, as far as possible.
▪ Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for signal application.
▪ Immunity to External Interface.	All data transmission on telecom cables/ OFC/Radio. All Signalling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.
▪ Train Working Under emergency	Running on site with line side signal.
▪ Environmental Conditions	Air-conditioners for all equipment rooms (except UPS room).
▪ Maintenance philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling equipments shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs under taken in the central laboratory/ manufacturer's premises.

4.6.3 Specifications

4.6.3.1 Line Side Signalling and Train Protection

Line Side Signalling and Train protection is the primary function of the train control systems. This sub-system will be inherently capable of achieving the following objectives in a fail-safe manner.

- Prevent rear-end or side collision resulting from one train trying to over-take the other.
- Prevent trains being routed on the conflicting routes.
- Prevent the possibility of points / switches moving just ahead of or under train.
- Not hindering the vehicles attaining maximum permissible speed.

Basic sub-system will include the following modules:-

i) Train detection
ii) Train Protection
iii) Solid State Interlocking
iv) Signal and speed enforcement.
v) Brake assurance
vi) Interface with electrical sub-systems of the vehicle like brake control.

- Track circuits will be used for vehicle detection.
- Balise will be used for transmission of data from track to train
- Sub-system/components will conform to international standards like BS, IS, CENELEC, IEC, ITU-T etc.

4.6.3.2 The cab borne equipment

These will be of modular sub-assemblies for each function for easy maintenance and replacement. The ATP assemblers will be fitted in the vehicle integrated with other equipment of the rolling stock.

4.6.3.3 Train Supervision

Train supervision system will be installed in the Operation control center and at the stations with point and crossings and will have a panoramic view of the sectional jurisdiction showing the status of tracks, points, signals and the vehicles operating in the relevant section/ whole system. The system shall provide train information in real time and in printouts for later analysis. It shall be possible to set route of trains at terminals, mid-terminals and runback stations, etc. both locally and remotely. It shall have audio-visual alarms for deficiencies / malfunctioning.

4.6.3.4 SSI at Stations

This sub-system is used for controlling vehicle movements into or out of stations automatically from a workstation. All stations having points and crossings will be provided with workstations for local control. Track occupancy, point position, etc. will be clearly indicated on the workstation. It will be possible to operate the workstation locally, if the central control hands over the operation to the local station. The system design will be on the basis of fail-safe principle.

The equipment will withstand tough environmental conditions encountered in a Mass Transit System. Control functions in external circuits will be proved both in the positive and negative wires. Suitable IS, IRS, BS standards or equivalent international standards will be followed in case wiring, installation, earthing, cabling, power supply and for material used in track circuits, relays, point operating machines, power supply etc.

4.6.4 Space Requirement for S & T Installations

Adequate space for proper installations of all Signalling equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for S & T equipment shall be generally 40 sq.m for UPS Room (common for signaling and telecom) and 40 sq.m at interlocked station with points & 25 sq.m at other stations for Signalling. These areas shall also cater to local storage and space for maintenance personnel to work. At the OCC and the Depot, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

4.6.5 Maintenance Philosophy for Signalling systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipments shall be followed. Card / module / sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralised S&T repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipments to rectify the faults and undertake minor repairs. Cards / modules / equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

4.7 TELECOMMUNICATION

4.7.1 Introduction

The telecommunication system acts as the communication backbone for Signalling systems and other systems such as SCADA, AFC etc and provides telecommunication services to meet operational and administrative requirements of metro network.

4.7.2 Telecommunication

4.7.2.1 Overview

The telecommunication facilities proposed are helpful in meeting the requirements for

1. Supplementing the Signalling system for efficient train operation.
2. Exchange of managerial information
3. Crisis management during emergencies
4. Passenger information system

The proposed telecom system will cater to the following requirements:

- Train Traffic Control
- Assistance to Train Traffic Control
- Maintenance Control
- Emergency Control
- Station to station dedicated communication
- Exchange Telephone
- Passenger Announcement System within the station and from Central Control to each station.
- Centralised Clock System
- Train Destination Indicator
- Instant on line Radio Communication between Central Control and Moving Cars and maintenance personnel.
- Data Channels for Signalling, SCADA, Automatic Fare Collection etc.

4.7.2.2 Telecommunication System and Transmission Media

i) Optical Fibre Cable - Main Telecommunication Bearer

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a optical fiber cable is proposed to be laid in ring configuration with path diversity.

SDH STM-1 155 Mbps based system shall be adopted with SDH nodes at every station, OCC and depot. Access 2MB multiplexing system will be adopted for the lower level at each node, equipped for channel cards depending on the requirement of channels in the network. Further small routers and switches shall be provided for LAN network at station.

ii) Telephone Exchange

For a optimised cost effective solution a mix of medium and small exchanges are planned. Three EPABX of 512 ports will be provided at four locations preferably one at the OCC, one at an intermediate station and other at the depot. Small exchanges of 30 port each shall be at each station. These are to be connected together through optical fiber, which will provide communication at each stations and depots. The Exchanges will serve the subscribers at all the stations, OCC and depot. The exchanges will be interconnected at multiple 2 MB level through optical fibre cable. The Exchanges shall be software partitioned for EPABX and Direct Line Communication from which the phones shall be extended to the stations.

iii) Mobile Radio Communication

Mobile Radio communication system having 8 channels is proposed for on-line emergency communication between Motorman (Front end and Rear end) of moving train and the Central Control. The system shall be based on Digital Trunk Radio Technology to TETRA International standard. This system now is widely adopted for mobile radio communication in metro / rapid transit services abroad. All the stations and Car Depot will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets.

These persons will be able to communicate with each other as well as with central control. To provide adequate coverage, based on the RF site survey to be carried out, base stations for the system will be located at a site conveniently selected after detailed survey. Preliminarily it is anticipated that minimum seven Radio Base stations shall be required, interlinked to the Central Radio Equipment at the OCC through channels on the optical fibre system.

The frequency band for operation of the system will be that for TETRA in 400/800 MHz band depending upon availability of frequency. Instant mobile radio communication between the motorman of the moving cars from any place and the Central Control can be established. The motorman can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

iv) Passenger Announcement System

The system shall be capable of announcements from the local station as well as from OCC. Announcements from OCC will have over-riding priority in all announcements.

v) Centralised Clock System

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the operation control center. The Master Clock signal shall also be required for synchronization of SDH and Exchanges. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Master's Room and other service establishments etc.

vi) Train Destination Indicators

These shall be located at convenient locations at all stations to provide bilingual visual indication of the status of the running trains and will typically indicate information such as destination, arrival/departure time, and also special messages in emergencies. The boards shall be provided at all platforms and concourses of terminal & junction stations.

vii) Network Monitoring and Management

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a network management systems (NMS), which will help in diagnosing faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance.

The proposed NMS system will be covering radio communication, Optical Fiber Transmission system and Telephone Exchange.

4.7.2.3 Standards

The standards proposed to be adopted for telecommunication systems are shown in Table below:

System	Standards
• Transmission System	**SDH based** for the entire telecom network.
• Transmission Media	**Optical Fibre system** as the main bearer for bulk of the telecommunication network,
• Telephone Exchange	EPABX of 512 ports is to be provided at four locations preferably one at OCC, one at an intermediate station and other at both depot. Further small exchanges shall be at each station.
• Train Radio System	**Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel and central control.**
• Train Destination Indicator System	**LED based boards** with adequate visibility to be provided at convenient location at all stations to provide bilingual visual indication of the status of the running trains, and also special messages in emergencies.
• Centralized clock system	Accurate display of time through a synchronisation system of slave clocks driven from a master clock at the OCC and sub – master clock in station. This shall also be used for synchronisation other systems.
• Passenger Announcement System	**Passenger Announcement System** covering all platform concourse areas with local as well as Central Announcement.
• Redundancy (Major System)	Redundancy on Radio base station equipment. Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
• Environmental Conditions	All equipment rooms to be air-conditioned except UPS room.
• Maintenance Philosophy	System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. Philosophy of preventive checks of maintenance to be followed. System networked with NMS for diagnosing faults and co-ordination. Card/module level replacement shall be done in the field and repairs undertaken in the central laboratory/manufacture's premises.

4.7.3 Car Depot

Car Depot will be provided with a Mobile Radio Dispatcher System for Depot/Yard communication connected from the central infrastructure at the OCC, to provide communication from the Depot Control Room to Mobile sets in the Cabs of the cars and hand held sets with the maintenance personnel of the depot.

All the offices and the Maintenance installations at Car Depot will be connected with EPABX telephones and will be fed from the nearest Exchange.

4.7.4 Space Requirement for Telecom Installations

Adequate space for proper installations of all Telecommunication equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for S & T equipment shall be generally 40 sq.m each for Telecomm Room, UPS Room (common for signal and telecom). These areas shall also cater to local storage and space for maintenance personnel to work. Radio tower shall be located at approximately 5 km interval along the section. The tower may be placed as near to Base Station Equipment Rooms as possible but not more than 40 - 50 m away from it. Necessary land/ space acquisition (8mX8m) for the same should be planned. However at detailed design stage it can be checked whether these can be provided over the station. At the OCC and the Depot, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

4.7.5 Maintenance Philosophy for S & T systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipments shall be followed. Card / module / sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipments to rectify the faults and undertake minor repairs. Cards / modules / equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

4.8 AUTOMATIC FARE COLLECTION

4.8.1 Introduction

Mass Rapid Transit Systems handle large number of passengers. Ticket issual and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower.

In view of above, computer based automatic fare collection system is proposed.
AFC system proves to be cheaper than semi-automatic (manual system) in long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines, overall less cost of recyclable tickets (Smart Card/Token) in comparison to paper tickets and prevention of leakage of revenue.
Relative advantages of automatic fare collection system over manual system are as follows:

A) Manual fare collection systems have the following inherent disadvantages:

1. Large number of staff is required for issue and checking of tickets.
2. Change of fare structure is time consuming as has to be done at each station.
3. Manipulation possible by jamming of mechanical parts.
4. Staff and passenger interaction leading to more chances of confrontation.
5. 100% ticket checking at entry / exit impossible.

B) Automatic fare collection systems have the following advantages:

1. Less number of staff required.
2. Less possibility of leakage of revenue due to 100% ticket check by control gates.
3. Recycling of ticket fraudulently by staff avoided.
4. Efficient and easy to operate, faster evacuation both in normal and emergency.
5. System is amenable for quick fare changes.
6. Management information reports generation easy.
7. System has multi-operator capabilities. Same Smart Card can be used for other applications also,
8. AFC systems are the worldwide accepted systems for Metro environment.

The proposed ticketing system shall be of Contactless Smart Token/ Card type. The equipments for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Master's room. Equipment and installation cost of Contactless Smart Card /Token based AFC system is similar to magnetic ticket based AFC system, but Contactless system proves cheaper due to reduced maintenance, less wear and tear and less prove to dusty environment.

C) Choice of Control Gates

Retractable flap type Control Gates are proposed which offer high throughput (45 passengers per minute), require less maintenance and are latest in modern metros internationally. Tripod turnstile type or pneumatic flap type gates offer less throughput and require more maintenance. Bi-parting flap gates though offer good throughput but require more discipline from patrons.

D) Passenger Operated Machine

Space for provision of Passenger Operated Machines (Automatic Ticket Dispensing Machines) for future, shall be provided at stations.

4.8.2 Standards

The standard proposed for AFC systems are as under:

Standards	***Description***
• Fare media	a) **Contactless smart token** – For single journey. They shall have stored value amount for a particular journey. Tokens are captured at the exit gate. b) **Contactless smart card** – For multiple journeys.
• Gates	Computer controlled retractable flap type automatic gates at entry and exit. There will be following **types of gates**: • **Entry** • **Exit** • **Reversible – can be set to entry or exit** • **Disabled –** Wide reversible gate for disabled people.
• Station computer, Central computer and AFC Net work	All the **fare collection equipments** shall be connected in a **local area network** with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control centre through the optic fibre communication channels. The centralised control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
• Ticket office machine (TOM/EFO)	Manned **Ticket office machine** shall be installed in the stations for selling cards/ tokens to the passengers.
• Ticket reader and portable ticket decoder.	**Ticket reader** shall be installed near EFO for passengers to check information stored in the token / cards.
• UPS (uninterrupted power at stations as well as for OCC).	**Common UPS of S&T system will be utilised.**
• Maintenance philosophy	Being fully Contactless systems, manpower requirement for maintenance is much less compared to system with magnetic tickets. However, adequate facilities to be provided similar to that of S&T systems.

4.8.3. Integration of AFC with Suburban/Bus System

Common Smart Card based ticketing for both Suburban and Bus systems is not proposed at this stage as this will require installation of AFC system at all suburban stations and in buses also. A Clearing House system will also be required for separation of revenue among various operators. However, the proposed system has multioperator capability and in future this will be possible to integrate various transport providers and other agencies.

Entry/Exit

Ticket Collecting System

4.9 ROLLING STOCK

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. In a metro city like Mumbai, the forecasted Peak Hour Peak Direction Traffic (PHPDT) precludes use of Light Rail Vehicle. Considering the future expected population increase, the use of Mass Rapid Transit Rail Vehicle of similar to DMRC has been considered

4.9.1 Optimisation of Coach Si e

The Versova -Andheri- Ghatkoper, Line-1 is on elevated track i.e. 8-10 meter above ground level. Considering the clearances and also the space required for service and cables etc., the coach with following principal dimensions has been prescribed

Table 6.4.1

Si e of the coach

	Length	Width at Door	Height over AC portion of Roof
Driver Motor Car	**21.84 m**	3.2 m	3.9 m
Trailer car	**21.74 m**	3.2 m	3.9 m

Principal dimensions are shown in **Figure 4.9.1 & 4.9.2.**

4.9.2 PASSENGER CARRYING CAPACITY

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibuled to distribute the passenger evenly in all the coaches. Criteria for the calculation of standing passengers are 3 persons per square meter of standing floor area in normal state and 6 persons in Crush State of peak hour.

Therefore Driving Trailer with 21.84 m carbody length, with 3.2 m carbody width and longitudinal seat arrangement conceptually have the capacity of 43 seated, 239 standing thus a total of 282 passengers for a car, and a Motor car with 21.74 m carbody length, with 3.2 m carbody width and longitudinal seat arrangement conceptually have the capacity of 50 seated, 257 standing thus a total of 307 for a car is envisaged considering a standee area of 6 persons/sq. meter. **Table 6.4.2** shows these figures.

Table 6.4.2

Carrying Capacity of Mass Rail Vehicles

	Driving Motor car		**Trailer car / Non-driving motor car**		4 car Train	6 car Train	8 car Train
	Normal	Crush	Normal	Crush	Crush	Crush	Crush
Seated	43	43	50	50	136	286	386
Standing	120	239	129	257	992	1506	2020
Total	163	282	179	307	1178	1792	2406

NORMAL-3 Per/sqm of standee area
CRUSH -6 Per/Sqm of standee area

4.9.3 WEIGHT

The weights of motor cars and trailers are estimated as in Table 6.4.3, referring to the experiences in Delhi Metro. The average passenger weight has been taken as 60 kg.

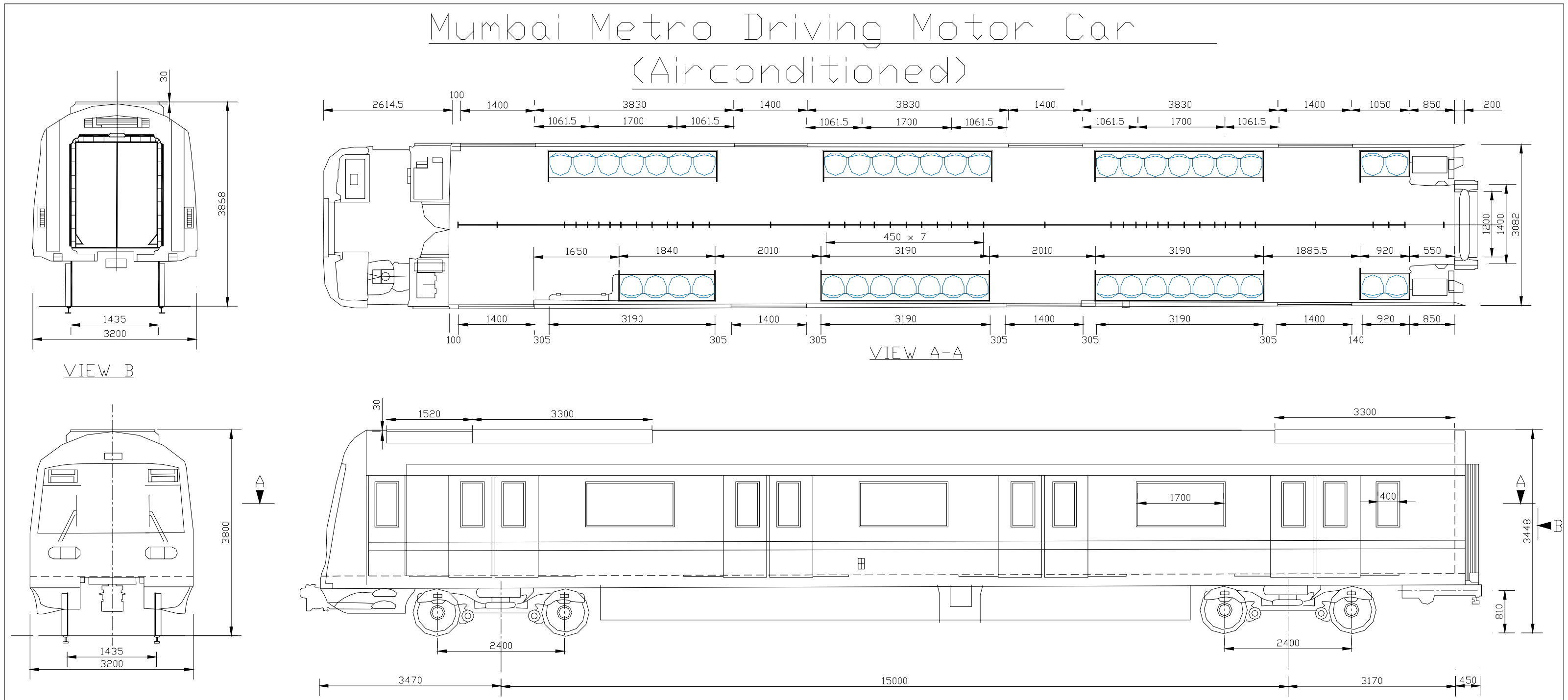
Table 6.4.3
Weight of Mass Rail Vehicles (TONS)

	DMC	**TC**	**MC**
TARE	42	42	42
Passenger			
(Normal)	9.8	10.7	10.7
(Crush)	16.9	18.4	18.4
Gross			
(Normal)	51.8	52.7	52.7
(Crush)	58.9	60.4	60.4

Heavy rush of passenger, having 10 standees per sq. meter can be experienced occasionally. As done in DMRC, it will be advisable to design the coach with sufficient strength so that even with this overload, the design will not result in overstresses in the coach. Coach and bogie should therefore be designed for 17 T axle load.

4.9.4 Required Power

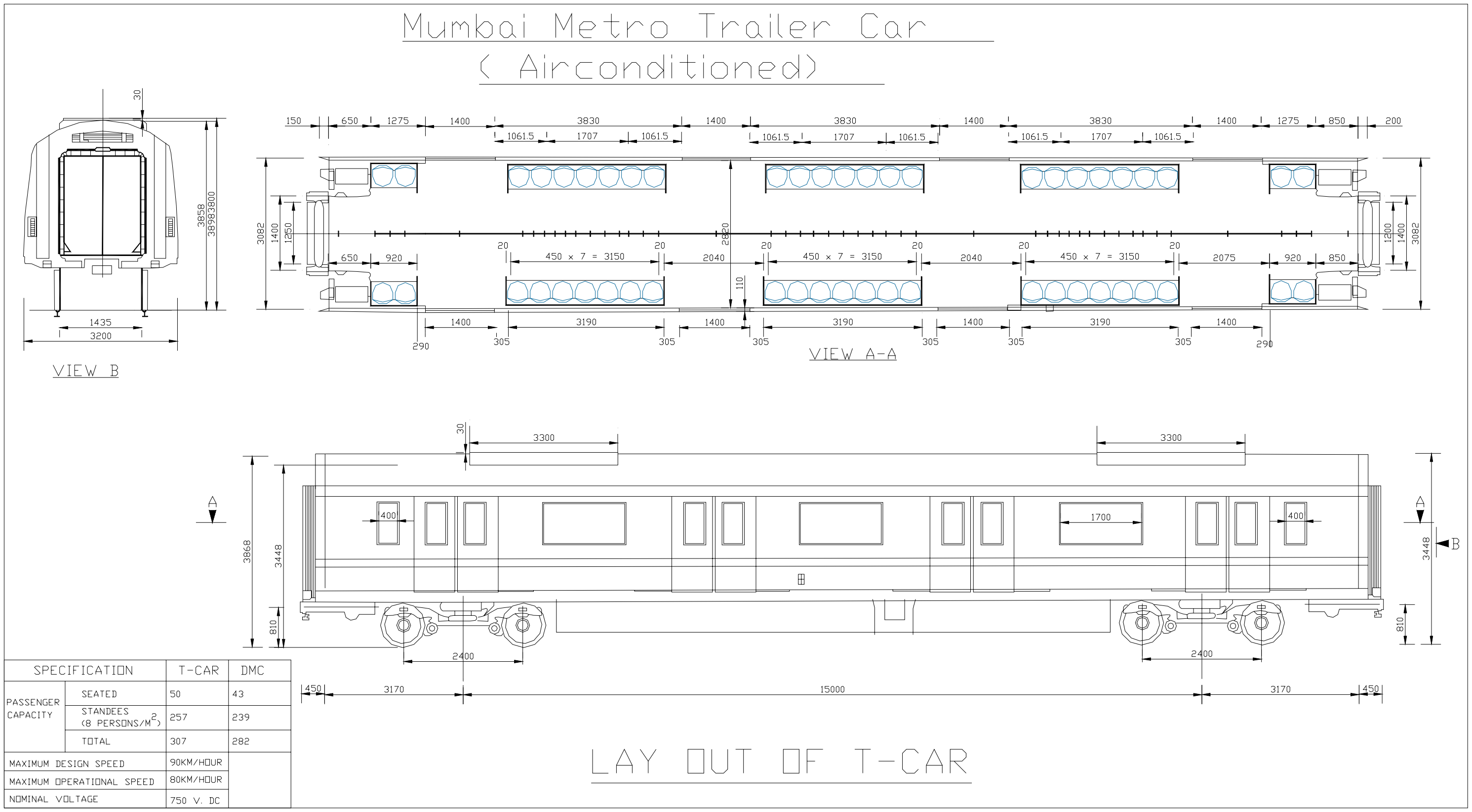
For a typical average intersection distance of 1 Km, the running time will be 82.5 sec to 72.85 sec to achieve schedule speed of 32 to 35 KMPH with dwell station time of 30 sec. To achieve this running time between stations, the following values of acceleration and deceleration were assumed in consideration of riding comfort, adhesion and requirement of make up time.



LAY OUT OF DM-CAR

SPECIFICATION		T-CAR	DMC
PASSENGER CAPACITY	SEATED	50	43
	STANDEES (6 PERSONS/M^2)	257	239
	TOTAL	307	282
MAXIMUM DESIGN SPEED		90KM/HOUR	
MAXIMUM OPERATIONAL SPEED		80KM/HOUR	
NOMINAL VOLTAGE		750 V. DC	

FIG. 1 - Driving Motor Car Layout



SPECIFICATION		T-CAR	DMC
PASSENGER CAPACITY	SEATED	50	43
	STANDEES (8 PERSONS/M^2)	257	239
	TOTAL	307	282
MAXIMUM DESIGN SPEED		90KM/HOUR	
MAXIMUM OPERATIONAL SPEED		80KM/HOUR	
NOMINAL VOLTAGE		750 V. DC	

Fig. 2 - Trailer Car layout

Max. Acceleration: 0.78 m/s^2
Max. Deceleration 1.0 m/s^2 (Normal brake)
More than 1.3 m/s^2 (Emergency brake)

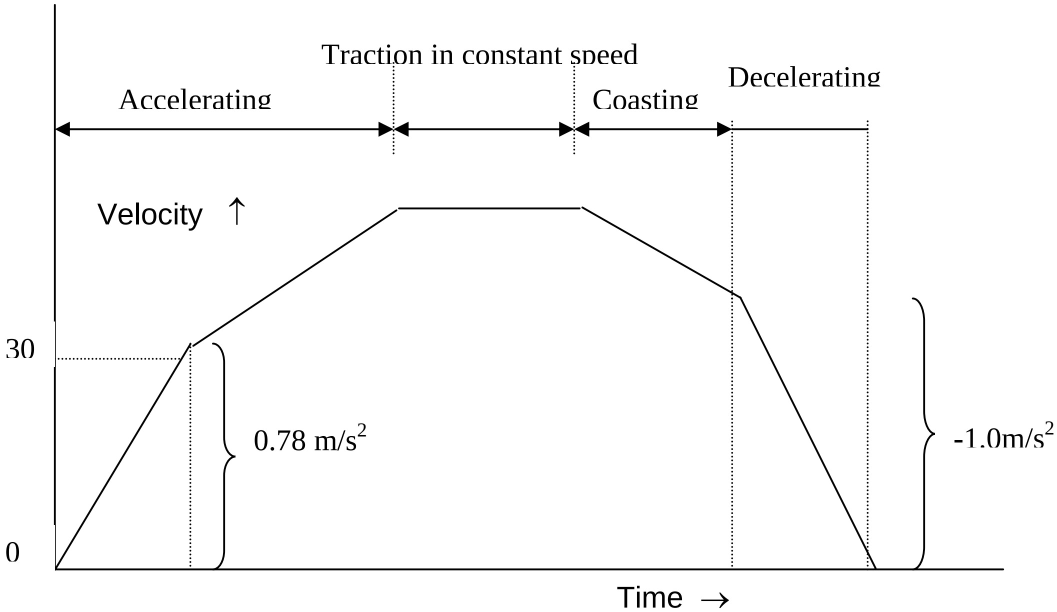


Fig 4 - Simplified velocity – time operation curve

Necessary power for a train of about 239 t in gross weight to accelerate in 0.78 m/s^2 at schedule speed of 32 Km/h, on a level and straight track would be about 1,450 KW.

Since the track on a viaduct could possibly be constructed with mild gradients on a level and the traction motors could be operated with overload for a short time, 8 traction motors with about 220 KW installed on a four car train would be enough, even if the equivalent gradients on a curved section of track are considered. It was also assessed that failure of one motor car in a train running on a 4% and 5% grade having a R-100 curvature will still be giving sufficient acceleration to the train to clear the section.

4.9.5 Coach design and basic parameters

The important criteria for selection of rolling stock are as under:

(i) Proven equipment with high reliability
(ii) Passenger safety feature
(iii) Energy efficiency
(iv) Light weight equipment and coach body
(v) Optimised scheduled speed
(vi) Aesthetically pleasing Interior and Exterior
(vii) Low Life cycle cost
(viii) Flexibility to meet increase in traffic demand

The controlling criteria are reliability, low energy consumption, lightweight and high efficiency leading to lower annualised cost of service. The coach should have high rate of acceleration and deceleration.

4.9.6 Selection of Technology

Low life cycle cost

The low life cycle cost is achieved by the way of reduced scheduled and unscheduled maintenance and high reliability of the sub-systems. It is possible to achieve these objectives by adopting suitable proven technologies. The selection of following Technologies has been adopted to ensure low life cycle cost.

(I) Car body

In the past carbon high tensile steel was invariably used for car bodies. In-fact almost all the coaches built by Indian Railways are of this type. These steel bodied coaches need frequent painting and corrosion repairs which may have to be carried out up to 4-5 times during the service life of these coaches. It is now standard practice to adopt stainless steel or aluminium. The car bodies with aluminium requires long and complex extruded sections which are still not manufactured in India. Therefore aluminium car body has not been considered for use. Stainless steel sections are available in India and therefore Stainless steel car bodies have been specified. No corrosion repair is necessary on stainless steel cars during the service life of the cars.

The stainless steel car body leads to energy saving due to light weight. It also results in cost saving due to easy maintenance and reduction of repair cost from excellent anti corrosive properties as well as an improvement of riding comfort and safety in case of crash or fire. Austenitic stainless steel with yield point of 70kg/mm2 has been recommended as in Delhi Metro. For coach design, buffing load of 80 Tones has been considered as it is a stand alone system .A design life of 30 years for coach has been recommended.

(II) Bogies

Bolsters less light weight bogies with rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 4,20,000km. The use of air spring at secondary stage is considered with a view to keep the floor level of the cars constant irrespective of passenger loading unlike those with coil spring. The perturbations from the track are also dampened inside the car body on account of the secondary air spring along with suitable Vertical Hydraulic Damper. The primary suspension system improves the curve running performance by reducing lateral forces through application of conical rubber spring. A smooth curving performance with better ride index is being ensured by provision of above type of bogies

INTERIOR VIEW

(I) Braking System

The brake system shall consist of –

(i) An electro-pneumatic (EP) service friction brake
(ii) A fail safe, pneumatic friction emergency brake
(iii) A spring applied air-release parking brake
(iv) An electric regenerative service brake
(v) Provision of smooth and continuous blending of EP and regenerative braking

The regenerative braking will be the main brake power of the train and will regain the maximum possible energy and pump it back to the system thus fully utilise the advantage of 3 phase technology. The regenerative braking should have air supplement control to bear the load of trailer car. In addition , speed sensors mounted on each axle control the braking force of the axles with anti skid valves, prompting re-adhesion in case of a skid .The brake actuator shall operate either a tread brake or a wheel disc brake .

(II) Propulsion System Technology

In the field of Electric Rolling Stock, DC series traction motors have been widely used due to its ideal characteristics and good controllability for traction applications. But these required intensive maintenance because of commutators and electro-mechanical contactors, resistors etc

The brush less 3 phase induction motors have now replaced the d.c. series motors in traction applications. The induction motor, for the same power output, is smaller and lighter in weight and ideally suited for rail based Mass Rapid Transit applications. The motor tractive effort and speed is regulated by ‘Variable Voltage and Variable frequency’ control and can be programmed to suit the track profile and operating requirements. Another advantage of 3 phase a.c. drive and VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed.

For Mumbai Mass Rapid Transit System, three phase AC traction drive that are self ventilated, highly reliable, robust construction and back up by slip/slid control have been recommended for adoption.

GANG WAYS

using insulated Gate Bipolar Transistors (IGBT). Thus three phase variable voltage variable frequency output drives the traction motors for propulsion.

The inverter unit uses optical fiber cable to connect the control unit to the gate interface. This optical l fiber cable transmits the gate signals to drive the advanced IGBT via the gate interface. This optical fiber cable provide electrical isolation between the advanced IGBT and the control unit and are impervious to electrical interference. These are recommended for adoption in Trains of Mumbai MRTS .

(III) Interior and gang ways

The passenger capacity of a car is maximized in a Metro System by providing longitudinal seats for seating and utilizing the remaining space for standing passenger . Therefore all the equipments are mounted on the under frame for maximum space utilization . The gangways are designed to give a wider comfortable standing space during peak hours along with easy and faster passenger movement especially in case of emergency .

(IV) Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of adequate width, on each side of the coach have been considered. These doors shall be of such dimensions and location that all the passenger inside the train are able to evacuate with in least possible time without conflicting movement .As the alignment passes through elevated section at 10 to 12 meters above ground, automatic door closing mechanism is envisaged from consideration of passenger safety. Passenger doors are controlled electrically by a switch in Driver cab. Electrically controlled door operating mechanism has been preferred over pneumatically operated door to avoid cases of air leakage and sluggish operation of doors.

PASSENGER DOORS

The door shall be of Plug Swing Type as this has the advantage of being flush with coach body when closed giving it a stream line look apart from increasing the available space along width inside the coach.

(VI) Air –conditioning

With passenger loading of 6 persons/m^2 for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, the air conditioning of coaches has been considered essential. Each coach shall be provided with two air conditioning units capable of automatically controlling interior temperature throughout the passenger area at 27 °C with 65% RH at all times under varying ambient condition up to full load. For emergency situations such as power failure or both AC failure etc ventilation provision supplied from battery will be made .Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the coach, during an emergency condition , such as fire outside the train causing excessive heat and smoke to be drawn in to the coach .

(VII) Cab Layout

The modern stylish driver panel shall be FRP moulded which give maximum comfort and easy accessibility of different monitoring equipments to the driver along with clear visibility. The driver seat has been provided at the left side of the cabin.

DRIVING CAB

4.9.6 Communication

The driving cab of the cars are provided with continuous communication with base Operational Control Center and station control for easy monitoring of the individual train in all sections at all the time.

Public Address and Passenger Information Display System is provided in the car so that passengers are continuously advised of the next stoppage station, final destination station, interchange station, emergency situations if any, and other messages. The rolling stock is provided with Talk Back Units inside the cars which permit conversation between passengers and the drivers in case of any emergency.

4.9.7 Noise and Vibration

The train passes through heavily populated urban area .The noise and vibration for a metro railway become an important criteria from public acceptance view point. The source of noise are (i) rail-wheel interaction (ii) noise generated from equipment like Blower, Compressor ,air conditioner, door , Inverter etc.(iii) traction motor in running train .For elimination and reduction of noise following feature are incorporated :-

- Provision of anti drumming floor and noise absorption material
- Low speed compressor , blower and air conditioner
- Mounting of under frame equipments on anti-vibration pad
- Smooth and gradual control of door
- Provision of GRP baffle on the via-duct for elimination of noise transmission
- Provision of sound absorbing material in the supply duct and return grill of air conditioner
- Sealing design to reduce the aspiration of noise through the gap in the sliding doors and piping holes

The lower vibration level has been achieved by provision of bolster less type bogies having secondary air spring.

4.9.8 Passenger Safety Features

(i) ATP

The rolling stock is provided with Continues Automatic Train Protection to ensure absolute safety in the train operation. It is an accepted fact that most of the accidents take place on account of human error. Adoption of this system ensures freedom from human error. The on board computerized ATC system compare and verify the continuous data like speed etc .for safest train control

(ii) Fire

The rolling stock is provided with fire retarding materials having low fire load, low heat release rate, low smoke and toxicity inside the cars. The electric cables used are also normally low smoke zero halogen type which ensures passenger safety in case of fire.

(iii) Crash worthiness features

The rolling stock is provided with inter car couplers having crashworthiness feature which reduces the severity of injury to the passengers in case of accidents.

(iv) Gangways

Broad gangways are provided in between the cars to ensure free passenger movement between cars in case of any emergency.

Main Parameters of Mumbai Rolling stock	
Gauge	1435 m
Rake formation	
4 Car	DT-MC-MC-DT
6 Car	DT-MC-T-MC-MC-DT
8 Car	DT-MC-TC-MC-TC-MC-MC-DT
	DT = Trailer car with cab
	MC = Motor Car
	TC = Trailer Car
Minimum operational life	30 years
Curves and Grades	
Min Horizontal curve	
In Main line	100 m
In Depot	100m
Min curve Vertical	1500 m
Maximum Gradient	
In main line	3%
In Depot	4%
Performance Parameters	
Maximum Design speed	90 kmph
Maximum Operating speed	80 Kmph
Station Stoppage Time	30 Sec
Schedule speed	32 Kmph
Level of coasting	8%
Axle load	17 T
Adhesion	
Traction	18%
Braking	16%
Acceleration	0.78 m/s/s ± 5%
Service braking rate	1.0m/s/s
Emergency braking rate	1.3m/s/s
Jerk rate	0.70±0.05m/s/s/s
Reliability	No delay to service of 3 minutes or more, and no premature withdrawal of a train from service, shall occur in less than 40,000 km/train

Ride index Train control	2.5 ATO and ATP – MC ATO – RC
Car body **Vehicle dimensions** ***Length*** Cab length Length over body DT MC TC Length over body with fairing DT MC TC Length over body between coupler buffer faces DT MC TC	 2430mm 21,640mm 21,340mm 21,340mm 21,840mm 21,740mm 21,740mm 22,460 mm 22,240 mm 22,240 mm
Width Width at floor level Max. width over body	 3,082 mm 3200mm
Height Panto locked down condition from TOR Air conditioner portion of roof from TOR non-AC portion of roof from TOR Head room Height of floor from TOR Coupler Height	 4118mm 3898mm 3868mm 2075.5mm 1130mm 810mm
Train length 4 car train 6 car train 8 car train	 89,400mm 133,880mm 178,360mm
Bogie Bogie wheel base	 2400mm

Distance between bogie centers Wheel diameter (new) Wheel diameter (fully worn)	15,000mm 860mm 780mm
Gangway	
Width	1400mm
Clear Width	1250mm
Length	450mm
Gangway Head room	1900mm
DOOR	
Door type	Externally hung, sliding, biparting door
Door opening width	1400mm
Automatic obstruction detection feature	Provided
Push back feature	Provided
Type of window	Double glazed
Material of coach	Stainless steel
Flatness of the body	1mm/1000mm
Carrying capacity	
Seating arrangement	Longitudinal
Coach carrying capacity	
DT	282 (seating - 43; standing - 239)
MC	307 (seating - 50; standing - 257)
TC	307 (seating - 50; standing - 257)
Train Carrying capacity	
4 car train	1178 (seating - 186; standing - 992)
6 car train	1792 (seating - 286; standing - 1506)
8 car train	2406(seating - 386; standing -2020)
Weight	
Tare Weight DT	42T
Tare Weight MC/TC	42T
Passenger weight	60 kg
Passenger weight DT(kg)	16920
Passenger weight MC(kg)	18420
Train weight in tare condition	
4 car train	168
6 car train	252

8 car train	336
Buffing force	1200 kN
Fire load Fire standard	22000 MJ for RC BS 6853
Type of cables	Low smoke Halogen free flame retardant cables
Illumination level	300 Lux at 1 metre above FL
Couplers Cab ends Non cab end	 Automatic at the end of unit Semi permanent at inner end of unit
Bogie Primary suspension Secondary suspension Wheel disc dia Wheel disc type Flange lubrication system Bearing attention	 Chevron rubber Air spring New – 860 mm Worn out - 780 mm Mono block Not provided Life > 3 million km
Brake system Brake Wheel slid protection	 Electro pneumatic service brake Electric regenerative brake Pneumatic friction Emergency Parking brake Smooth and continuos blending Electric brake fade speed <5 kmph Digital wheel slide protection
Propulsion details Traction system Voltage Transformer Type Transformer capacity Traction Motors TM Mounting arrangement Power converter/ Inverter Power converter/ Inverter	 25 KV AC OHE Silicon oil cooled 1170 kVA 4 x 220 kW (continuous) self ventilated transversely mounted 3 phase induction motor Bogie mounted IGBT Voltage source inverter with PWM, air cooled 220 kV

No of converter/inverter per motor car	2
Auxiliary Inverter	151 KVA
Type of Battery	Ni-Cd
Supply of Emergency load	> 60 minutes
Air conditioning	
No of Air condition	2 per car
Mounting Arrangement	Roof mounted
Type of coolant	R22
Inside temperature	29 ºC with 65% humidity –RC 27 ºC with 65% humidity –MC
Out side temperature	43 ºC with 33% humidity
Emergency air supply	18 m^3/ hour / person
Cab Ventilation	Separate cab AC with air supply of 144 m^3/ hour
Communication system	Two way communication between OCC and driver Emergency passenger announcement Simplex conversation between passenger and driver Conversation between both cabs Automatic voice announcement system Passenger information system

Chapter 5.0

Civil Engineering

5.1 GEOMETRIC DESIGN NORMS

5.1.1 General

The design parameters related to the Metro system described herewith have been worked out based on a detailed evaluation, experience and internationally accepted practices. Various alternatives were considered for most of these parameters but the best-suited ones have been adopted for the system as a whole.

The design parameters as suggested in the earlier DPR for Andheri - Ghatkopar section have also been modified so as the same parameters are applicable for all metro corridors in Mumbai.

5.1.2 Hori ontal Alignment

On consideration of maximum allowable cant of 125 mm and cant deficiency of 100 mm on Metro tracks, the safe speed on curves of radii of 400 m or more is 80 km/h. On elevated section use of curves with minimum radius of 200 m, having speed of 60 km/h shall be adopted. There are, however, exceptional situations where due to site constraints; use of sharper curves is unavoidable. Under such situations on this project, curves of 100-m radius (safe speed of 40 km/h) have been adopted.

For maximum permissible speed on curve with various radii **Table 5.1** may be referred.

Hori ontal curves

Curve radius in mid section:
Elevated Section

Minimum		200 m
Absolute minimum	:	100 m
Minimum curve radius at stations	:	1000 m
Maximum permissible cant (Ca)	:	125 mm
Maximum cant deficiency (Cd)	:	100 mm

Transition curves

The existing roads also have frequent curves. For the Metro alignment, which normally follows the median of the road, similar curves are introduced for the Metro alignment. However it is necessary to provide transition curves at both ends of the circular curves for comfort and safety of the passengers. Due to change in gradients at various locations in the corridor it is necessary to provide frequent vertical curves along the alignment. In case of ballastless track, it is desirable that the vertical curves and transition curves of horizontal curves do not overlap. These constraints may lead to reduced lengths of transition curves. However for safety and comfort of passengers, the transition curves have to be designed with certain minimum parameters.

- Minimum length of Transitions of

Horizontal curves (m)	:	0.44 times actual cant or cant deficiency (in mm), which ever is higher.
Desirable	:	0.72 times actual cant or cant deficiency, (in mm) which ever is higher

- No overlap is allowed between transition curves and vertical curves.
- Minimum straight between two Transition curves : either 25 m or NIL.
- Minimum curve length between two transition curves: 25 m

5.1.3 Vertical Alignment

a) Elevated Sections

The viaducts carrying the tracks will have a vertical clearance of minimum 5.5 m above road level. For meeting this requirement with the '**U'** shaped pre-stressed concrete girders, the rail level will be about 8.5 m above the road level. However, at stations which are located above central median, the rail level will be 10.5 m above the road level if no mezzanines are provided and the ticketing and other technical areas are located outside the right of way of the roads. If, however, concourses are provided below the station structures, then the rail level shall be 12 m above road level. These levels will, however, vary marginally depending upon where the stations are located.

The distance between track centers on the elevated section is kept as 4.1 m uniform through out the corridor to standardize the superstructure. However, at scissors crossings the track centers are kept at 4.5 m . Scissors cross overs are proposed at three locations, one each at terminal stations for train reversal purpose and another for Airport link at Airport Road Station.

b) Gradients

Normally the stations shall be on level stretch. In limiting cases station may be on a grade of 0.1 %. Between stations, generally the grades may not be steeper than 2.0 %. However, Where existing road gradients are steeper than 2 %, gradients upto 4% (compensated) can be provided in short stretches on the main line.

- Maximum gradient at stations : 0.1 %
- Desirable gradient at stations : level
- Maximum gradient in mid section:
  - Normal : 2.0 %
  - Exceptional : 4.0 %

c) Vertical Curves

Vertical curves are to be provided when change in gradient exceeds 0.4%. However it is recommended to provide vertical curves at every change of gradient.

- radius of vertical curves:
  - On main line (desirable) : 2500 m
    (minimum) : 1500 m
  - Other Locations : 1500 m
  - Minimum length of vertical curve : 20 m

5.1.4 Design Speed

The maximum sectional speed will be 80 km/h. However, the applied cant, and length of transition will be decided in relation to normal speeds at various locations, as determined by simulation studies of alignment, vertical profile and station locations. Computerized train simulation studies need to be conducted with proposed gradients at the time of detailed design stage. This is with the objective of keeping down the wear on rails on curves to the minimum.

Table 5.1

Cant, Permitted speed and Minimum Transition length for various Curves

Radius	Actual Cant	Cant Deficiency	Permitted Speed	Minimum Transition
(m)	(mm)	(mm)	(km/h)	(m)
3000	20	8.72	80	10
2000	30	13.09	80	15
1000	50	36.17	80	25
800	60	47.72	80	30
500	90	82.35	80	40

400	**125**	**90.43**	**80**	**55**
300	**125**	**100**	**70**	**55**
200	**125**	**100**	**55**	**55**
150	**125**	**100**	**50**	**55**
120	**125**	**100**	**40**	**55**
100	**125**	**100**	**40**	**55**

5.1.5 Station Locations

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport. However effort has also been made to propose station locations, such that inter station distances are as uniform as possible. The average spacing of stations is kept close to one km.

5.2 DESCRIPTION OF ALIGNMENT

5.2.1 Introduction

An West-East corridor from Andheri to Ghatkopar was identified as priority corridor in SMART (Selection of Mass Rapid transit System) study carried out by MMRDA under Indo-German Technical Co-operation through consortium led by TEWET in association with DE-Consult & TCS during the year 1997-2000. Further, in the year 2003 MMRDA appointed M/s. CES (Consulting Engineering Services (I) Pvt. Ltd.) to update the SMART report and also examine the feasibility of extending the corridor up to Versova towards West.

In Mid 2003, MMRDA engaged DMRC to prepare a Master plan for a Metro Rail System for the entire Greater Mumbai with horizon year as 2031. In this plan, a total network of 146.5 kms consisting of seven corridors was identified for implementation in three phases. The Master Plan incorporates the extension of Ghatkopar - Andheri corridor to Versova. Total length of the priority corridor is 11.51Km. Subsequently, MMRDA sought the services of DMRC for preparation of detailed project report for the part of phase – I corridors of the master plan (48.3km) as under:

In addition to the SMART study report and it’s CES update, MMRDA desired to upgrade the feasibility study between Andheri - Ghatkopar to DPR level. **For this purpose the available data of Topographic survey handed over by MMRDA has been used. As per scope of work,no fresh surveys need to be carried out in the eastern segment. But, fresh survey has been carried out in Golibar road area.** However for Andheri - Versova section, fresh surveys were carried out.

5.2.2 Project Area

The project area has two distinct sections:

(i) Versova-Andheri (western segment) and Andheri-Ghatkopar (Eastern segment). Versova is the old fishermen village located in the west cost. The Versova-Andheri area has developed in the last 20 years and has mixed land use predominantly residential and education institutions. Whereas, Andheri-Ghatkopar (upto Saki Naka) is the earlier development. Andheri is the most important sub urban station on western Railway and Ghatkopar is the most important station on Central railway. This area serves the Marol industrial area of MIDC, Sahar International airport and nearby developing office/commercial complexes. The section Saki Naka to Ghatkopar is mainly residential and do not have proper road access due to undulating terrain caused by a local hillock.

The metro corridor is proposed, as elevated, traverses through the center of the existing arterial roads of Jai Prakash Road and Mathuradas Vasanji Road (Andheri-Kurla Road). A small length of the road near Asalpha is not existing but is taken up for development by MMRDA as a part of MUIP. The total length of the corridor is 11.07km. A maintenance depot with link line to North – South corridor is proposed at Jai Prakash Road near D.N. Nagar in about 12.25 Hectares of land, which is almost vacant. This location of the depot is suitable for North – south corridor also. An alternative depot location is in the Godrej land (Exhibition ground) on North east of Ghatkopar station, measuring 20 Ha. This land is recommended for acquisition for depot facilities which will be needed if complete Metro Network is to be commissioned or if D N Nagar land is not available.

(ii) DP Road in Asalpha Area

DP Road with a ROW of 45.7 m has been planned which is proposed to pass over the hill at Asalpha across Kadam Road, Golibar Road, Lal Bahadur Shastri Marg opposite to Hirachand Desai road meeting Eastern Express Highway.

A sharp curve has been planned in the DP Road just after crossing the Mehta Road, perhaps to reduce the affected properties. This may require review as metro alignment can not take such sharp curve and requires construction of portals. Further, two viaducts have been planned in the D P Road before reaching Kadam Road as the existing ground is too low.

DP Road has been planned with almost no cutting of the hill though it appears that Kadam road needs to be diverted. **The road level of the proposed DP Road near the Sarvodaya Hospital is such that the metro alignment has to be kept very high on Golibar Road and up to Ghatkopar Station. Thus, the longitudinal section of the proposed D. P. Road needs to be reviewed.**

5.2.3 Reference Point

For planning convenience and also to enable flexibility in deciding end points in either direction, center line of the proposed Andheri Metro station (center line of the plat form) is assumed as Reference Point **ZERO.** The chainage towards Ghatkopar in eastern direction shall be written with a suffix **E'** and the chainage towards Versova in western direction shall be written with a suffix **W'.**

As explained in the previous para, the center line of the proposed Andheri metro station is assumed as 0.000. The center of the Andheri Metro station is located at 9.83 m east of the inter section point of center lines of MV Road & Andheri Station road.

5.2.4 Proposals Under MUIP

The MMRDA has decided to Implement MUIP (Mumbai Urban Infrastructure Project) which will include flyovers, elevated roads , construction of missing road links, widening of roads etc. The implementation of Phase-I scheme of MUIP has commenced since May 2004. The major MUIP schemes in the vicinity of Versova-Andheri-Ghatkopar corridor are given below:

a) Road Widening

The roads along which the alignment is proposed, are being widened to their full Right of Way (ROW) as indicated in DP (Development Plan) and are detailed below:

S.No	Road	Stretch	ROW as per DP	Reference of DP Sheet
1	Versova Road/ Jai Prakash Road	Versova to West of Andheri Rly.Stn (SV Road)	27.45M (90'00'')	No.W/38 of K/west Ward; No.W/39 of K/East & K/west Ward;
2	M.V.Road	East of Andheri Rly.Stn to Western Express	27.45M(90'00'')	No.W/42 of K/East & K/west Ward;

		Highway.		
3	M.V.Road /Andheri-Kurla Road	WEH to Surodiya Chowk/Junction with Pipe Line road.	36.60M (120’00’’)	No.W/42 of K/East & K/west Ward;
4	Andheri – Ghatkopar Road	Surodiya Chowk/Junction with Pipe Line road to Junction with DP Road	45.7M (150’00’’)	No.W/43 of K/East Ward;E/18 of N&L ward.
5	DP Road	Subhash Nagar to Sarvodaya Hospital	45.7M(150’00’’)	E/18 of N&L ward; E/21 of N&L ward.
6	Golibar Road	Up to Junction with LBS Marg	18.30M(60’00’’)	E/22 of N ward.
7	Hira Chand Desai Marg	Junction with LBS Marg to Ghatkopar Rly.stn.	18.30M(60’00’’)	E/22 of N ward.

It was indicated by MMRDA, **that road widening /construction activity will be taken up prior to Metro construction** and the roads with their full ROW will be available for Metro construction. During discussions with MMRDA authorities, it was also informed that the road widening would be carried out on either side equally with respect to the present road center. Hence, the alignment planning, station planning, assessment of land requirement for the Metro system and other associated facilities etc. have been done accordingly. Some adjustment to median shall be needed as the metro alignment does not matches exactly with the central of existing median.

b) New Flyovers, Missing Links and Elevated Roads

The roads along which the alignment is proposed are being widened to their full Right of Way (ROW) as indicated in DP (Development Plan) sheets.

(i) A flyover is proposed across Jay Prakash road in North- South direction at its junction with linking road.

(ii) A flyover cum ROB is indicated across W. Rly tracks connecting Jai Prakash Road and M.V. Road. The CES report on updation of SMART study has therefore suggested to locate the Andheri-Metro station leaving row of M. V. Road.

(iii) A three armed flyover (FL3) at the junction of MV Road with ` Maha Kali caves Road' is proposed.

(iv) Further, a continuous elevated road (EL1) from Surodiya Chowk (Junction of MV Road & Guru Hargovindji Road) up to Saki Naka Junction is proposed.

It may be observed that MRTS alignment proposed in this corridor is elevated at level ranging between 8.5 and 12m. This will clearly clash with the proposals of the flyovers and elevated road and auto rickshaw deck. There are 2 options (i) Raise the level of MRTS to about 18 - 20m or (ii) Realign the flyover. The option (i) is costly as well as passenger friendly. It is strongly recommended that MRTS system be given the highest priority for implementation. The need for flyover be re-examined in view of likely reduced road traffic and redesigned later. Thus these schemes need review and are to be integrated with the metro system. Some of the schemes may not be required (or deferred) due to construction of the metro. However the ROB at Andheri station may be required. In such a case the alignment proposed in feasibility report can be adopted with shift in Station Location.

c) Proposals under MUTP

SATIS scheme at Andheri

MMRDA has prepared GAD for the proposed SATIS scheme at Andheri suburban railway station, which is part of MUTP. The sanctioned GAD includes an elevated continuous deck for Auto rickshaw to the west of Andheri. One arm of this deck along Jai Prakash Road.

This scheme also needs to be reviewed as providing metro, ROB and auto track will require major remodelling of roads on both side of the Andheri station.

5.2.5 Eastern Segment

The Eastern segment of the Ghatkopar – Andheri –Versova, corridor starts at Km.0.00 and runs along the center of the M.V Road . The alignment crosses the elevated Western Express Highway in double elevated position and continues on the MV Road, (Andheri – Kurla Road) and Andheri – Ghatkopar Road up to Subhash Nagar. From Subhash Nagar, the alignment follows the proposed DP road through Asalpha Village up to its intersection with Golibar Road. In this particular stretch between Subhash Nagar and Golibar road the alignment passes through cutting of two hillocks on either side of Kadam road. After deviating from DP road near Sarvodaya Hospital it continues on Golibar road and crosses the Lal Bahadur Shastry Marg and terminates at Ghatkopar Railway station on Hirachand Desai Marg. Length of the eastern segment is 7.860 Kms and is abutted by mixed land use viz. Residential, Commercial and Institutional. The roads along which alignment is proposed have different ROW as indicated in earlier.

As advised by MMRDA, the data such as topographic survey, Utilities, Geo-technical investigation etc., available from the feasibility report for the metro and the drawings prepared for the DP road in Asalpha area by other consultants. However the longitudinal section of existing ground profile does not match in the 2 sets of drawing. No fresh surveys have been carried out, excepting Environmental & Social Impact assessment studies and Topographic survey of Golibar Road.

(i) Alignment from Km 0.000 to Km E 0.800.

This stretch of the alignment along M.V.Road is almost straight. The Andheri Metro Station lies in this stretch. The alignment is located on the center of the existing road.

(ii) Alignment from Km E 0.800 to Km E 3.700

Alignment in this stretch is also more or less straight except mild curves. The most important feature in the alignment is crossing of N.S. flyover along Western Express Highway (WEH), which crosses M V Road in elevated position. Width of the WEH flyover and the roads on either side of it is about 61 m. Hence a special spanning arrangement with 60 m span is proposed. The Rail level will be at a height of 21.27m from the existing road level and it will be highest rail level in this particular corridor. A gradient of 3.2% rise is provided for a distance of 350 m prior to crossing the WEH.

Following four stations have been located in this stretch .

1.	WEH station	at Km. E 0.995
2.	Chakala Station	at Km. E 2.279
3.	Airport road Station	at Km. E 3.014
4.	Marol Naka Station	at Km. E 3.660

Airport Connection

In the original feasibility report, connection to the international airport has been suggested from airport road station. It has been proposed to run few trains from Versova to Airport station, however, this connection requires shifting of airport road station towards west to provide for the turnouts and crossovers for a right turn. Alternative alignment for this link is also included in DPR. However, the link may not be beneficial & viable as very few potential users will be attracted to this link since, the metro trains are not planned for carrying heavy baggages with the passengers & from international Airport normally carry.

The airport station is proposed as a side platform with single platform line and the second line has been proposed for stabling. The cost estimate for the same has been given in the DPR.

(iii) Alignment from Km E 3.700 to Km E 5.000

This stretch of the alignment has six curves out of which two curves are with radius less than 300M. One station i.e., Saki Naka at Km.E4.696 is located on the center of the Andheri – Kurla road and at a distance of 130 m East of Saki Naka Junction.

(iv) Alignment from Km E 5.000 to Km E 6.350

This portion the alignment runs along the center of the Andheri-Ghatkopar road and this stretch has three curves with radius 300 m and above. Subhash Nagar station is located at Km E6.046.

(v) Alignment from Km E 6.350 to Km E7.200

Alignment in this stretch is planned along the center line of the proposed DP road with ROW of 45.7 m under MUIP, which passes through Asalpha village.The alignment will be cutting between E6.916 and km E7.163. At Km. E 7.200, the alignment deviates from the DP road through a right hand curve of radius 100M towards Ghatkopar Rly. Station on to Golibar road.

(vi) Alignment from Km E7.200 to Km E7.450

After taking off from the DP road, the alignment follows the Golibar Road and crosses LBS Marg and then follows the center of the Hira Chand Desai Marg up to Ghatkopar Railway station. The Ghatkopar metro station is located at Km E 7.786.

At present, the Ghatkopar station will be the eastern terminal of the corridor. Due to space constraints, beyond the station, a crossover is proposed to be located in front of the station, for train reversal purposes.

5.2.6 Western Segment

The western segment of the Ghatkopar – Andheri –Versova, corridor starts at Km.0.00 and runs along the center of the M.V Road in western direction.

The alignment crosses Western Railway tracks in elevation and follows the J.P.Road, up to it's terminal at Versova. The entire alignment has been planned as elevated. The J.P Road is almost straight except at few locations. The corridor road is abutted by mixed land use viz. Residential, Commercial and Institutional. The proposed ROW of this road is 27.45 M and the road is being widened to its full ROW under MUIP road widening scheme. A total of three stations are located on this alignment. Out of the three stations, two are located on the center of the road and one is located away from the center of the road (but within the ROW) due to site constraints. MRTS corridor from Colaba to Charkop would cross each other at the junction of J.P Road with New Link road. The North - South corridor would cross the East – West corridor in double elevation. A maintenance depot offering facilities for minor repairs and stabling is being planned North-East of this junction. Length of the western segment is 3.210Kms.The alignment at different stretches is detailed as below:

(i) Alignment from Km. 0.000 to Km. W 0.160

This stretch of the alignment lies in railway portion and is straight and crosses the western railway tracks in skew. This includes the crossing of W. Rly tracks. The alternative studied are described below:

a) Crossing of Western Railway Tracks Near Andheri Railway Station.

A notable feature of the elevated alignment is that the alignment crosses Andheri suburban station having six railway tracks. The proposed metro alignment is crossing the western railway tracks in skew. The center to center distance between the end tracks along the metro alignment is 39.4m and the crossing length of the metro alignment in the railway property is 53.8m. All these lines are electrified with 1500 V dc traction which is under conversion to 25 kV ac traction. The layout of the tracks is shown in the plan enclosed as **Fig.5.1**

Line No. 1 is Down Harbour
Line No. 2 is Up Harbour

Line No. 3 is Down Local
Line No. 4 is Up Local
Line No. 5 is Down Through/Fast
Line No. 6 is Up Through/Fast

b) Spanning arrangement options:

Two alternative spanning arrangements for crossing the Railway lands have been considered. They are :

(i) Alt. 1 : Single span across railway tracks.
(ii) Alt II : Two spans of 35 m and 25m.

Alt. 1 (Single span)

For spanning the 6 tracks, by a single span the minimum clear distance between the piers should be as follows:

a)	Distance between centres of end tracks	= 39.4
b)	Lateral clearance for the end tracks (2 X 2.65 m)	= 5.3
c)	Clear span (a) + (b)	= 44.7
d)	Overall Span (C + 2.5m-pier thickness)	= 47.2

A single span of 47.2m, would therefore be adequate technically. But ,foundations for the support piers of the span will be rather close to end tracks and it would perhaps be necessary to keep line No. 1 and 6 out of commission during the period of piling for foundations and constructions of the piers. This would require the co-ordination with the Railway authorities.

As a clearance of 4.8 m to line No.1 and 9.6 m to line No.6 from the railway boundary is available, the overall span length can be calculated as below :

a)	Distance between centres of end tracks	= 39.4
b)	Lateral clearance for the end tracks (4.8+9.6 m)	= 14.4
c)	Clear span (a) + (b)	= 53.8
d)	Overall Span (C + 2.5m-pier thickness)	= 56.3

Use of a span of 56.3 m would ease construction without hampering the normal railway operations. The span can be constructed by balanced cantilever method (in case of prestressed concrete) or by launching of through type steel girders with composite deck structure.

The highest Rail top level of the western railway tracks is at RL 10.72 m. The proposed rail level being RL 21.25m, vertical clearance obtainable above the Western Railway tracks would be more than the desired 6.0 m vertical clearance.

Alt. II : Crossing with 2 Spans

Crossing of the tracks with 2 spans of 35.0 m &25.0 m, will require construction of an intermediate pier in between line nos. 2&3. This will also help in lowering the rail level of the Metro tracks due to reduction in the depth of the girders. Launching of girders shall also be easy as standard spans can be utilised.

c) Preferred spanning arrangement

Out of two discussed alternatives, Alternative –II, i.e., crossing of Rly. tracks with two spans is considered to be the best. But, it requires permission from & co-ordination with the Railways . In the event of railways disagreement to alternative-II, the alternative –I is recommended. Though, this alternative appears to be little more costly, but it would be easier and ultimately proves to be an economical option. Co-ordination with the Railways will be easy and minimal in this alternative.

(ii) Alignment from Km. W 0.160 to Km. W 0.480

At present , the ROW of JP Road, from west of Andheri station for a length of about 300 m, is very limited and below 20 m. Most of the properties/structures abutting this stretch on either side are old structures having single or double storey. Number of trials were made by locating the alignment off the road in northern side and southern side of the J.P.Road to minimise the affected property. But, this has not improved the situation. Since, the ROW as per DP is 27.45M , it is proposed to keep the alignment on the center of the J.P.Road. The alignment in this stretch is almost straight with one curve of radius 1500m.

(iii) Alignment from Km. W 0.480 to Km. W 2.949

The ROW in this stretch up to Seven Bungalows Junction is wide enough and is of the order of 30 m with variations at few places, but minimum being 20 m. Hence, the alignment in this stretch has been planned on the center of the road. In this stretch two stations viz. Azad Nagar at Km.W1.344 and D.N.Nagar station at Km.W2.154 are located on the center of the road.

Between Km. W 0.480 and Km. W 1.129**,** right of way of road is 20 to 28 m. The existing road is on sharp curves. Hence, a reverse curve with two circular curves on either end with radius as sharp as

121.2m and 270 m on the either end are provided with no straight portion in between. The alignment is mostly on the middle of road.

Between Km. W1.107 and W1.403 the alignment is almost straight. However, a flatter curve of radius 2500 is provided in this stretch on which station Azad Nagar at W1.344 is located on the middle of the road. The right off way in this particular stretch is in the order of 25 to 30 m.

The stretch between Km.W1.403 and Km.W1.692 the road is on a curve hence a reverse curve with 2 circular curves on either end with a radius of 425 m and 457 m is provided with zero straight in between. Right of way in this stretch is sufficient and the alignment is almost on the center of the road.

Between Km. W1.692 and Km. W2.927, the road is almost straight. However only one curve with a radius of 7000 m is provided and the alignment is located on the center of the road. The N-S alignment (Colaba - Charkop) crosses, the alignment at Km.W2.056. Both the alignments are being elevated, the N-S corridor will be crossing the E – W corridor in double elevation. As a multi-level station is not possible at this location of crossing , due to site constraints, the stations are being planned in L shape with common concourse. Just after the D.N.Nagar station towards Versova, on the northern side of the alignment, an open land of about 12.25 Hectares (350mX 350m) is available. This land would be suitable for locating a maintenance depot with stabling & workshop facilities.

iv) Alignment from Km. W 2.949 to Km. W 3.210

The seven Bungalows bus depot is located north of J.P Road in this location and the western terminal of the metro named as ` Versova , is located at Km. W 3.139 towards north of the J.P.Road. Due to the site constraints, the alignment here is little away from the central verge, and the road here requires realignment.

In the present phase of implementation, it is proposed to construct the corridor up to Seven Bungalows junction only. Accordingly, dead end is located at km. W 3.210 west of the Versova station along the J. P. Road. A scissors crossing to enable reversal facilities has been provided before (east of)the versova station. This very cross over also provide access to Depot from UP&DN lines. However, alignment for future extension beyond Versova station is also shown.

The take off for the depot is at chainage Km E2.970. A third line is necessary from this point to the Versova station for providing isolation from main lines. The viaduct in this stretch is to be designed specifically for carrying 3 tracks.

5.2.7 Terminal Stations

a) Western terminal :

Versova metro station will be the western terminal on Versova-Andheri –corridor. Due to its proximity to near by residential settlements, BEST bus depot and availability of vacant land the present station location offers good integration facilities. The dead end on the western end at Km W3.210 is located on the JP road.

A 1 in $8^{1/2}$ scissors cross over is provided before this station to enable train reversal as well as entry to depot.

b) Eastern Terminal :

Ghatkopar metro station will be the eastern terminal on Versova-Andheri – Ghatkopar corridor. This station is located abutting the Ghatkopar Sub-urban railway station providing better integration with it.
A 1 in $8^{1/2}$ scissors cross over is provided in front of the station to enable train reversal.

List of stations with chainages and inter station distances are indicated in **Table 5.2**

Table 5.2

LIST OF STATIONS (VERSOVA - GHATKOPER)			
SL.NO	**NAME**	**CHAINAGE**	**INT.-DIST(M)**
	DEAD END	**W 3210.00**	**-**
1	**VERSOVA**	**W 3139.6**	**-**
2	**D N NAGAR**	**W 2139.24**	**1000.36**
3	**AZAD NAGAR**	**W 1344**	**795.24**
4	**ANDHERI**	**0**	**1344**
5	**WEH**	**E 995.9**	**995.9**
6	**CHAKALA**	**E 2279.09**	**1283.19**
7	**AIR PORT ROAD**	**E 3014.28**	**735.19**
8	**MAROL NAKA**	**E 3660.12**	**645.84**
9	**SAKINAKA**	**E 4696.02**	**1035.9**
10	**SUBHASH NAGAR**	**E 6046.49**	**1350.47**
11	**ASALPHA ROAD**	**E 6788.51**	**742.02**

12	**GHATKOPER**	**E 7786.31**	**997.8**
	DEAD END	**E 7860.00**	**-**
	AVG.INT.STN DITANCE		**910.50**

Depot Location

A depot has bee proposed at D N Nagar, which is close to the terminal station on Western end. The depot connection is provided from Versova. The depot is proposed on elevated deck to save space in depot area as well as properties and blocking road in case the depot tracks are to be brought on surface from Versova station. **The depot at this location is useful for the North - South alignment also as rake interchange can take place**. The elevated depot is also helpful in providing rake interchange line to N - S corridor which is crossing Andheri - Versova section in double elevation.

In the feasibility study one of the alternative for depot location has been shown at the Godrej land which is North – East of the Ghatkopar Station by the side of Andheri – Ghatkopar link road. The alignment for this depot takes off after Asalpha Road station and goes on the middle of the D P Road. The alignment crosses the Lal Bahadur Shastri Marg and moves on Andheri – Ghatkopar link road. Further, it goes on the northern side of the road over bridge to cross the central railway tracks and moves into the depot location. It is proposed that the depot at this location to be on the surface.

In case this route is not to be served for passengers services, a single line for depot connection is sufficient. However, for emergency it is proposed to provide double line on this section also. The route length is about 1.625 Km. No station has been proposed on this section as this alternative is only for operational requirement. However this alternative will result in perpetually higher operation cost due to ideal running of all trains from depot to the main line.

5.2.8 Major Roads along the Route

The alignment from East - West traverses along few major roads as indicated in **Table 5.3.** The major roads across the alignment are shown in **Table 5.4.**

TABLE 5.3
MAJOR ROADS ALONG THE ALIGNMENT

S. No.	Road	Stretch	ROW as per DP	Reference of DP Sheet
1	Versova Road/ Jai Prakash Road	Versova to West of Andheri Rly.Stn(SV Road) Km W3.700 to Km W0.225	27.45M(90'00'')	No.W/38 of K/west Ward; No.W/39 of K/East & K/west Ward;
2	M.V.Road	East of Andheri Rly.Stn to Western Express Highway. Km W 0.125 to Km E0.875	27.45M(90'00'')	No.W/42 of K/East & K/west Ward;
3	M.V.Road /Andheri-Kurla Road	WEH to Surodiya Chowk/Junction with Pipe Line road. Km E 0.875 to Km E2.465.	36.60M(120'00'')	No.W/42 of K/East & K/west Ward;
4.	Andheri – Ghatkopar Road	Surodiya Chowk/Junction with Pipe Line road to Junction with DP Road Km E2.465 to Km E6.350.	45.7M(150'00'')	No.W/43 of K/East Ward;E/18 of N&L ward.
5.	DP Road	Subash Nagar to Sarvodaya Hospital Km E6.350 to Km E7.200.	45.7M(150'00'')	E/18 of N&L ward; E/21 of N&L ward.
7	Golibar Road	Up to Junction with LBS Marg Km E7.200 to Km E7.455.	18.30M(60'00'')	E/22 of N ward.
8	Hira Chand Desai Marg	Junction with LBS Marg to Ghatkopar Rly.stn. Km E7.455 to Km E7.761	18.30M(60'00'')	E/22 of N ward.

TABLE 5.4
MAJOR ROADS ACROSS THE ALIGNMENT

S. No.	Name of the Road	Chainage (km)	Position w.r.t. alignment
1.	Dr. N. R. P. Chowk	W 3.550	R
2.	To Link Road	W 3.000	R
3.	Subedar Ramji Chowk	W 2.617	C
4.	Indian Oil Circle	W 2.043	C
5.	Veera Desai Road	W 1.369	L
6.	Dada Bhai Road	W 1.230	R
7.	Ceaser Road	W 1.110	L
8.	Road	W 0.750	R
9.	S. V. Road	W 0.230	C
10.	Andheri Station	W 0.009	R
11.	O. N. Dass Road	E 0.105	C
12.	Jamadar Ramesh Chowk	E 0.353	C
13.	W. E. Highway	E 0.875	C
14.	Sriniwas road	E 2.322	R
15.	Church Road	E 3.033	L
16.	Airport Road	E 3.250	R
17.	Arya Colony Road	E 3.500	L
18.	Andheri Kurla Road	E 4.557	C
19.	Asalpha village Road	E 6.382	L
20.	Ghatkopar Road	E 6.600	C
21.	Kadam Road	E 6.835	C
22.	LBS Marg	E 7.460	C
23.	J V Road	E 7.677	C

L – Left, C – Cross, R – Right

5.2.9 Vertical Alignment

Due to undulating terrain in stretches, the gradient on roads is steep at few locations with ups and downs at short intervals. The existing road gradients and average road levels of Western Segment & Eastern Segment are indicated in **Table 5.5 & Table 5.6.**

Table 5.5
Existing Road Profile - Eastern Segment

1.	**M. V. Road**	**Grade (%)**	**Road levels**
I	W 0.230 – E 0.491	1.15 RISE	12.33
II	E 0.491 – E 0.566	1.41 FALL	15.82
III	E 0.566 – E 0.816	LEVEL	15.33
IV	E 0.816 – E 0.1416	1.54 RISE	20.15
2.	**Mathura Dass Vasanji Road**		
I	E 1.416 – E 1.641	0.20 RISE	24.98
II	E 1.641 – E 2.016	2.30 FALL	20.90
III	E 2.016 – E 2.866	0.31 FALL	15.25
3.	**Andheri – Kurla Road**		
I	E 2.866 – E 3.841	0.21 FALL	12.92
II	E 3.841 – E 4.366	0.51 FALL	10.56
4.	**Andheri – Ghatkopar Road**		
I	E 4.366 – E 5.091	0.31 RISE	10.37
II	E 5.091 – E 5.741	0.82 RISE	14.17
III	E 5.741 – E 6.366	2.36 RISE	24.22
IV	E 6.366 – E 6.591	3.12 FALL	25.07
V	E 6.591 – E 6.966	4.54 RISE	31.17
VI	E 6.966 – E 7.216	6.87 FALL	32.21
5.	**Hirachand Desai Road**		
I	E 7.216 – E 7.806	2.45 FALL	13.42

Table 5.6
Existing Road Profile - Western Segment

S. No.	**Chainage (Km.)**	**Grade (%)**	**Road Levels (Avg.)**
1.	**Jai Prakash Road/Versova Road**		
I	W 3.700 – W 3.659	4.91 FALL	7.34
II	W 3.659 – W 3.409	1.0 FALL	4.83
III	W 3.409 – W 1.809	LEVEL	3.70
IV	W 1.809 – W 1.534	0.17 RISE	4.09
V	W 1.534 – W 1.184	LEVEL	4.32
VI	W 1.184 – W 0.230	0.41 RISE	6.26

Due to these reasons the gradient along the proposed alignment also varies and at few locations exceeds 2%. At one location i.e. while crossing Western Express Highway, a gradient of 3.2% is provided.

As mentioned in earlier, the longitudinal section of DP Road needs to be reviewed to avoid very tall piers for the metro system on Golibar road up to Ghatkopar Station. The difference between ground level on approach of Golibar road and road at Ghatkopar station is 26.15 m in a length of 486 m. If the metro rail level is provided with 6.62 m vertical clearance over the D P Road near Sarvodaya Hospital, the pier height just after the Sarvodaya Hospital is about 24 to 25 m and even with 3.77 % down gradient towards Ghatkopar. The rail level at the Ghatkopar station shall be 28.78 m i.e. about 22 m above road level.

In view of the above it is proposed that the L-section of the D P Road is reviewed and lower Asalpha hill area to accommodate the metro alignment

To avoid very tall piers, L section between Subhash Nagar and Ghatkopar has been modified so that the tallest pier is about 12 to 13 m high. In this proposal the alignment passes below the viaduct at D P Road at Chainage E 7200 / E 7250 (D P Road level may have to be raised by 1 m). However this required cutting of hill by about 10.5 m. This will require protection work for D P Road viaduct.

The Vertical profile (gradient list) of Eastern Segment & Western Segment is given in **Table 5.7 & Table 5.8** respectively.

Table 5.7

Vertical Alignment - Eastern Segment
Proposed Rail Level

FROM CHAINAGE	TO CHAINAGE	GRADE	RISE/FALL
W 78.91	E 146.09	0	LEVEL
E 146.09	E 531.09	1	RISE
E 531.09	E 911.09	3.2	RISE
E 911.09	E 1171.09	0	LEVEL
E 1171.09	E 1451.09	-1.5	FALL
E 1451.09	E 1791.09	0.1	RISE
E 1791.09	E 1951.09	-2.8	FALL
E 1951.09	E 2186.09	-1.02	FALL
E 2186.09	E 2386.09	0	LEVEL

E 2386.09	E 2646.09	-2	FALL
E 2646.09	E 2906.09	1.2	RISE
E 2906.09	E 3126.09	0	LEVEL
E 3126.09	E 3346.09	-2.3	FALL
E 3346.09	E 3566.09	1.4	RISE
E 3566.09	E 3801.09	0	LEVEL
E 3801.09	E 4046.09	-1.5	FALL
E 4046.09	E 4426.09	0.3	RISE
E 4426.09	E 4626.09	1.1	RISE
E 4626.09	E 4846.09	0	LEVEL
E 4846.09	E 5006.09	-1.5	FALL
E 5006.09	E 5406.09	1.2	RISE
E 5406.09	E 5746.09	1.5	RISE
E 5746.09	E 5946.09	2.6	RISE
E 5946.09	E 6156.00	0	LEVEL
E 6156.00	E 6720.00	0.5	RISE
E 6720.00	E 6870.00	0	LEVEL
E 6870.00	E 7130.00	-0.5	FALL
E 7130.00	E 7686.09	-3	FALL
E 7686.09	E 7850.00	0	LEVEL

Alternative over DP Road (Not Recommended)

From Chainage	To Chainage	Grade	Rise/Fall
E 5946.09	E 6156.00	0.00	LEVEL
E 6156.00	E 6720.00	1.50	RISE
E 6720.00	E 6870.00	0.00	LEVEL
E 6870.00	E 7130.00	2.30	RISE
E 7130.00	E 7686.09	-3.77	FALL
E 7686.09	E 7850.00	0.00	LEVEL

Table 5.8
Vertical Alignment - Western Segment

FROM CHAINAGE	TO CHAINAGE	GRADE	RISE/FALL
w 3210.00	w 3058.91	0	LEVEL
w 3058.91	w 2778.91	-0.3	FALL
w 2778.91	w 2628.91	-1.7	FALL
w 2628.91	w 2378.91	0.45	RISE
w 2378.91	w 2253.91	1.25	RISE

w 2253.91	w 2028.91	0	LEVEL
w 2028.91	w 1903.91	-2.4	FALL
w 1903.91	w 1753.91	1	RISE
w 1753.91	w 1472.53	0.75	RISE
w 1472.53	w 1228.91	0	LEVEL
w 1228.91	w 1153.91	-0.8	FALL
w 1153.91	w 603.91	0.82	RISE
w 603.91	w 458.91	-0.2	FALL
w 458.91	w 303.91	-1.2	FALL
w 303.91	W 78.91	2	RISE
W 78.91	E 146.09	0	LEVEL

Comparison of difference in Rail Level in two alternatives

	Rail level difference from Ground Level	
Chainage	**Recommended L Section (below D P road)**	**Alternative L Section (above D P road)**
E 6046	12.96	12.96
E 6146	10.95	10.95
E 6246	8.65	9.55
E 6346	5.25	7.17
E 6446	4.41	7.31
E 6546	10.53	14.43
E 6646	13.62	18.54
E 6746	9.46	16.24
E 6846	6.06	11.50
E 6946	-3.39	4.23
E 7046	-9.84	0.63
E 7146	-1.12	11.64
E 7246	13.26	25.28
E 7346	12.19	23.45
E 7446	12.61	23.10
E 7546	12.15	21.87
E 7646	13.12	22.08
E 7746	13.15	21.78

5.2.10 Curvature

There are many sharp turns and curves along the roads. This necessitates provision of curves for metro alignment also to keep the same at the median of the roads. The radius of curves is kept as low as 100 m to reduce the property acquisition. About 42.76% of the length of the alignment is on curves on eastern segment and about 45.68% of the length of the alignment is on curves on western segment. The details of curves on Eastern segment & Western segment are given **Table 5.9 & Table 5.10** respectively.

TABLE 5.9
DETAILS of CURVES – EASTERN SEGMENT

CHAINAGE							
TP1	TP2	TP3	TP4	RADIUS	TRANSITION	CURVE LENGTH	STRAIGHT BETWEEN TWO CURVES
W 14.48	E 0.52	E 61.83	E 76.83	2000	15	61.31	107.19
E 184.02	E 199.02	E 228.21	E 243.21	2700	15	29.20	151.13
E 394.34	E 409.34	E 472.77	E 487.77	2000	15	63.43	127.93
E 615.71	E 625.71	E 676.01	E 686.01	4000	10	50.31	382.98
E 1069.00	E 1124.00	E 1266.27	E 1321.27	400	55	142.28	59.09
E 1380.37	E 1420.37	E 1563.68	E 1603.68	500	40	143.31	29.64
E 1633.31	E 1663.31	E 1701.35	E 1731.35	750	30	38.04	137.56
E 1868.91	E 1908.91	E 1989.05	E 2029.05	500	40	80.14	128.36
E 2157.41	E 2167.41	E 2203.03	E 2213.03	3500	10	35.62	59.50
E 2272.53	E 2287.53	E 2354.72	E 2369.72	2500	15	67.19	174.64
E 2544.35	E 2559.35	E 2584.80	E 2599.80	2000	15	25.44	166.04
E 2765.84	E 2795.84	E 2828.45	E 2858.45	800	30	32.61	381.76
E 3240.21	E 3250.21	E 3278.00	E 3288.00	3000	10	27.78	442.58
E 3730.57	E 3785.57	E 3816.65	E 3871.65	270	55	31.07	73.53
E 3945.17	E 4000.17	E 4195.99	E 4251.00	300	55	195.82	78.33
E 4329.33	E 4339.33	E 4371.51	E 4381.51	4000	10	32.18	86.23
E 4467.74	E 4522.74	E 4557.16	E 4612.16	250	55	34.42	62.45
E 4674.61	E 4699.61	E 4798.02	E 4823.02	1000	25	98.41	66.58
E 4889.60	E 4919.60	E 4950.25	E 4980.25	800	30	30.65	74.54
E 5054.79	E 5109.79	E 5148.77	E 5203.77	300	55	38.98	252.78
E 5456.55	E 5511.55	E 5637.27	E 5692.27	400	55	125.73	355.55
E 6047.82	E 6062.82	E 6107.79	E 6122.79	2500	15	44.97	149.78
E 6272.57	E 6327.57	E 6362.10	E 6417.10	252	55	34.53	NIL
E 6417.10	E 6472.13	E 6501.32	E 6556.32	185	55	29.19	NIL
E 6556.32	E 6596.37	E 6622.20	E 6662.20	706	40	25.83	273.20
E 6935.40	E 6990.40	E 7023.66	E 7078.66	225	55	33.26	103.15

E 7181.81	E 7236.81	E 7348.10	E 7403.10	100	55	111.29	78.14
E 7481.24	E 7501.24	E 7545.75	E 7565.75	1500	20	44.51	193.78
E 7759.53	E 7769.53	E 7803.09	E 7813.09	5500	10	33.56	440.24
E 8253.33	**EASTERN END**						

TABLE 5.10
DETAILS of CURVES – WESTERN SEGMENT

CHAINAGE							
TP1	**TP2**	**TP3**	**TP4**	**RADIUS**	**TRANSIT ION**	**CURVE LENGTH**	**STRAIGHT BETWEEN TWO CURVES**
W 3733.66	**WESTERN END**						
W 3584.54	W 3549.54	W 3518.85	W 3483.85	650	35	30.69	38.54
W 3445.32	W 3420.32	W 3385.25	W 3360.25	1168	25	35.07	NIL
W 3360.24	W 3305.24	W 3249.59	W 3194.59	150	55	55.66	68.02
W 3126.56	W 3101.56	W 3045.18	W 3020.18	1100	25	56.39	NIL
W 3020.16	W 2990.16	W 2955.89	W 2925.89	898	30	34.28	1067.60
W 1858.28	W 1848.28	W 1818.43	W 1808.43	7000	10	29.85	115.50
W 1692.92	W 1637.92	W 1595.79	W 1540.79	457	55	42.13	NIL
W 1540.78	W 1485.78	W 1459.26	W 1404.26	425	55	26.53	25.07
W 1379.18	W 1369.18	W 1329.96	W 1319.96	3000	10	39.22	66.36
W 1253.60	W 1238.60	W 1208.62	W 1193.62	2500	15	29.98	83.17
W 1110.45	W 1055.45	W 858.83	W 803.83	275	55	196.63	NIL
W 803.75	W 748.75	W 714.43	W 659.43	121	55	34.33	83.01
W 576.42	W 546.42	W 521.21	W 491.21	930	30	25.21	65.74
W 425.47	W 395.47	W 364.95	W 334.95	900	30	30.52	79.53
W 255.43	W 245.43	W 211.03	W 201.03	5000	10	34.40	186.55
W 14.48	E 0.52	E 61.83	E 76.83	2000	15	61.31	107.19

5.2.11 Junction station

The Proposed corridor Versova – Andheri – Ghatkopar and the another Phase – I corridor Colaba – Bandra – Charkop (North - South) along the link road (Kamalakar Pant Valakar Marg) cross each other in elevation at the junction of JP road & Link road near D.N.Nagar. The North – South corridor will be crossing the East – West corridor in double elevation. As construction of a combined multilevel station involves acquisition of large number of properties, it is proposed to stagger the two stations and providing common concourse.

5.2.12 Stabling yard layout

Versova – Andheri – Ghatkopar corridor does not have any stabling facility at its east end. A maintenance depot offering facilities for minor repairs, stabling and rake interchange between the two corridors has been planned North-West of the proposed D.N.Nagar metro station, which has direct approach from the J.P.road.

5.3 STATION PLANNING

5.3.1 GENERAL

Stations on the Line

The proposed Versova-Andheri-Ghatkopar MRTS corridor runs eastwards from Versova to Ghatkopar via D N Nagar, Azad Nagar, Andheri, WEH, Chakala, Airport Road, Marol Naka, Saki Naka, Subhash Nagar, and Asalpha covering a distance of approximately 11-kms from centre of Versova station to Ghatkopar Station.

A total of 12 stations have been planned along the proposed Corridor. Beginning from Versova, all stations are proposed to be elevated. Average inter-station distance is one km, though it varies from 0.645-km to 1.35-km due to landuse and topographic reasons. (Refer **Figure 5.3.1**).

Station location criteria
Land related issues

- Suitability from point of view of traffic integration is a main criterion for fixing station locations. Stations have been located in such away as to be near established traffic interchange nodes so that they fit in the existing transport network and provide seamless intermodal transfer
- Adequate width of road (in case of station being in the middle of road, elevated or underground)
- Availability of land for locating entry exit structures Parking and Dispersal facilities, DG set, Fire tank.
- Stations are located in a way minimize property acquisition

Alignment related issues

- Inter station distance to about 1 km
- Stations are not located on gradients, and are always to be on horizontal alignment.
- Alignment should be straight to the extent possible. In case the station must be located on curves due to other pressing demands, the curve should not be sharper than 1000 m radius.

Structural constraints

- Although stations are preferred to be close to road intersection, the effort is to locate them not over the intersection so that the station structure does not hamper the traffic flow.

Construction issues

- Possibility of creating traffic diversions during construction period

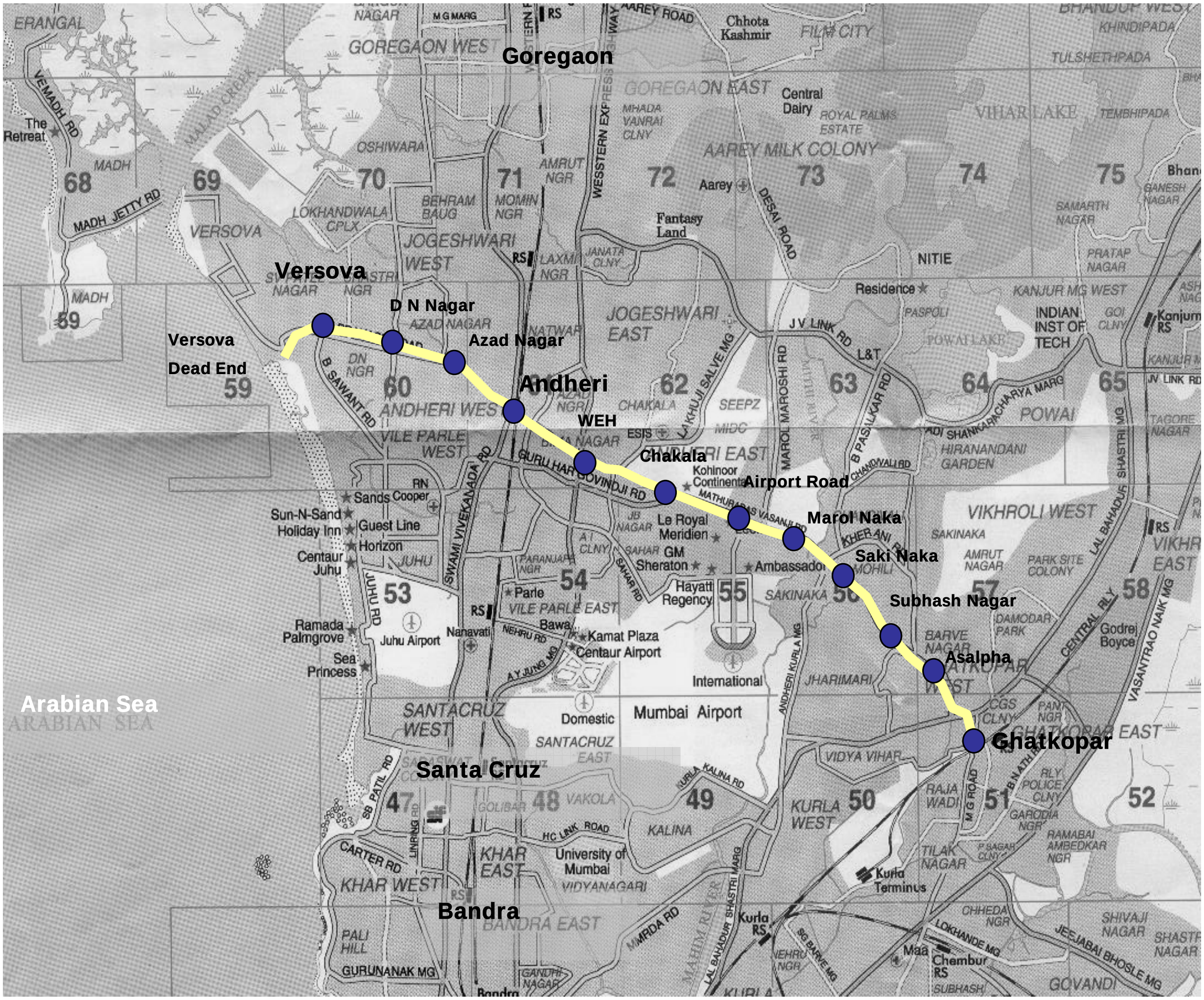


Figure 5.3.1 VERSOVA – ANDHERI - GHATKOPAR MRTS CORRIDOR

Other considerations

- Urban Design Impact (including to adjoining properties)
- A distinctive corporate image
- Provision of potential links to parking facilities
- Provision of potential links to adjoining properties and footbridges
- Safeguards to pedestrians and adjoining properties from noise and air pollution
- Traffic safety on the roads
- No decrease in pedestrian utility at footpath level

Rail Levels and Alignment

Proposed elevated alignment traverses about 11.07-kms in length. The general rail level is approximately 12-m above road and is governed by a ground clearance of 5.50-m. This in turn determines the level of the entire station structure on the elevated section. In order to keep the land acquisition to minimum, alignment is planned generally in middle of the road and a two-level elevated station design has been proposed. Entry/exit structures to the proposed stations have been planned in the space available within the right of way as proposed by Mumbai Metropolitan Region Development Authority (MMRDA) in its development plan. Wherever necessary, roads are aligned to match the alignment of rail tracks of proposed MRTS to place the viaduct on median of the road.

Platforms

All the elevated stations have been planned along side platforms. Care has been taken to locate stations on straight alignment only. However, in some stations, site constraints have become the deciding criteria and a curve of 1000-m radius has been introduced.
The sequence of stations along with their respective chainages, site and platform characteristics are presented in the **Table 5.3.1**.

Table 5.3.1 STATION LOCATION CHARACTERISTICS

Name of Station	**Chainage (in km)** W – West E - East	**Distance from Previous Station (in km)**	**Rail Level (RL in m)**	**Height from Adjacent Ground (in m)**	**Platform Type and Nos**	**Alignment Description**
Versova	W3.139		16.44	13.00	Side Platforms, 2 Nos.	Straight
D N Nagar	W2.139	1.00	15.60	12.07	Side Platforms, 2 Nos.	Straight
Azad Nagar	W1.344	0.80	16.11	12.15	Side Platforms, 2 Nos.	Partly on 1000 m curve

Andheri	0.000	1.34	22.45	12.64	Side Platforms, 2 Nos.	Straight
WEH	E0.995	1.00	38.46	21.49	Side Platforms, 2 Nos.	Straight
Chakala	E2.279	1.28	27.84	12.77	Side Platforms, 2 Nos.	Straight
Airport Road	E3.014	0.74	25.58	13.63	Side Platforms, 2 Nos.	Straight
Marol Naka	E3.660	0.65	23.36	11.96	Side Platforms, 2 Nos.	Straight
Saki Naka	E4.696	1.04	22.88	11.83	Side Platforms, 2 Nos.	Partly on 1000-m curve
Subhash Nagar	E6.046	1.35	35.30	12.96	Side Platforms, 2 Nos.	Straight
Asalpha Road	E6.788	0.74	38.12	8.28	Side Platforms, 2 Nos.	Off the road, Straight
Ghatkopar	E7.786	1.00	20.14	13.94	Side Platforms, 2 Nos.	Straight

5.3.2 STATION LOCATIONS

5.3.2.1 VERSOVA STATION (Chainage W 3.139)

The station is located in Seven Bungalow area of Versova, near the BEST bus terminal. Station center is in front of compound wall of Eversweet Apartments and Balkrishna Cooperative Housing Society building. Existing road and setbacks in the properties are not wide enough to accommodate the stations and entry/exit stairs. The alignment has therefore been pushed away from seaside towards bus terminal to the extent that the station building edge is at least 15 m away from the buildings in compounds of the affected properties.

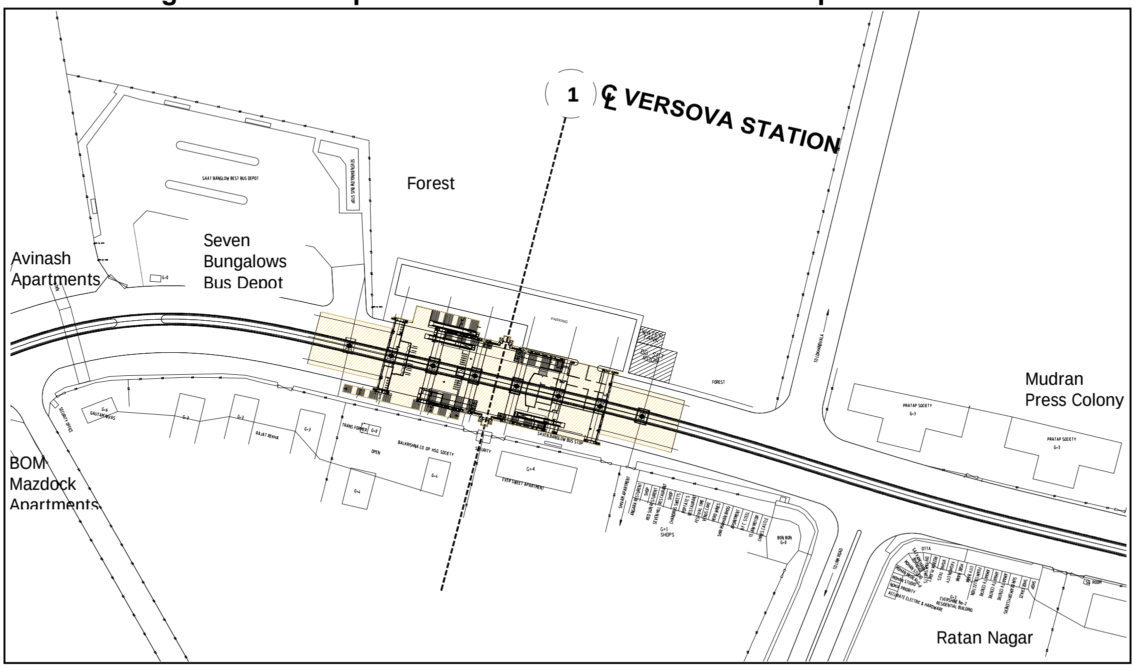
Road under the station is proposed to be realigned to match the alignment of rail tracks. Entry / exit stairs are provided on both side of the road. These are also integrated with the interchange facility i.e. private vehicles parking on bus terminal side of station. (Refer fig 5.3.2)

Catchment of station would largely be the dense residential area around the station and would extend to Sanjeev Enclave, Ratan Nagar, Avinash Apartments, BOM mazdock Apartments and Mudran Press Colony. The station may also cater to areas upto Sunder Wadi and Joseph Patel Wadi. (Refer fig 5.3.3)

Figure 5.3.2: Site Conditions- Versova

Bus terminal in *Seven Bungalows*	View of the catchment area	Narrow right of way available at station location

Figure 5.3.3: Proposed Versova Station Area Development Plan



5.3.2.2 D N NAGAR STATION (Chainage W 2.139)

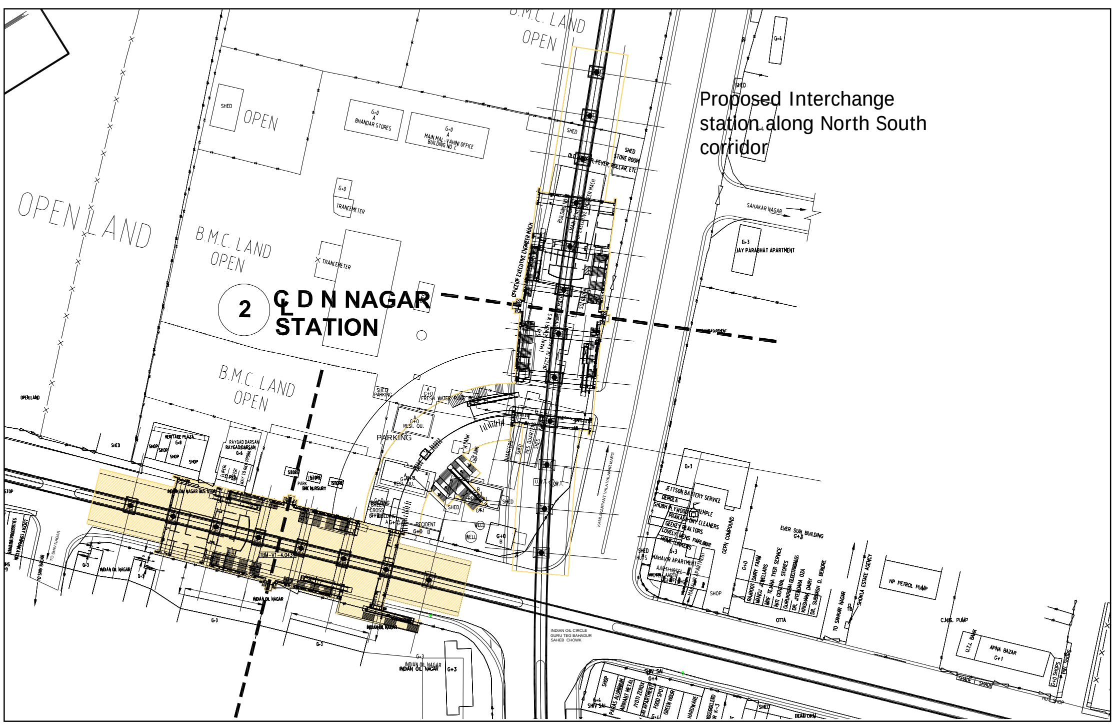
DN Nagar would serve as interchange between the *Colaba-Bandra-Charkop* corridor and the *Versova -Andheri-Ghatkopar* corridor with the former going over the later. The two corridors cross over at Indian oil Nagar Intersection. However the interchange between the two has not been planned right at the intersection due to paucity of space at road intersection and a dense built up area around the intersection. Instead an L shaped configuration has been adopted for the interchange station. Common concourse for the two lines has been planned and is located in the open land available on the north west of the intersection, opposite Indian Oil Nagar residential area. *(Refer fig 5.3.4)*

Figure 5.3.4: Site Conditions- DN Nagar

View of the *Jay Prakash Road-Andheri Link Road* Intersection at *Indian Oil Nagar*	Open space on the north west of the intersection

The station would act as interchange station between the two proposed East West and North South MRTS corridors. Station would cater to DN Nagar, Indian Oil Nagar, New LIC Colony, Madhuban Colony and MHADA Colony Phase I. Catchment area of the station may extend to Shanti Nagar and Bahadurgarh Colony. *(Refer fig 5.3.5)*

Figure 5.3.5: Proposed D N Nagar Station Area Development Plan



5.3.2.3 AZAD NAGAR STATION (CHAINAGE W 1.344)

Azad Nagar station is located near Andheri Sports Club, in the middle of the road with centerline in front of Garden Court Restaurant. Alignment is straight and platforms are about 13m above road level. Previous DN Nagar station is at a distance of 811-m from the proposed station.

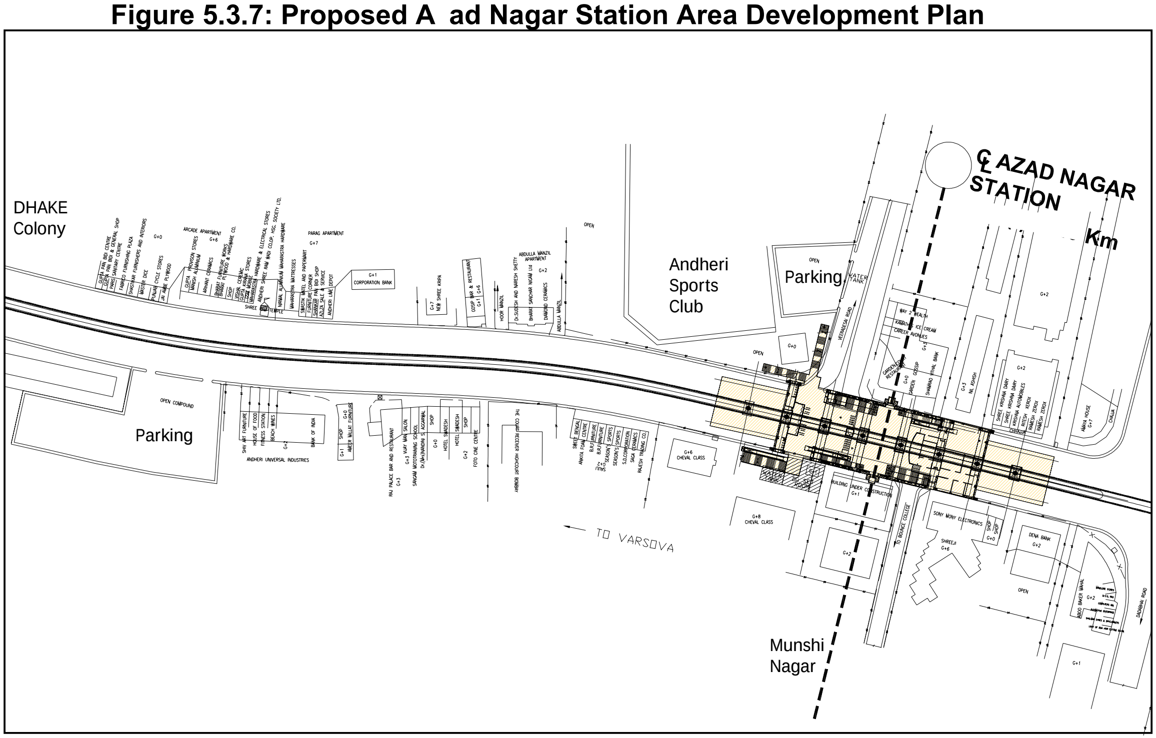
Adequate right of way is available at the station location for passage of three traffic lanes under the station structure and locating the station columns by the roadside. Land acquisition would be required for locating the entry/ exit stairs, in the compound of Andheri Sports Club on north of alignment and in the compound of Cheval Class Apartments on the south of the alignment. *(Refer fig 5.3.6)*

Commuters from Azad Nagar area, MHADA Colony Phase II & III, DHAKE Colony, Tepgaon and Dattaguru Nagar would use the station. Catchment of the station may extend to Munshi Nagar, Amboli, Mahalaxmi Colony and Andheri Industrial Area. *(Refer fig 5.3.7)*

Figure 5.3.6: Site Conditions- A ad Nagar

View of *Jay Prakash Road*	Corner of *Andheri Sports Club*

Figure 5.3.7: Proposed A ad Nagar Station Area Development Plan



5.3.2.4 ANDHERI STATION (Chainage 0.0)

The station is in Andheri East near the Andheri station of Western Railway. Station centerline passes through open land on the north of alignment by the side of New Nagardas Road. This is an elevated station and side platforms are approximately 13.0 m above the ground. The station is 1240 – m from the previous Azad Nagar station.

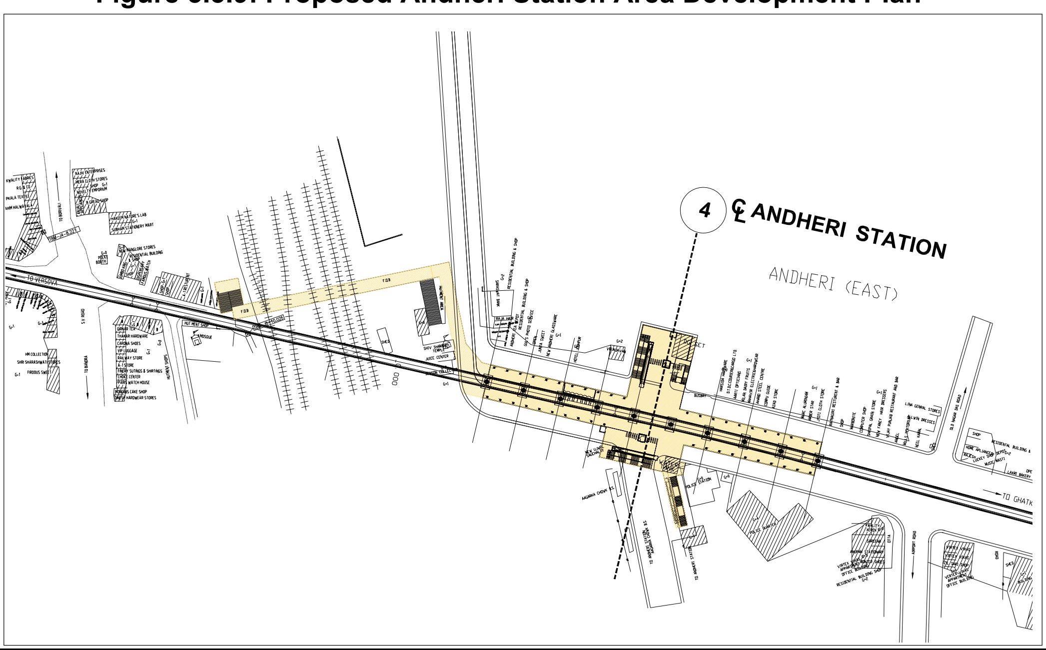
Road under the station is proposed to be widened as proposed by MMRDA in its Development Plan and realigned to match the alignment of the rail tracks and the station structure. Three lanes on each direction have been planned within the right of way. Entry / exit stairs are provided on both side of the road beside the station structure. Northern Entry/Exit structures are linked to existing Foot Over Bridge on Western Railway main line at concourse level. Southern Entry/Exit Structures have been provided on New Nagardas Road near Police station above the intersection. *(Refer fig 5.3.8)*

Major traffic at this station comprises the interchange passengers arriving at the WR station by suburban trains and going towards Versova/ Ghatkopar. *Park & Ride* facility for passengers has been planned on the open land below the concourse structure. Catchment of station would largely be the dense residential area around the station at Andheri East & West Side and would extend to Bima Nagar, Vijay Nagar, Part of Vile Parle West & Azad Nagar, and Natwar Nagar. The station may also cater to passengers coming from Swami Vivekanand Road. *(Refer fig 5.3.9)*

Figure 5.3.8: Site Conditions - Andheri

Suburban station in *Andheri*	View of Existing Foot over bridge at station location

Figure 5.3.9: Proposed Andheri Station Area Development Plan



5.3.2.5 WEH STATION (Chainage E 0.995)

WEH Station is located close to Western Express Highway and Andheri Kurla Road intersection. The station is doubly elevated due to existing WEH Flyover at the intersection. Centerline of station is passing through HP Petrol Pump on north of the alignment. The station is 996-m from the previous Andheri station. Side platforms are approximately 13.00 – m above the ground.

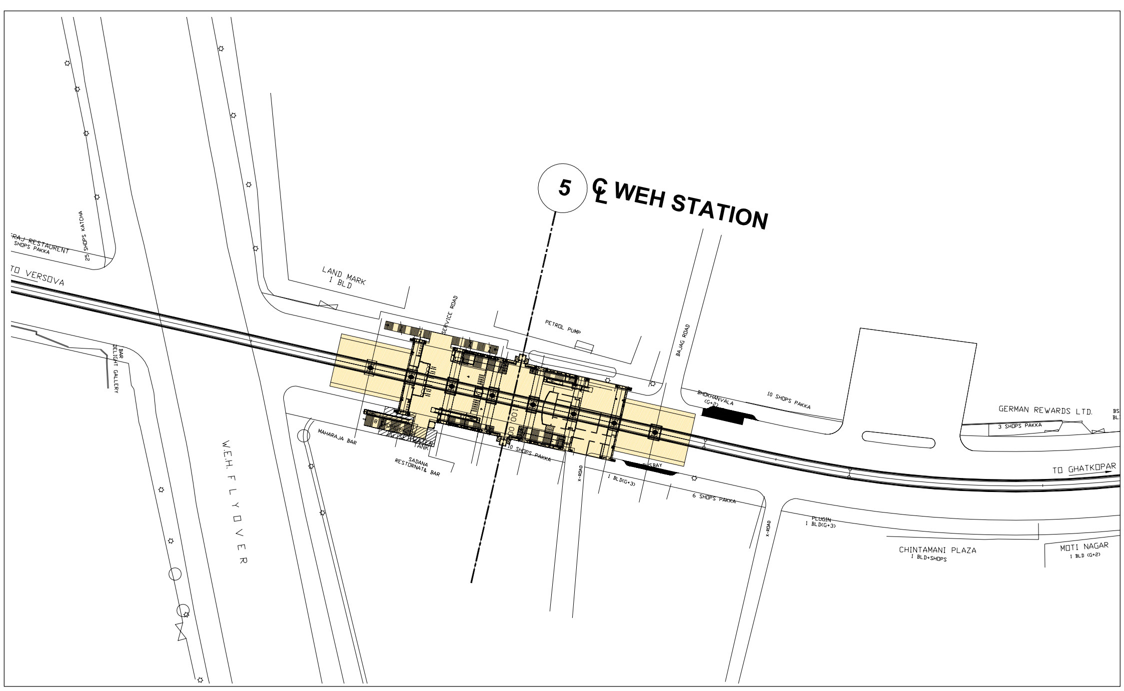
Entry/Exit Structures on both sides have been planned besides the Andheri Kurla Road with proposed right of way of 36.60 m in Development Plan by MMRDA. Provision of 3 lanes for each direction has been made under the station structure. Northern entry/exit structure of station has been planned on the space between Landmark Shopping Centre and HP Petrol Pump whereas southern stairs are located in front of Maharaja Bar & Restaurant. *(Refer fig 5.3.10)*

The station would cater to residential areas in and around Satyadarshan Colony, Govind Wadi, part of Bima Nagar, part of Azad Nagar and catchment may extend to MHADA Colony in Jogeswari East, Air India Colony, and part of Paranjape Nagar. *(Refer fig 5.3.11)*

Figure 5.3.10: Site Conditions- WEH

			
View of existing Flyover on Western Express Highway		View of the catchment area	Space available at station location in front of Petrol Pump

Figure 5.3.11: Proposed WEH Station Area Development Plan



5.3.2.6 CHAKALA STATION (Chainage E 2.279)

Elevated Chakala station is located near Guru Nanak Chowk, the intersection of Andheri Ghatkopar Link Road and Andheri Kurla Road. Centerline of station passes through RPJ Tower on the southern side of alignment. The station is 1283–m from the previous WEH station. Side platforms are approximately 13.00 – m above the ground level.

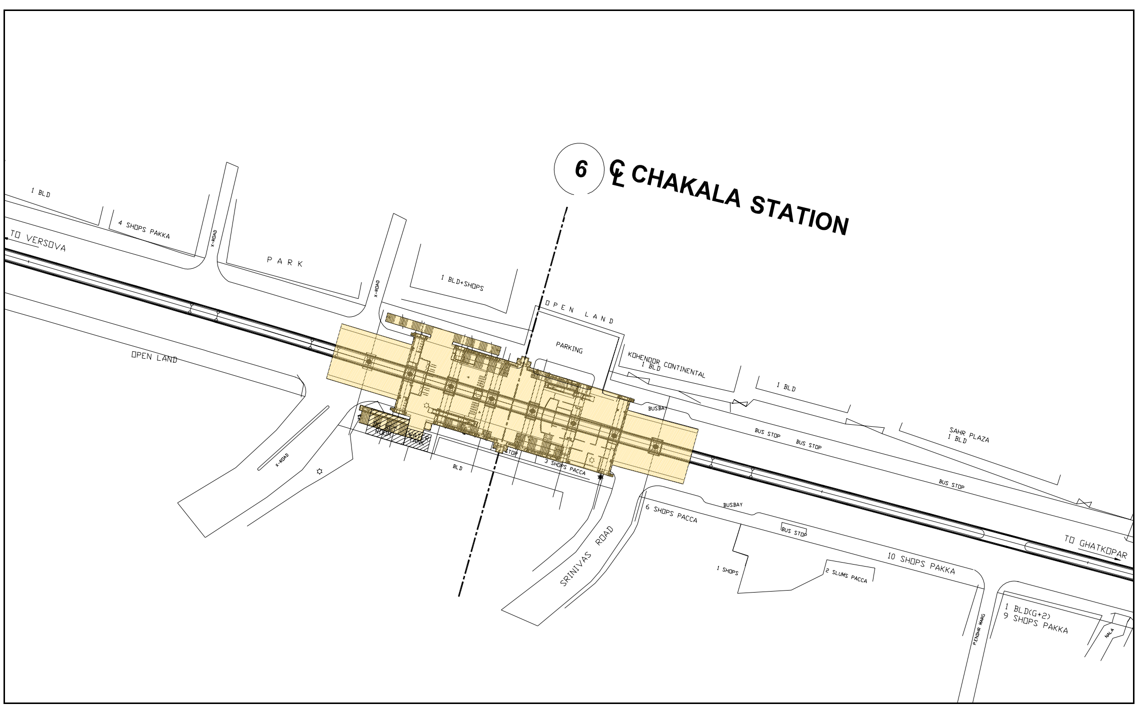
Entry/exit structures on both sides have been planned on footpaths along the Andheri Kurla Road with proposed MMRDA right of way of 36.60 m. Provision of 3 lanes for each direction traffic has been made. Northern access of the station has been planned in front of Kohinoor Continental whereas southern stairs are located on the footpaths along the Sriniwas Road. *(Refer fig 5.3.12)*

Catchment of the station would extend to JB Nagar, part of Sahar and Air India Colony. The station would also cater to areas upto Paranjape Nagar, Vile Parle East, Jogeshwari East, SEEPZ and MIDC area. *(Refer fig 5.3.13)*

Figure 5.3.12: Site Conditions- Chakala

Wide right of way available at station location	Station Location besides the Andheri Kurla Road	View of the catchment area

Figure 5.3.13: Proposed Chakala Station Area Development Plan



5.3.2.7 AIRPORT ROAD STATION (Chainage E 3.014)

Airport Road station is an elevated station on the proposed East West corridor and located on the central verge along Andheri Kurla Road and is closely planned close to the Airport Road intersection in front of Hotel Leela. Centerline of the station lies besides Church Road and is passing through Petrol Pump on the south of the alignment. The station is 735-m from the previous Chakala station. Side platforms are approximately 13.00 – m above the ground.

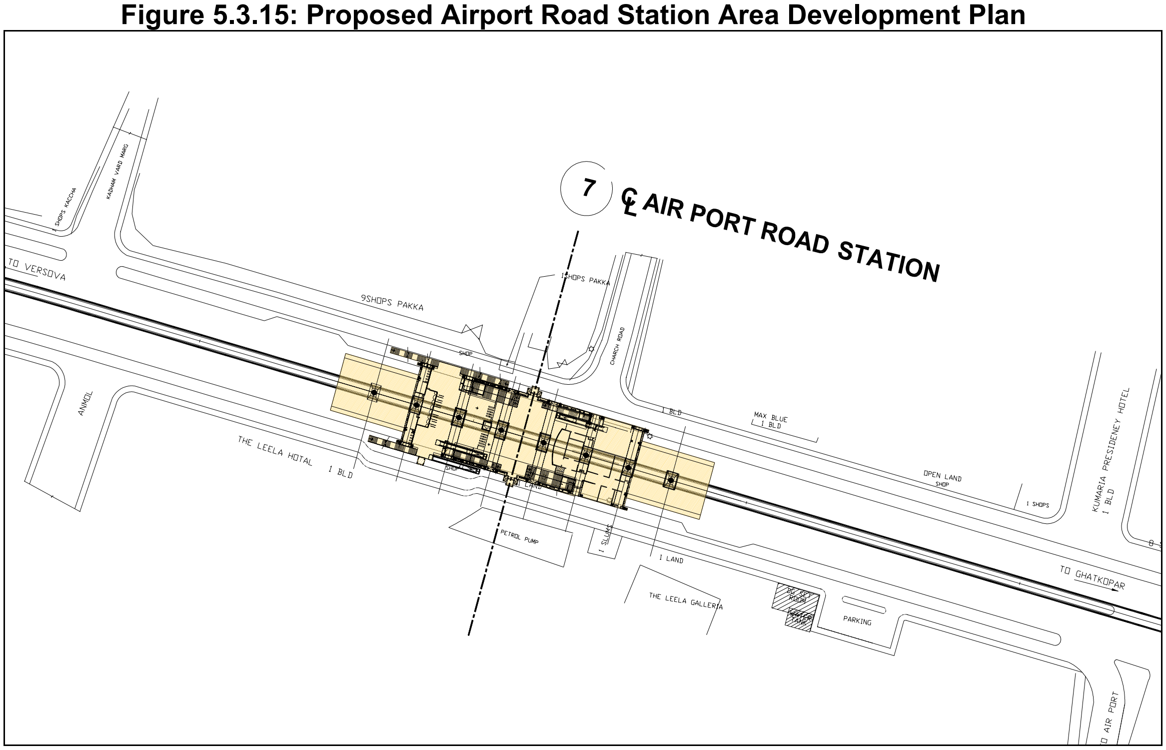
Entry/exit structures have been planned on the footpaths on both sides along the AK Road such that 3 lanes for each direction traffic are available. Northern Entry/Exit structures of the station have been planned near Leela Business Park whereas southern structures are located in front of Petrol Pump. *(Refer fig 5.3.14)*

The station would cater to residential area around the Ashok Nagar, Greater Indira Nagar, Sai Freepark Colony, part of J B Nagar, Kanti Nagar and commercial areas along the Andheri Kurla Road. Catchment of the station would extend to P&T Colony, CPWD Colony, Santacruz, and Sahar. *(Refer fig 5.3.15)*

Figure 5.3.14: Site Conditions- Airport Road

			
Intersection of Airport Road with AK Road	Available space at station location along Andheri Kurla Road		View of the catchment area

Figure 5.3.15: Proposed Airport Road Station Area Development Plan



5.3.2.8 MAROL NAKA STATION (Chainage E 3.660)

Marol Naka Station is located on the central verge of Andheri Kurla Road near Arya Colony Road intersection. Centerline of the station is passing through Everest Chamber on north of the alignment. Side platforms are approximately 13.00 – m above the ground level.The station is 646-m from the previous Airport Road station.

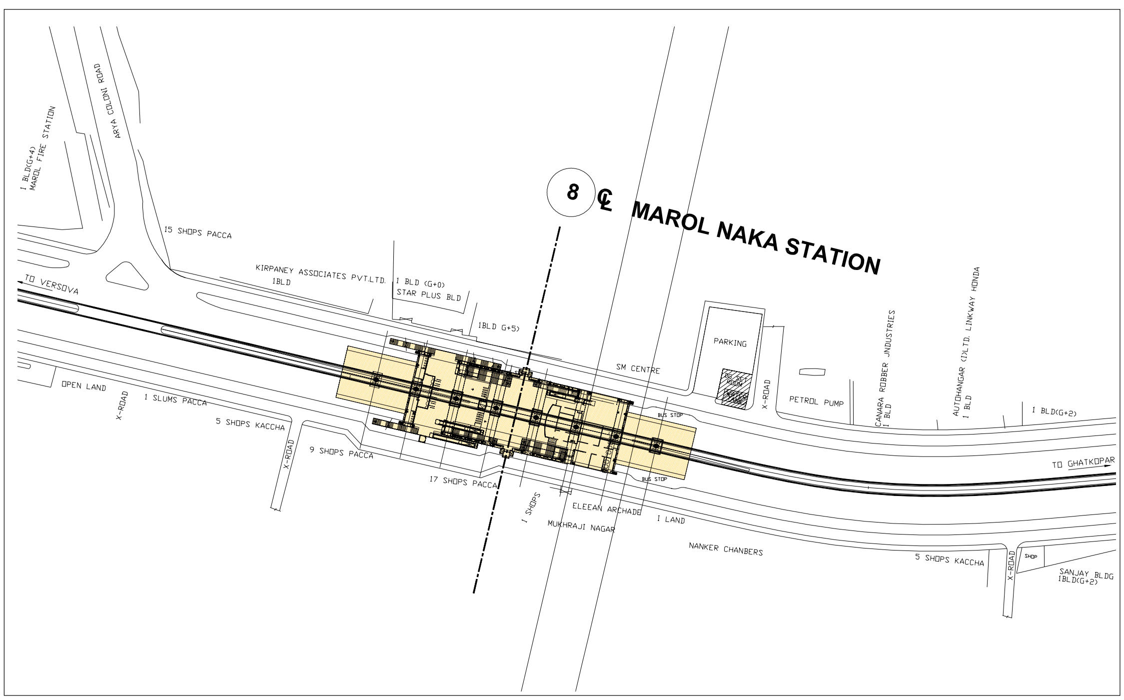
Side entry/exit structures have been planned along the Andheri Kurla Road with proposed ROW of 45.70- m. Northern Entry/Exit structures of the station have been planned on the footpath between in front of Everest Chamber whereas southern structures are located in front of Elecon Arcade. *(Refer fig 5.3.16)*

The Station would cater to Navpada, Chimatpada, Ganesh Nagar and Yadav Nagar. Catchment area of station would extend to Chandivali and Arya Colony to the north of alignment whereas part of Jharimari on the south of the alignment. *(Refer fig 5.3.17)*

Figure 5.3.16: Site Conditions- Marol Naka

			
Space available besides the right of way at station location			View of the catchment area

Figure 5.3.17: Proposed Marol Naka Station Area Development Plan



5.3.2.9 SAKI NAKA STATION (Chainage E 4.696)

Saki Naka station is located on the central verge of Andheri Kurla Road near D Samant Chowk (Saki Naka) intersection. Station centerline passes through Udipi Restaurant on the south of alignment besides the Cross Road to Jaganath Temple. This is an elevated station and side platforms are approximately 13.0 m above the ground level. The station is 1036-m from the previous Marol Naka station.

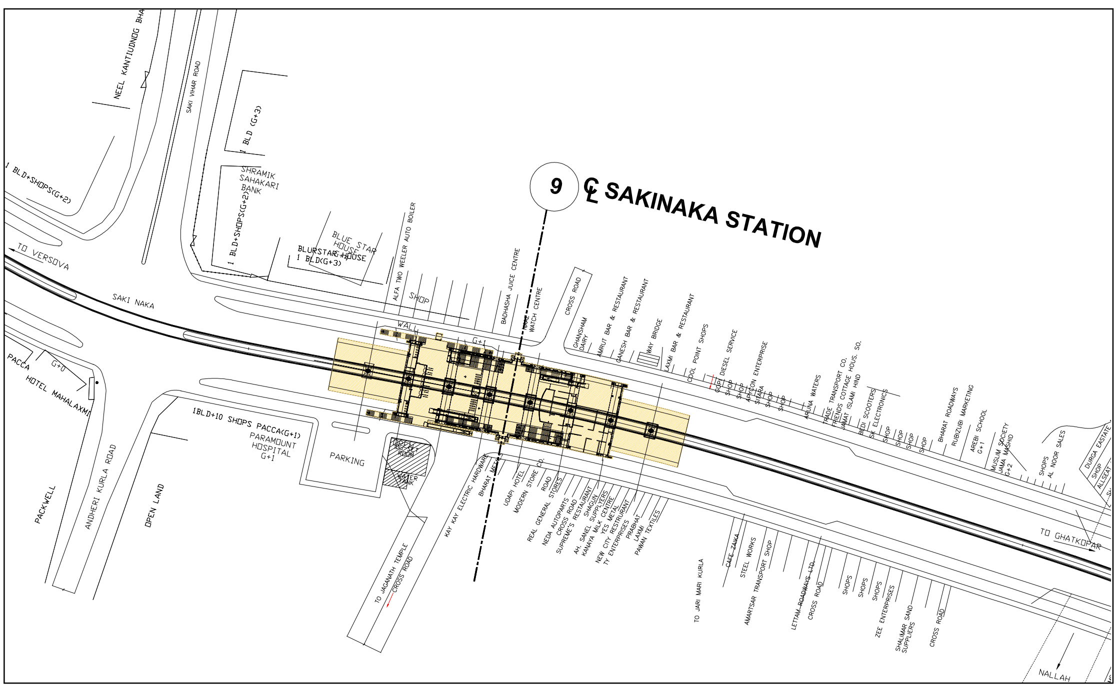
Road under the station is proposed to be widened to 45.70-m ROW. Three lanes on each direction have been planned within the ROW under the station structure. Entry / exit stairs are provided on footpaths on both side of the road beside the station structure. Northern Entry/Exit structures are located in front of Blue Star House whereas southern entry/exit structures have been provided on open space near Cross Road to Jaganath Temple. *(Refer fig 5.3.18)*

Catchment of the station would largely extend to Nairwadi, Sag Baug and part of Candivali, Saki Vihar. The station may also cater to areas upto Hiranandani Garden from Powai Lake side on the north of the alignment and part of Jharimari on the south of the alignment. *(Refer fig 5.3.19)*

Figure 5.3.18: Site Conditions- Saki Naka

			
View of busy Saki Naka (Datta Samant Chowk)		View of the catchment area	Wide right of way available at station location

Figure 5.3.19: Proposed Saki Naka Station Area Development Plan



5.3.2.10 SUBHASH NAGAR STATION (Chainage E 6.046)

Subhash Nagar Station is an elevated station and located on the central verge along Andheri Ghatkopar Road. Centerline of the station lies besides Amol Super market building on the south of the alignment. The station is 1350-m from the previous Saki Naka station. Side platforms are approximately 13.00 – m above the ground.

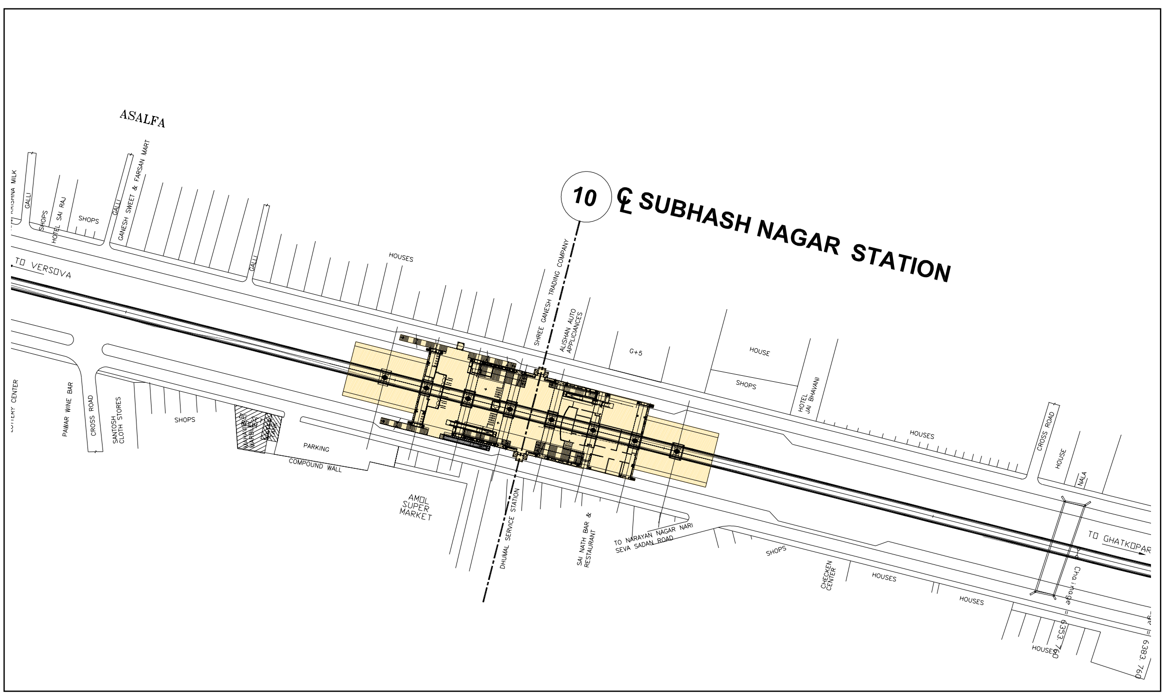
Side entry/exit structures have been planned on the footpaths on both sides along the Andheri Ghatkopar Road such that 3 lanes for each direction traffic would be available below the station structure. Northern entry/exit structures of the station have been planned on the footpath near Shree Ganesh Trading Company whereas southern structures are located in front of Amol Super Market. *(Refer fig 5.3.20)*

Commuters from Mohili, part of Nairwadi and Jharimari are likely to use this station, whose catchment may extend to part of Vidya Vihar, Lokmanya Tilak Nagar and Milind Nagar as well. *(Refer fig 5.3.21)*

Figure 5.3.20: Site Conditions- Subhash Nagar

View of the available space at station location along Andheri Ghatkopar Road

Figure 5.3.21: Proposed Subhash Nagar Station Area Development Plan



5.3.2.11 ASALPHA ROAD STATION (Chainage E 6.788)

Asalpha Road station is an elevated station and located in the existing depression of the hillock beside the Kadam road. Proposed Andheri Ghatkopar Road passes through the hillock and station is proposed to be located off the road. Centerline of station would pass through the Jagruti Nagar settlement.

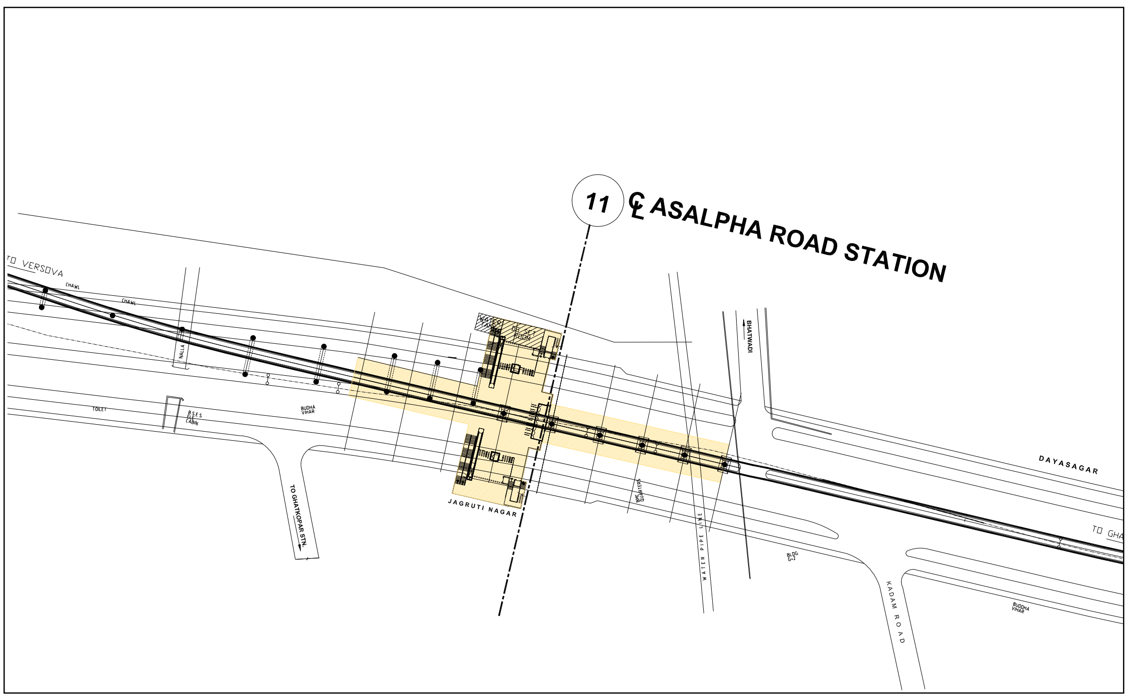
Andheri Ghatkopar Road under the station is going to be of 45.70-m right of way as per Development Plan. Three lanes on each direction have been planned under the station structure. Entry / exit stairs are provided in footpaths on both side of road besides the station structure. *(Refer fig 5.3.22)*

Catchment area for this station is Barve Nagar, Jagruti Nagar, Buddha Vihar and would stretch to Damodar Park, Amrut Nagar. Commuters from part of Jharimari and Park site Colony are also potential users of this station. *(Refer fig 5.3.23)*

Figure 5.3.22: Site Conditions- Asalpha

			
Proposed Link to Andheri Ghatkopar Road	Station Location near the Village Asalpha	View of the catchment area	Village settlement existing at station location

Figure 5.3.23: Proposed Asalpha Station Area Development Plan



5.3.2.12 GHATKOPAR STATION (Chainage E 7.786)

Ghatkopar station is last station on the proposed East West Corridor and located near the Ghatkopar suburban railway station on Hirachand Desai road. This is an elevated station on the central verge of the road. Centerline of station is passing through the Ashok Bar & Restaurant on north of the alignment. Side platforms are approximately 13.00-m above the ground level. The interstation distance is 1007-m between the previous Asalpha Road and Ghatkopar station.

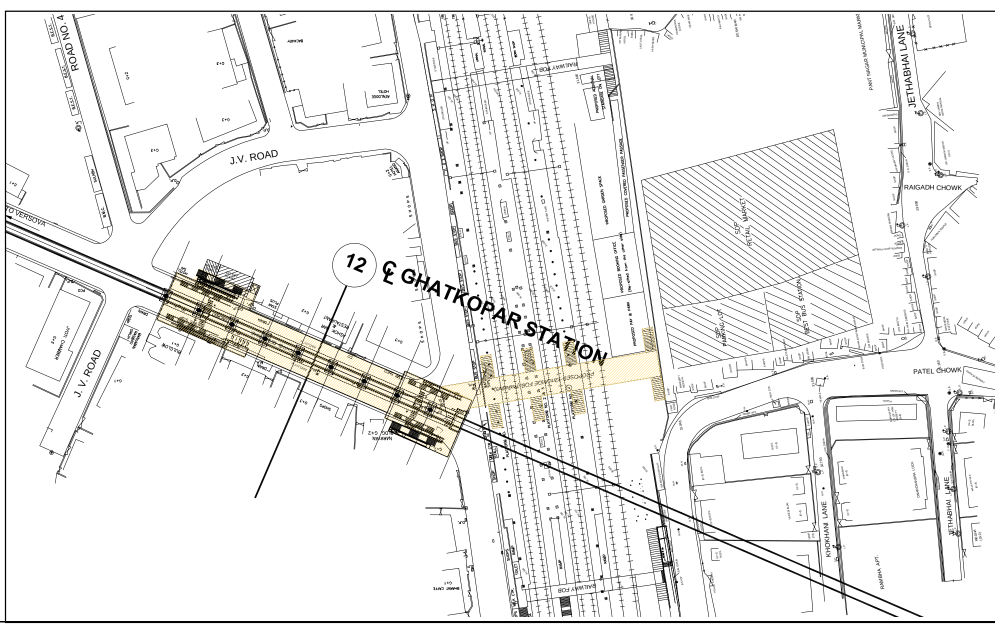
Road under the station would be of 18.30-m right of way as proposed by MMRDA in its Development Plan. Two lanes on each direction would be available below the station structure. Northern Entry/Exit structures are linked to existing Foot Over Bridge on Central Railway main line at concourse level. Another northern entry/exit is planned near Hotel Sai on JV Road intersection. Southern Entry/Exit structure has been provided on the space where land would be acquired from existing Narayan Building. *Park and Ride* facility for passengers has been planned on the land besides the concourse entry structures. *(Refer fig 5.3.24)*

Major traffic to this station comprises the passengers arriving through suburban trains on Central Railway main line and going towards Andheri. The station would cater to the Vidya Vihar, Rajawadi, MG Road Pant Nagar and CGS Colony. Railway Police Colony, Tilak Nagar, P Sagar Colony, Garodia Nagar and Ramabai Ambedkar Nagar would also fall within the catchment of this station. *(Refer fig 5.3.25)*

Figure 5.3.24: Site Conditions- Ghatkopar

View ofHirachand Desai Road	View overlooking the GhatKopar Suburban Railway Station	View of the catchment area

Figure 5.3.25: Proposed Ghatkopar Station Area Development Plan



5.3.3 STATION PLANNING

5.3.3.1 Planning and Design Criteria for Stations

Salient features of a typical station are as follows:

1. The station can be divided into public and non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.
2. The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized emergency scenario e.g. missed head ways, train delays & accidents.
3. The platform level at elevated stations is determined by a critical clearance of 5.50-m under the concourse above the road intersection, allowing 3.00-m for the concourse height, about 1-m for concourse floor and 2.00-m for structure of tracks above the concourse. Further, the platforms are 1.09-m above the tracks. This would make the platforms in an elevated situation at least 12.50-m above ground.
4. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.
5. The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimise cross flows of passengers and provide adequate circulation space.
6. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
7. Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right-of-way allocated to the MRTS.
8. Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The list of such areas are given below in **Table 5.3.2.**

Table 5.3.2
STATION ACCOMMODATION

1. Station Control Room	12. Security Room
2. Station Master's Office	13. First Aid Room
3. Information & Enquiries	14. Miscellaneous Operations Room
4. Ticket Office	15. Platform Supervisor's Booth
5. Ticket Hall Supervisor & Excess Fare Collection (Passenger Office)	16. Signaling Room
6. Cash and Ticket Room	17. Communications Room
7. Staff Area	18. Station Substation
8. Staff Toilets	19. Fire Tank and Pump Room
9. Station Store Room	20. Commercial Outlets and Kiosks
10. Refuse Store	21. UPS and Battery Room
11. Cleaner's Room	

10. The DG set, bore well pump houses, ground tank for fire fighting and pump houses would be located in one area on ground.
11. The system is being designed to inimize its attraction to potential passengers and the following criteria have been observed:
    - Minimum distance of travel to and from the platform and between platforms for transfer between lines.
    - Adequate capacity for passenger movements.
    - Convenience, including good signage relating to circulation and orientation.
    - Safety and security, including a high level of protection against accidents.

12. Following requirements have been taken into account:
    - Minimum capital cost is incurred consistent with inimize g passenger attraction.
    - Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
    - Flexibility of operation including the ability to adapt to different traffic conditions changes in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.
    - Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
    - Provision of display of passenger information and advertising.
13. The numbers and sizes of staircases/escalators are determined by checking the capacity against AM and PM peak flow rates for both normal and emergency conditions.
14. In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to inimize unnecessary walking distances and cross-flows between incoming and outgoing passengers**.**
15. Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice-versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).

5.3.3.2 Typical Elevated Station- (Refer Drg. No. 5.3.26) The station is generally located on the road median. Total length of the station is ~135-m. All the stations are two-level stations. The concourse is concentrated in a width of about 90-m in the middle of the station, with staircases leading from either side of the road. Passenger facilities like ticketing, information, etc as well as operational areas are provided at the concourse level. Typically, the concourse is divided into public and non-public zones. The non-public zone or the restricted zone contains station operational areas such as Station Control Room, Station Master's Office, Waiting Room, Meeting Room, UPS & Battery Room, Signalling Room, Train Crew Room & Supervisor's Office, Security Room, Station Store Room, Staff Toilets, etc. The public zone is further divided into paid and unpaid areas.

Since the station is generally in the middle of the road, minimum vertical clearance of 5.5-m has been provided under the concourse. Concourse floor level about 6.5-m above the road. Consequently, platforms are at a level of about 12.5-m from the road. To reduce physical and visual impact of the elevated station, stations have been made narrow towards the ends.
With respect to its spatial quality, an elevated MRT structure makes a great impact on the viewer as compared to an *At-grade* station. The positive dimension of this impact has been accentuated to enhance the acceptability of an elevated station and the above ground section of tracks. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.

Platform roofs that can invariably make a structure look heavy; have been proposed to be of steel frame with aluminium cladding to achieve a light look. Platforms would be protected from the elements by providing an overhang of the roof. In order to allow unhindered traffic movement below the stations, portals across the road have been proposed in the concourse part, over which the station structure would rest. The rest of the station structure is supported on a single column, which lies unobtrusively on the central verge.

5.3.3.3 Passenger Amenities-Passenger amenities such as ticketing counters/automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Sufficient numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/escalators. Maximum capacity required at any station by the year 2021 for normal operation has been adopted for all stations. For this purpose, *peak minute traffic* is assumed to be 2% of the *peak hour traffic*.

5.3.3.4 Concourse-Concourse forms the interface between street and platforms. In elevated stations, this is contained in a length of about 90-m in the middle of the station. This is where all the passenger amenities are provided. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct *paid* and *unpaid* areas. The *'unpaid area'* is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the *'paid area', which* includes access to the platforms. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimise cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed in front of the ticketing gates.

5.3.3.5 Ticketing Gates-Ticketing gates' requirement has been calculated taking the gate capacity as 45 persons per minute per gate. Passenger forecast for the horizon year 2021 has been used to compute the maximum design capacity. At least two ticketing gates shall be provided at any station even if the design requirement is satisfied with only one gate. Uniform space has been provided in all stations where gates can be installed as and when required.

5.3.3.6 Ticket Counters and Ticket Issuing Machines (TIMs)-It is proposed to deploy manual ticket issuing in the beginning of the operation of the line. At a later stage, automatic TIMS would be used for which space provision has been made in the concourse. At present, ticket counters would be provided, which would be replaced with TIMS in future. Capacity of manual ticket vending counters is taken to be 10 passengers per minute and it is assumed that only 40% of the commuters would purchase tickets at the stations while performing the journey. The rest are expected to buy season tickets or prepaid card, etc. Accordingly, the requirement of ticket counters has been calculated and the same provided for in the plans.

5.3.3.7 Platforms-A uniform platform width of 4.5-m wide excluding staircases and escalators in the central section is proposed for the elevated stations. This platform width has been checked for holding capacity of the platform for worst case scenario (two missed headways) in the design year.

5.3.3.8 Stairs, Escalators and Lifts for Normal and Emergency Operations- Provision has been made for escalators in the paid area i.e. from concourse to platforms. On each platform, one escalator has been proposed. In addition, two staircases with a combined width of 6-m is provided on each Side platform connecting to the concourse. These stairs and escalator together provide an escape capacity adequate to evacuate passengers in emergency from platforms to concourse in 5.5 minutes. While calculating the waiting passengers on the platform in emergency, 2 missed headways are assumed and the train arriving is assumed to be carrying peak section load. Lifts have been provided one each on either platform, to provide access for elderly and disabled. Since the rise from road to concourse is about 6.5-m, it is proposed to provide escalators and lifts in addition to stairs for vertical movement of passengers from street to concourse.

5.3.3.9 Passenger Information Kiosks and Commercial Kiosks-Passenger Information Kiosks and Commercial Kiosks are provided in the unpaid and paid areas of the concourse respectively.

5.3.3.10 Summary of passenger amenities required and proposed at stations based on projected traffic for the year 2021 is given in the **Table 5.3.3**.

Table 5.3.3
PASSENGER TRAFFIC AND RE UIREMENT OF AMENITIES IN STATIONS
(Projections for Year 2031)

Station	Daily Traffic	Peak Minute Boarding	Total Peak Minute Traffic Including Alighting	Ticketing Gates	Ticket Counters	Stairs Width (in m) on Each Platform	Lifts Provided At Each Station		Escalators Provided At Each Station	
							G to C	C to P	G to C	C to P
1. Versova	**5810**	*6*	12	2	1	6.00	1	2	2	2
2. D N Nagar	**58470**	*52*	117	3	3	6.00	1	2	2	2
3. Azad Nagar	**184630**	*207*	369	9	9	6.00	1	2	2	2
4. Andheri	**287230**	*329*	574	13	14	8.00	1	2	2	2
5. WEH	**59930**	*55*	120	3	3	6.00	1	2	2	2
6. Chakala	**78040**	*72*	156	4	3	6.00	1	2	2	2
7. Airport Road	**70**	*0*	0	2	1	6.00	1	2	2	2
8. Marol Naka	**70900**	*66*	142	4	3	6.00	1	2	2	2
9. Saki naka	**61020**	*52*	122	3	3	6.00	1	2	2	2
10. Subhash Nagar	**70**	*0*	0	2	1	6.00	1	2	2	2
11. Asalpha Road	**9550**	*13*	19	2	1	6.00	1	2	2	2
12. Ghatkopar	**381850**	*339*	764	17	14	8.00	2	4	2	4

Note: G- ground/ street level, C- concourse level, P- platform level

5.3.4 TRAFFIC INTEGRATION

5.3.4.1 Concept of Traffic Integration-The objective of an integrated transport system and traffic movement is to offer maximum advantage to commuters and society from traffic and planning consideration. Various modes of transport need to be integrated in a way that each mode supplements the other. A large proportion of MRTS users will come to and depart from various stations by public, hired and private modes, for which integration facilities need to be provided at stations to ensure quick and convenient transfers.

In order to ensure that entire MRTS function as an integrated network and provides efficient service to the commuter, the following steps have been identified:

- Suitable linkages are proposed so that various corridors of MRTS are integrated within themselves, with existing rail services and with road based modes.
- Parking and circulation area requirements are worked out for each station and are planned on the basis of prevailing norms.
- Facilities needed at various stations are planned in conformity with the type of linkages planned there.

Traffic and transport integration facilities are provided for two different types of linkages:

- Feeder links to provide integration between various MRTS corridors and road based transport modes i.e. public, hired, and private vehicles.
- Walk links to provide access to the pedestrians.

5.3.4.2 Modewise Parking Requirement at Stations- It is recommended to provide parking areas at stations for PARK & RIDE facilities and for Taxis etc. A computer model calculates passenger volumes and modal split at stations. Parking needs for hired as well as personal modes have been calculated in addition to space requirement for drop and ride facilities. The model assumes 80% -90% of the feeder passenger trips to be walk trips (or interchange with local trains at Andheri and Ghatkopar) as the influence area of each station is highly builtup. Of the vehicular feeder trips, about 30% are assumed to be made by buses and the residual distributed among autos/rickshaws (50%) and two-wheelers/ cycles (20%). **Table 5.3.4** provides summary of station wise traffic integration pattern.

Table 5.3.4
MODE WISE PARKING/HALTING RE UIREMENT AT STATIONS

Station Name	Number of Parking Bays			Area required		
	Bus	Ricksha w/Auto/ Taxi	Two Wheeler /Cycles	Rickshaw /Auto/ Taxi	Two Wheeler /cycles	Total
1. Varsova	1	1	42	**6**	**80**	**86**
2. D N Nagar	1	8	434	**48**	**825**	**873**
3. Azad nagar	2	23	1,380	**138**	**2,621**	**2,759**
4. Andheri	2	19	-	**114**	**-**	**114**
5. WEH	1	8	430	**48**	**818**	**866**
6. Chakala	1	10	560	**60**	**1,063**	**1,123**
7. Airport Road	1	1	1	**6**	**2**	**8**
8. Marol Naka	1	9	508	**54**	**964**	**1,018**
9. Saki naka	1	8	466	**48**	**885**	**933**
10. Subhash Nagar	1	1	1	**6**	**2**	**8**
11. Asalpha Road	1	2	88	**12**	**168**	**180**
12. Ghatkopar	2	24	-	**144**	**-**	**144**

It is seen from the above table that interchange with buses and IPT modes is required at all the stations, *Park and Ride* facility has also been made at all stations except Andheri and Ghatkopar, where land is acutely short and about 90% of the metro traffic is expected to be generated through interchange with western and central railway respectively.

5.3.4.3 Approach Adopted in Planning Traffic Integration Facilities- Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate parking areas for various modes likely to come to important stations including feeder bus/mini-buses. Provisions have been made for peak hour demand. Traffic integration facilities were identified on the basis of location of station and its proximity to other existing/proposed activity generating or attracting landuses. These facilities have been provided directly under the stations/adjacent area in the MRTS corridor. Further, area planning ensures that dispersal of large volumes of pedestrians is adequately provided for.

5.3.4.4 Operational Integration-Integration at operational level will be required to synchronise the timings of the MRTS services and the feeder service. For an efficient interchange, walking and waiting time at these stations will need to be minimised. Introduction of common ticketing and their availability at convenient locations will be necessary to ensure forecast patronage of the system. Last but not the least will be the need for an integrated passenger information system covering all the modes through the publication of common route guides, time tables and information boards at terminals and in the train coaches for providing updated information for users of the system.

5.4 VIADUCT STRUCTURE

5.4.1 Choice of Superstructure

The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the formwork for a wide span ranges.

5.4.2 The following type of superstructures have been considered.

(i) Pre-cast segmental box girder using external unbonded tendon.
(ii) Pre-cast segmental U-Channel superstructure with internal pre-stressing.

The segmental construction has been chosen mainly due to the following advantages.

- Segmental construction is an efficient and economical method for a large range of span lengths and types of structures. Structures with sharp curves and variable super elevation can be easily accommodated.

- Segmental construction permits a reduction of construction time as segments may be manufactured while substructure work proceeds, and assembled rapidly thereafter.

- Segmental construction protects the environment as only space required for foundation and sub-station is required at site. The superstructure is manufactured at a place away from busy areas and placement of superstructure is done with the system erected from piers at heights.

- Segments are easy to stack in the casting yard/sticking yard in more than one layer, thereby saving in requirement of space.

- It is easier to transport smaller segments by road trailers on city roads.

- It is easy to incorporate last minute changes in span configuration if the site situation so warrants.

- Interference to the traffic during construction is significantly reduced.

- Segmental construction contributes toward aesthetically pleasing structures and good finishes.

- The overall labour requirement is less than that for conventional methods.

- Better quality control is possible in the casting yard.

- During construction, the technique shows an exceptionally high record of safety.

5.4.3 Comparative advantages/disadvantages of the above two types of superstructures examined are given below:

5.4.3.1 Precast Segmental Box Girder using External Unbonded Tendon.

This essentially consists of precast segmental construction with external prestressing and dry joints and is by far most preferred technique in fast track projects. In such construction the prestressing is placed outside the structural concrete (inside the box section) and protected with high density polyethylene tubes, which are grouted with special wax or cement. The match cast joints at the interface of two segments are provided with shear keys as in traditional segmental construction. However, epoxy is dispensed with because water tight seal at the segment joints is not required in association with external tendons. The schematic arrangement is shown at **Fig.5.4.1 (enclosed).**

The main advantages of dry-jointed externally prestressed precast segmental construction can be summarized as follows:-

- Simplification of all post-tensioning operations, especially installation of tendons.
- Reduction in structural concrete thickness as no space is occupied by the tendons inside the concrete.
- Good corrosion protection due to tendons in polyethylene ducts; the grout inspection is easier and leaks, if any, can be identified during the grouting process.
- Simplified segment casting. There is no concern about alignment of tendons. Increased speed of construction.
- The elimination of the epoxy from the match-cast joints reduces costs and increases speed of construction further.
- Replacement of tendons in case of distress is possible and can be done in a safe and convenient manner.
- Facility for inspection and monitoring of tendons during the entire service life of the structure.

5.4.3.2 Precast Segmental U-Channel Superstructure with Internal Prestressing.

The single U type of viaduct structure is also a precast segmental construction with internal prestressing and requires gluing and temporary prestressing of segments. The match cast joints at the interface of two segments are also provided with shear keys. The main advantages for this type of structural configuration of superstructure are:-

1. Built in sound barrier.
2. Built in cable support and system function.
3. Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
4. Built in structural elements capable to maintain the trains on the bridge in case of derailment (a standard barrier design allow this)
5. Built in maintenance and inspection path on either side of the track.

Although, there may be a saving in the construction time for Option 1 by almost one day but the option 2 is recommended for Mumbai Metro Project considering the advantages as highlighted above, particularly, considering the fact that option 2 has an inbuilt features such as top flange of ‘U’ Channel acts as an evacuation path on either side of the tracks and also possibility to lower the longitudinal profile of the elevated viaduct. For option 2 **Fig.5.4.2 (enclosed)**.

5.4.3.3 Construction Methodology

Pre-Cast Construction

For the elevated sections it is recommended to have pre-cast segmental construction for super structure for the viaduct. For stations also the superstructure is generally of pre-cast members. The pre-cast construction will have following advantages:-

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical.
- Minimum inconvenience is caused to the public utilising the road as the superstructure launching is carried out through launching girder requiring narrow width of the road.
- As the pre-cast elements are cast on production line in a construction depot, very good quality can be ensured.
- The method is environment friendly as no concreting work is carried at site for the superstructure.

5.4.3.4 Casting of Segments

For viaducts segmental pre-cast construction requires a casting yard. The construction depot will have facilities for casting beds, curing and stacking area, batching plant with storage facilities for aggregates and cement, site testing laboratories, reinforcement steel yard and fabrication yard etc. An area of about 2.5 Hact. To 3 Hact is required for each construction depot.
For casting of segments both long line and short line method can be adopted. However the long line method is more suitable for spans curved in plan while short line method is good for straight spans. A high degree of accuracy is required for setting out the curves on long line method for which pre calculation of offsets is necessary. Match casting of segments is required in either method. The cast segments are cured on the bed as well as in stacking yard. Ends of the segments are to be made rough through sand blasting so that gluing of segments can be effective.
The cast segment will be transported on trailers and launched in position through launching girders.

5.4.3.5 Launching Scheme

Launching girder is specially designed for launching of segments. The suggested launching scheme is designed in such a way that initially the launching girder is erected on pier head at one end of the work. The segments are lifted in sequence and when the lifting is over, they are dry matched while hanging from the launching girder. After dry matching, the segments are glued with epoxy and pre-stressed from one end. The girder is lowered on the temporary / permanent bearings after pre-stressing. The launching girder then moves over the launched span to next span and the sequences continue. **See Fig. 5.4.3 to 5.4.8 (enclosed).**

5.4.4 Structural System of Viaduct
5.4.4.1 Superstructure

The superstructure of a large part of the viaduct comprises of simply supported spans. However at major crossing/over or along existing bridge, special steel or continuous unit will be provided.
Normally the U-Channel girder having a soffit width of 9.0 m (approx) accommodates the two tracks situated at 4.0m c/c. The U-Channel superstructure for almost all the simply supported standard spans will be constructed by precast prestressed segmental construction with epoxy bonded joints.

The max spans c/c of piers of standard simply supported spans constructed by precast segmental construction technique has been proposed as 25.0m. The usual segments shall be 3.0m in length except the Diaphragm segments, which shall be 2.0m each. The other standard spans (c/c of pier) comprises of 28.0m, 31.0m, 22.0m, 19.0m & 16.0m, which shall be made by removing/adding usual segments of 3.0m each from the center of the span. Depth of the superstructure is so chosen that top of flange of U-Channel will be used as a evacuation walkway in an emergency.

The dimensions of end diaphragm will be finalized based on simply supported span of 31.0m and the same will be also kept for all simply supported standard span. The top level of both the end diaphragms of adjoining spans on the same piers is kept same so that expansion joint can be installed at top and continuity of profile of end diaphragm on the same pier can be maintained. The arrangement has been selected from aesthetic considerations.

The economical span (i.e. with optimum prestressing ratio) will be designed for the 25m situation.

Standard span up to 25.0m will be provided throughout the viaduct as far as possible. At crossings, where spans requires to be increased upto 31.0m, simply supported spans will be provided.

For major crossing having spans greater than 40.0m, special units normally of 3 –span construction or steel girders have been envisaged.

All these continuous units (in case provided at obligatory location) will be constructed by cast-in-situ balanced cantilever construction technique. The top profile of superstructure of continuous unit (for the full length) will be retained the same as for standard spans so that evacuation walkway will be available even in continuous units. The increase in depth of U-channel will be accomplished by thickening the soffit slab (towards downside). At the end of continuous unit, the profile and thickness of soffit slab will be done to the extent that it will match with the profile and depth of end diaphragm of adjoining simply supported spans. The thickness of soffit slab will be increased smoothly toward penultimate support. In order to reduce the dead weight of the girder, voids will be also provided in the thickened soffit slab at bottom. These will be circular near the end of continuous unit and oblong near the penultimate support.

5.4.4.2 Substructure

The viaduct superstructure will be supported on single cast-in-place RC pier.
The shape of the pier follows the flow of forces. For the standard spans, the pier gradually widens at the top to support the bearing under the box webs.

At this preliminary design stage, the size of pier is found to be limited to 1.6m diameter of circular shape for most of its height so that it occupies the minimum space at ground level where the alignment often follows the central verge of existing roads.

To prevent the direct collision of vehicle to pier, a Jersey Shaped crash barrier of 1.0m height above existing road level has been provided all around the pier. A gap of 25mm has been also provided in between the crash barrier and outer face of pier. The shape of upper part of pier has been so dimensioned that a required clearance of 5.5m is always available on road side beyond vertical plane drawn on outer face of crash barrier. In such a situation, the minimum height of rail above the existing road is 8.4m.

The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.8m. The space between the elastomeric bearings will be utilized for placing the lifting jack required for the replacement of elastomeric bearing. An outward slope of 1:200 will be provided at pier top for the drainage due to spilling of rainwater , if any.

The transverse spacing between bearings would be 3.2m (to be studied in more details).

The orientation and dimensions of the piers for the continuous units or steel girder (simply supported span) have to be carefully selected to ensure minimum occupation at ground level traffic. Since the vertical and horizontal loads will vary from pier to pier, this will be catered to by selecting the appropriate structural dimensions.

5.4.5 Foundations Recommendations

From Geo-investigations discussed in subsequent paras it is apparent that substrata comprises of completely weathered rock followed by highly to moderately weathered and slightly weathered to fresh brown grey Breciia/Shale/Lime stone/ Basalt at varying depths of 3.5m to 8m, 4.5m to 9m and 7m to14.8 respectively. Hence, pile foundations with varying pile depths depending on depth of rock from ground level may have to be provided on a case by case basis.

5.4.6 Construction Methods

5.4.6.1 Deck – Simple Spans U Girder

Salient features of the precast segmental construction method technique as envisaged for the project under consideration are indicated below:

The superstructure shall be constructed “span by span” sequentially, starting at one end of a continuous stretch and finishing at the other end. Nos. of launching girders may be required so as to work on different stretches simultaneously to enable completion of the project in time.

The number of “breaks” in the stretch can be identified by nos of continuous units.

The suggested method of erection will be detailed in drawings to be prepared, at the time of detailed design. The launching girder (or, more accurately, the “assembly truss”) is capable of supporting the entire dead load of one span and transferring it to the temporary brackets attached to the pier. The governing weight of the segments will be of the order of 55t (to be finalized). The launching girder envisaged will be slightly greater than two span lengths. It must be able to negotiate curves in conjunction with temporary brackets.

Transportation of segments from casting yard to the point of erection will be effected by appropriately designed low-bedded trailers (tyre-mounted). The segments can be lifted and erected using erection portal gantry moving on launching girder.

U-girder segments shall be match cast at the casting yard before being transported to location and erected in position. Post-tensioned cables shall be threaded in-situ and tensioned from one end. It is emphasized that for precast segmental construction only one-end prestressing shall be used.

The prestressing steel and prestressing system steel accessories shall be subjected to an acceptance test prior to their actual use on the works. The tests for the system shall be as per FIP Recommendations as stipulated in the special specifications. Only multi-strand jacks shall be used for tensioning of cables. Direct and indirect force measurement device (e.g. Pressure Gauge) shall be attached in consultation with system manufacturer.

The Contractor shall be responsible for the proper handling, lifting, storing, transporting and erection of all segments so that they may be placed in the structure without damage. Segments shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and other undue stress. Members shall be lifted, hoisted or stored with lifting devices approved on the shop drawings.

5.4.6.2 Epoxy Bonded Joints and Shear Keys.

A minimum compressive stress of 3 kg/sqcm shall be provided uniformly over the cross-section for the closure stress on the epoxied joint until the epoxy has set. The curing period for application of the compressive stress, method of mixing and application of epoxy and all related aspects including surface preparation shall be as per approved manufacturer's specifications.

The purpose of the epoxy joint, which is about 1mm on each mating surface, shall be to serve as lubricant during segment positioning, to provide waterproofing of the joints for durability in service conditions and to provide a seal to avoid cross-over of grout during grouting of one cable into other ducts.

The epoxy shall be special purpose and meet requirements of relevant provision of FIP (International Federation of Prestressed Concrete)

The temporary compressive stress during the curing period shall be applied by approved external temporary bar prestressing (such as Macalloy or Diwidag bar systems or approved equivalent).

5.4.7 Construction of the Stations

5.4.7.1 It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimise land acquistion. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus a separate structural configuration is required (although this may necessitate the break in the launching operations at each station locations)

5.4.7.2 Sub-structure for the station portion will also be similar to that of viaduct and will be carried out in the same manner. However, there will be single viaduct column in the station area, which will be located on the median and supporting the concourse girders by a cantilever arm so as to eliminate the columns on right of way.

5.4.7.3 Super-structure will consist of 3 precast U Girders for supporting the track structure and I Girder / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast in situ prestressed cross girder will be required over the middle piers for supporting platform structure. Box shaped in situ prestressed cantilever cross girders are planned for supporting the concourse girders and escalators at mezzanine level. All the members will be pre-cast in a construction depot and launched at site through cranes.

5.4.8 Grade of Concrete

It is proposed to carry out construction work with design mix concrete through computerised automatic Batching Plants with following grade of concrete for various members as per design requirement/durability considerations.

i) Pile cap and open foundation	-	M -30
ii) Piers	-	M -40
iii) All precast element for viaduct and station	-	M -45
iv) Cantilever piers and portals	-	M -45
	-	M -60
v) Other miscellaneous structure	-	M - 30

For all the main structures, permeability test on concrete sample is recommended to ensure impermeable concrete.

5.4.9 Reinforcement and pretressed Steel

It is proposed to use HYSD 415 or TMT steel as reinforcement bars.
For pre-stressing work, low relaxation high tensile steel strands with the configuration 12 T 13 and or 19 K 15 is recommended (confirming to IS:14268).

5.4.10 Road width Required During Construction

As most of the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 9 m will be required for construction and the same will be barricaded. It is proposed that two lanes are provided for traffic on either sides during construction by widening of roads, if necessary. In certain cases, one way traffic may be resorted to.

All these actions will require a minimum period of about 4 to 6 months. During this period, the implementing agency can go ahead with the following preliminary works:

i) Preliminary action for diversion of utility and preparation of estimates there of.
ii) Reservation of land along the corridor, identification and survey for acquisition.

Once the Corporation is formed, the Corporation has to take action for appointment of consultant for Project Management and proof checking including preparation of tender documents. Simultaneously, action is also to be taken for detailed design for structures for elevated corridors.

5.5 Geotechnical Investigations

5.5.1 General Geology & Related Characteristics:

a) **Location-** The proposed corridor starts in the east at Ghatkopar Rly. Stn. on Hira Chand Desai Marg and runs along Golibar Road/V.B.Phadke Marg DP Road, Andheri-Ghatkopar Road, Andheri- Kurla Road, Mathurdas Vasanji Road, Jay Prakash Road up to Versova near Seven bungalows bus depot in the West. The site is accessible by all modes of surface transport for all seasons, excepting the DP road under construction through Aslapha village at present.

The consultants have carried out GT investigations in the western segment of the corridor i.e., from Versova to Andheri Rly. Station. A total of 8 bore holes have been drilled at an average distance of about 500 m each.

For the eastern segment, i.e., from Ghatkopar Rly.station to Andheri Rly.station, the geo-technical investigations already carried out by MMRDA through their agencies for various projects have been collected and presented here.

b) **Physiography and Climate**-The site is about 15m above mean sea level. The highest temperature in this city is around 35^{o}C and the minimum temperature is around 15^{o}C. The period between January to April and December is the dry period in this region. The Southwest monsoon period, between June and October, is the main rainy season. The average annual rainfall is about 2000mm.

c) **General Geology-** Mumbai and Konkan coastal area of Maharashtra state is underlain by Deccan Trap Basalts. These rocks are believed to be formed by a series of vast lava flows following volcanic eruptions towards the close of the Cretaceous period or early Tertiary era. The total thickness of the Deccan Traps is very variable, reaching an estimated maximum of 3000 metres along the coast.

A very wide variety of basalts and associated rocks such as volcanic Breccias, black tachylytic basalts, red tachylytic basalts seen at the surface as 'Red Bole' occur in the area covered by Deccan Trap basalts. All these volcanic rocks are hydrothermally weathered near the surface. The residual material resulting from the breakdown of the rock is known locally as "murrum" the properties of which vary in consistency and texture according to the degree of weathering and disintegration. On complete weathering of rock the soil becomes stiff yellow silty clay.

Marine Clays of Mumbai

Marine clays cover extensive areas in Mumbai/Coastal region, which are found along the shore as well as in creeks, tidal flats and formerly submerged areas. On the eastern front of Mumbai, island and coastal region, thick deposits of marine clays are found overlying murrum tuff and basaltic rock. The marine clay deposits vary in thickness from 2m to 20m. These soils are characterized by their high compressibility, low co-efficient of consolidation and very low shear strength. Above the bedrock, the residual 'murrum' often occurs along with gravel and weathered boulders.

5.5.2 Seismicity-Mumbai lies in seismic zone IV. Suitable seismic coefficient may be adopted in the design of structures to commensurate with the Indian Standard seismic zoning of the country IS.1893-1984 which is under revision after the occurrence of Gujarat Earthquake in January' 2001.

5.5.3 Field Investigations

This proposed corridor of the Mumbai MRTS is from section of Metro rail has to cover a corridor from Ghatkopar to Versova via Andheri. As stated earlier, the GT investigations have been carried out afresh for the western segment i.e., from Andheri to Versova and the GT investigation data already available with MMRDA has been collected and presented in the following paras. The details of boreholes along the corridor are shown in **Table 5.5.1**

Table 5.5.1
DETAILS OF BOREHOLES

BOREHOLE NUMBER	CHAINAGE (in m)	Ground R.L. (m)	GROUND WATER TABLE DEPTH (in m)	DEPTH OF INVESTIGATION (in m)		
				In SOIL	In ROCK	TOTAL
Western Segment(Andheri – Versova)						
JP-1	W0.0729	9.760	1.55	3.10	7.50	10.60
JP-2	W0.7259	6.340	3.70	5.50	6.00	11.50
JP-3	W1.1889	4.217	3.55	4.10	7.60	11.70
JP-4	W1.6839	3.977	3.90	7.60	8.15	15.75
JP-5	W2.1839	3.794	4.30	5.80	5.95	11.75
JP-6	W2.6939	3.802	4.75	5.70	11.30	17.00
JP-7	W3.1939	3.589	4.70	10.00	10.70	20.70
JP-8	W3.7039	8.578	9.00	14.45	10.30	24.75
Eastern Segment(Andheri –Ghatkopar)						
D1	E0.070	3.15	1.90	6.50	25.00	31.50
D2	E0.435	15.14	1.85	6.50	24.00	30.50
D3	E0.885	16.55	3.00	6.00	23.50	29.50

BOREHOLE NUMBER	CHAINAGE (in m)	Ground R.L. (m)	GROUND WATER TABLE DEPTH (in m)	DEPTH OF INVESTIGATION (in m)		
				In SOIL	In ROCK	TOTAL
S1	E1.355	22.68	2.60	10.75	5.18	15.93
S2	E3.195	11.19	2.50	5.00	10.64	15.64
S3	E7.400	19.96	1.80	2.50	12.70	15.20
S4	E5.890	18.41	2.20	5.00	10.50	15.50
S5	E6.515	19.27	4.00	4.50	10.68	15.18
S6	E7.550	14.64	2.60	4.50	9.95	14.45
S7	E7.700	32.02	2.00	9.00	6.24	15.24

5.5.4 Engineering Design Parameters- Based upon investigation done and the analysis made thereafter, following design parameters have been finalized as discussed in the subsequent paras.

5.5.5 Design Parameters for Elevated Corridor-The sub-soil strata at proposed site comprise of nine types of layers (based on field tests & laboratory test result data). Description of each layer along with various engineering parameters is as shown in **Table 5.5.2**

Table 5.5.2
LAYER TYPE AND DESCRIPTION

Layer	Description	Classification as per IS : 1498-1970	Relative Density/ Consistency	Observed in Bore Hole Nos.
Western Segment(Andheri - Versova)				
I	Road material & Backfill	-	-	JP-1 to JP-8
II	Silty Sand	SM-SC, SP-SC, SM, SC	Medium dense to dense	JP-8
III	Silty Sand	SP-SC, SM	Very dense	JP-1
IV	Sandy Clay	-	Soft	JP-7
V	Silty Clay	CH	Medium stiff to stiff	JP-1 and JP-3
VI	Silty Sandy Clay with gravel	CH, CI	Very stiff to hard	JP-2 to JP-5 and JP-8
VII	Completely weathered rock	CI, CH, GM	-	JP-7 and JP-8
VIII	Highly to moderately weathered SANDSTONE/ BRECCIA/ BASALT	-	-	JP-1 to JP-4 and JP-6 to JP-8
IX	Slightly weathered to	-	-	JP-1 to JP-8

	fresh BRECCIA/ SHALE/ LIMESTONE			
	ANDHERI TO GHATKOPAR			
I	Road material & Backfill	-	-	D1,D2,S1toS6
II	Silty Sand	SM-SC, SP-SC, SM, SC	Medium dense to dense	S5
III	Silty Sand	SP-SC, SM	Very dense	D3
IV	Sandy Clay	-	Soft	D2,S6
V	Silty Clay	CH	Medium stiff to stiff	S1,S4,S7
VI	Silty Sandy Clay with gravel	CH, CI	Very stiff to hard	S2,S5
VII	Completely weathered rock	CI, CH, GM	-	
VIII	Highly to moderately weathered SANDSTONE/ BRECCIA/ BASALT	-	-	D2,D3

5.5.6 Assessment of Liquefaction-Liquefaction is the sudden loss of shear strength of the loose fine-grained sands due to earthquake-induced vibration under saturated conditions. The liquefaction generally takes place in loose fine-grained sands with N value less than 15 and soil classification under SP. At this site generally silty clay is observed. Medium dense to very dense sand is also obtained and the 'N' value is generally greater than 15. Hence this site does not seem susceptible to liquefaction.

5.5.7 Construction Methodology

Type of Foundation- Considering the nature of soil, type of proposed structures (Elevated Rail Corridor) and expected loads on foundations, the recommended type of foundations is generally Pile Foundation, except at few locations where open foundation can be provided, where rock level is up to 6 m below GL.

Depth of Foundation-A foundation must have an adequate depth from considerations of adverse environmental influences. It must also be economically feasible in terms of overall structure.

Keeping in view the type of the proposed structure and the subsoil strata, the length of pile should be 10 to 30m as the piles are to be socketted in rock.

Pile Foundation-For the prevailing soil conditions and type of structures, bored cast-in-situ piles of 1200 mm or 1500 mm diameter are proposed to be adopted.

Piles transmit foundation loads through soil strata of low bearing capacity to deeper soil having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance.

Piles are suitable due to the following specific advantages over spread footings/raft foundation:

- Completely non-displacement.
- Carry the heavy superstructure loads into or through a soil stratum. Both vertical and lateral loads may be involved.
- Controls settlements when spread footing/raft foundation is on a marginal soil.
- Can resist uplift, or overturning.
- Applicable for a wide variety of soil conditions.

Recommended safe vertical load carrying capacity of piles of different lengths below the ground level are as shown in **Table 5.5.3.**

Table 5.5.3
SAFE VERTICAL LOAD CARRYING CAPACITY OF PILES
(Western Segment)

Bore hole No.	Minimum pile length required BGL (in m)	Pile capacity (in T)		
		For Dia 1.0 m	For Dia 1.20 m	for Dia 1.50 m
JP-1	10	314	452	707
JP-2	12	314	452	707
JP-3	12	314	452	707
JP-4	13	314	452	707
JP-5	12	314	452	707
JP-6	11	236	339	530
JP-7	18	314	452	707
JP-8	20	314	452	707

The minimum diameter of pile should be 1000mm. In borehole locations JP-1 to JP-5 confirmatory boreholes up to at least 20m depth are recommended to ascertain whether there is any weaker rock below.

In the geo-technical investigation data obtained from MMRDA for the eastern segment, vertical load carrying capacity of the pile foundations is not available. Only, bore logs are given. The load carrying capacity can be worked out if the soil properties & soil test results are available. However the bore log details indicate that the strata does not vary much and pile foundations can be designed.

5.6 UTILITY DIVERSIONS

5.6.1 Introduction

Besides the details of various aspects e.g. transport demand analysis, route alignment, station locations, system design, viaduct structure, geo-technical investigations etc. as brought out in previous chapters, there are a number of other engineering items, which are required to be considered in sufficient details before really deciding on taking up any infrastructure project of such magnitude. Accordingly, following engineering items have been studied and described in this chapter:

- Utilities and planning for their diversion during construction.
- Land acquisition necessary for the project both on permanent basis as well as temporary, including its break up between Government and private ownership.
- Potential of property development and assessment of likely revenues to be generated with a view to part finance the construction as well as operation costs of the project.
- Traffic diversion during construction.

5.6.2 Utility and Services

The proposed corridor starts in the east at Ghatkopar Rly. station on Hira Chand Desai Marg and runs along Golibar Road/V.B.Phadke Marg DP Road ,Andheri-Ghatkopar Road, Andheri- Kurla Road, Mathurdas Vasanji Road ,Jay Prakash Road up to Versova near Seven bungalows bus depot in the West.

The consultants have carried collected details of various utilities from concerned organisations directly for the western segment of the corridor i.e., from Versova to Andheri Rly. station. For the eastern segment, i.e., from Ghatkopar Rly. station to Andheri Rly. station, details of utilities collected by MMRDA through their agencies for various projects have been adopted

Large number of sub-surface, surface and over head utility services viz. sewers, water mains, storm water drains, telephone cables, O.H electrical transmission lines, electric poles, traffic signals, etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction, by temporary/permanent diversions or by supporting in position. Since these may affect construction and project implementation time schedule/costs, for which necessary planning/action needs to be initiated in advance.

5.6.3 Organisations/Departments with concerned utility services in Mumbai are mentioned in **Table 5.6.1**.

Table 5.6.1

UTILITY RESPONSIBILITY DEPARTMENTS

Sr. No.	ORGANIZATION/ DEPARTMENT	UTILITY SERVICES
1.	Municipal Corporation of Greater Mumbai(MCGM)	Roads, surface water drains, nallahs, Sewerage and drainage conduits, sewerage treatment plants, pumping stations, Water mains and their service lines, including hydrants, water treatment plants, pumping stations, Gardens etc.
2.	Public Works Deptt. (PWD)	Road construction & maintenance.
3.	Irrigation and Flood Department, MCGM	Nallahs/flood water drains etc.
4.	BEST (Bombay Electric Supply & Transportation)	Power cables and their appurtenances H.T. and L.T. lines, their pylons, electric light posts, pole mounted transformers, etc.
5.	Mahanagar Telephone Nigam Ltd. (MTNL)	Telecommunication cables, junction boxes, telephone posts, O.H. lines, etc.
6.	Mumbai Traffic Police	Traffic signal posts, junction boxes and cable connections, etc.
7.	Mahanagar Gas Ltd.	Gas lines
8.	BSES(Bombay Sub-urban Electric Supply) /Reliance Energy	Power cables and their appurtenances H.T. and L.T. lines, their pylons, electric light posts, pole mounted transformers, etc
9.	TATA Power	Power cables and their appurtenances H.T. and L.T. lines, their pylons, electric light posts, pole mounted transformers, etc
10.	MMRDA & MAHADA	Land development & Housing etc.
11.	TATA Tele Services	Telecommunication cables, junction boxes, telephone posts, O.H. lines, etc.
12.	Reliance Info. Ltd	Telecommunication cables, junction boxes, telephone posts, O.H. lines, etc.
13.	Western & Central Railway	Railway crossings, signals, railway bridges, etc.

5.6.4 Assessment of the type and location of underground utilities running along and across the proposed route alignment between Ghatkopar Station and Versova has been undertaken with the help of data available with MMRDA and also with concerned authorities, who generally maintain plans and data of such utility services. Particulars of main utilities i.e. trunk and main sewers/drainage conduits, water mains, OH & UG Electric cable, Telecom cable etc. have been marked on alignment plans.

5.6.5 Diversion of Underground Utilities

While planning for diversion of underground utility services viz. sewer lines, water pipelines, cables, etc., during construction of MRTS alignment, following guidelines have been adopted:

- Utility services have to be kept operational during the entire construction period and after completion of project. All proposals should therefore, ensure their uninterrupted functioning.

- The elevated viaduct does not pose much of a difficulty in negotiating the underground utility services, especially those running across the alignment. The utilities infringing at pier location can be easily diverted away from the pile cap location.
- In case a major utility is running along/across the alignment which cannot be diverted or the diversion of which is difficult, time consuming and uneconomical , the spanning arrangement of the viaduct and layout of piles in the foundation may be suitably adjusted to ensure that no foundation needs be constructed at the location, where utility is crossing the proposed alignment. The utility service can also be encased within the foundation piles.

5.6.6 At Grade Stretch

As the proposed alignment is completely elevated, there is no at grade stretch in this corridor.

5.6.7 Elevated Stretch

5.6.7.1 In this corridor, the alignment is almost on the center of the road except near Versova station due to site constraints. However, the Versova station and alignment in this stretch are within the ROW. The sewer/drainage lines generally exist in the service lanes i.e. away from main carriageway. However, in certain stretches, these have come near the central verge or under main carriageway, as a result of subsequent road widening.

5.6.7.2The major sewer/drainage lines and water mains running across the alignment and likely to be affected due to location of column foundations are proposed to be taken care of by relocating on column supports of viaduct by change in span or by suitably adjusting the layout of pile foundations. Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines. Details of sewer lines and storm water drains affected in elevated stretch along with their diversion proposals are indicated in **Table 5.6.2**. Similarly, details of affected water pipe lines in this stretch are indicated in **Table 5.6.3**.

Table 5.6.2

DETAILS OF AFFECTED SEWER LINES IN

S. No.	Chainage	Affected Length (in m)	Type & Diameter (in mm)	Position w.r.t. Alignment	Location
1	E-73-E 244	171m	300mm dia.	Along	A
3	E 500-E 555	55m	230mm dia	Along	A
4	E 1295-E 1365	68m	225mm dia	Along	A
5	E 1660-E 1833	173m	225mm dia	Along	A
6	E 3730-E 3946	216	300mm dia.	Along	A
7	W-73-E 218	145X2	300mm dia.	Along	A
8	0.00	8	225mm dia	Across	B
9	E 920-E 1065	145	225mm dia	Along	A
10	E 2207-E 2352	145	225mm dia	Along	A
11	E-2325	28	225mm dia	Across	B
12	E-2225	11	225mm dia	Across	B
13	E 3634-E 3792	98	300mm dia	Along	A
14	E 1330-E 1337	7	225mm dia	Along	A

Note:
“A” Sewer/SWD lines to be diverted away from pier location.
“B” Suitably locate the pier/change the pile layout to avoid diversion.

Table 5.6.3

DETAILS OF AFFECTED WATER PIPE LINE

S. No.	Chainage	Affected Length (in m)	Type & Diameter (in mm)	Position wrt Alignment	Location
1	E-1368-E 1452	84	48 mm dia. C.I.	Along	A
2	E 1420-E2205	785	24 mm dia. C.I.	Along	A
3	E 1908-E 2115	207	12 mm dia. C.I.	Along	A
4	E 1989-E 2100	111	6 mm dia. C.I.	Along	A
5	E 2350 –E 2550	200	24 mm dia. C.I	Along	A
6	E 3543- E 3588	45	18 mm dia. C.I	Along	A
7	E 3548-E 3588	40	6 mm dia. C.I.	Along	A
8	W-73-E 218	145X3	9 mm dia. C.I.	Along	A
9	W-73-E 218	145	12 mm dia. C.I.	Along	A
10	W-73-E 218	145X2	300 mm dia. C.I.	Along	A
11	W-20	24X2	300 mm dia. C.I	Across	B
12	0.00	22X2	300 mm dia. C.I	Across	B
13	E 920-E 1065	145X2	9 mm dia. C.I.	Along	A
14	E 920-E 1065	145	12 mm dia. C.I.	Along	A
15	E 920-E 1065	145	6 mm dia. C.I	Along	A
16	E 920-E 1065	145	24 mm dia. C.I.	Along	A
17	E 2207-E 2352	145X2	9 mm dia. C.I.	Along	A
18	E 2207-E 2352	145	6 mm dia. C.I	Along	A
19	E 2207-E 2352	145	12 mm dia. C.I.	Along	A
20	E 2207-E 2352	145	24 mm dia. C.I.	Along	A
21	E 2941-E 3086	145	6 mm dia. C.I	Along	A
22	E 2941-E 3086	145	12 mm dia. C.I.	Along	A

S. No.	Chainage	Affected Length (in m)	Type & Diameter (in mm)	Position wrt Alignmen t	Location
23	E 2941-E 3086	145	18 mm dia. C.I.	Along	A
24E	E 3588-E 3733	145	6 mm dia. C.I	Along	A
25	E 3588-E 3733	145	12 mm dia. C.I.	Along	A
26	E 3588-E 3733	145	18 mm dia. C.I.	Along	A
27	E 1280-E 1287	7X2	9 mm dia. C.I.	Along	A
28	E 1280-E 1287	7	24 mm dia. C.I.	Along	A
29	E 1305-E 1312	7	24 mm dia. C.I.	Along	A
30	E 1305-E 1312	7X2	9 mm dia. C.I.	Along	A
31	E 1330-E 1337	7X2	9 mm dia. C.I.	Along	A
32	E 1330-E 1337	7	24 mm dia. C.I.	Along	A
33	E 1456-E 1463	7X2	9 mm dia. C.I.	Along	A
34	E 1456-E 1463	7	24 mm dia. C.I.	Along	A
35	E 1386-E 1393	7X2	9 mm dia. C.I.	Along	A
36	E 1386-E 1393	7	48 mm dia. C.I.	Along	A
37	E 1386-E 1393	7	24 mm dia. C.I.	Along	A
38	E 1416-E 1393	7	24 mm dia. C.I.	Along	A
39	E 1416-E 1393	7	48 mm dia. C.I.	Along	A
40	E 1416-E 1393	7X2	9 mm dia. C.I.	Along	A
41	E 4427-E 4434	7	12 mm dia. C.I.	Along	A
42	E 4452-E 4459	7	12 mm dia. C.I.	Along	A
43	E 4476-E 4483	7	12 mm dia. C.I.	Along	A
44	E 4501-E 4508	7	12 mm dia. C.I.	Along	A
45	E-906	9	9 mm dia. C.I.	Across	B
46	E-2553	9	57 mm dia. C.I.	Across	B
47	E-2553	9	96 mm dia. C.I.	Across	B
48	E-3148	9	12 mm dia. C.I.	Across	B

S. No.	Chainage	Affected Length (in m)	Type & Diameter (in mm)	Position wrt Alignment	Location
49	E-3387	9	12 mm dia. C.I.	Across	B

Note:
"A" Water Pipe lines to be diverted away from pier location.
"B" Suitably locate the pier/change the pile layout to avoid diversion.

5.6.8 Gas Pipe Lines

There are few gas pipe lines with varying diameters belonging to Mahanagar gas Limited, Mumbai are running along and across the roads along which the metro alignment is proposed . Though, the alignment is planned almost along the center of the road en-route, few pipelines running across & along the alignment are likely to be affected by the alignment as detailed below in **Table 5.6.4**. All these pipelines are placed at a depth of about 1 Met below the ground.

Table 5.6.4
DETAILS OF AFFECTED GAS PIPELINE

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
1	E 164 –E 343	181	Along	A
2	E 1530-E 2205	725	Along	A
3	E 2350-E 2940	590	Along	A
4	E 3087-E 3230	143	Along	A
5	E 3280-E 3588	388	Along	A
6	E 2205-E 2350	145	Along	A
7	E 2312-E 2332	20	Along	A
8	E 2336-E 2356	20	Along	A
9	E 2941-E 3086	145	Along	A
10	E-3067	15	Across	A

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
11	E 3067-E 3092	25	Along	A
12	E 3588-E 3730	145	Along	A
13	E-3613	22	Across	A
14	E 4122-E 4129	7	Along	A
15	E 4145-E 4153	7	Along	A
16	E 4167-E 4174	7	Along	A
17	E-394	9	Across	B
18	E-2627	5	Across	B
19	E-3740	4	Across	B
20	E-4250	6	Across	B

Note:
"A" Gas Pipe lines to be diverted away from pier location.
"B" Suitably locate the pier/change the pile layout to avoid diversion.

The alignment being elevated , to avoid diversion of pipelines running across the alignment, necessary span adjustments are to be made . The pipelines running along the proposed alignment needs to be diverted at few stretches. At the time of project execution, the pipe line authorities should be contacted for necessary diversions and sufficient care should be taken to ensure their safety .

5.6.9 Aboveground Utilities

5.6.9.1 Above ground utilities namely street light poles, traffic signal posts, telecommunication posts, junction boxes, etc. are also required to be shifted and relocated suitably during construction, since these will be interfering with the proposed alignment. Approximate numbers of affected lamp/ telecome/elec. Posts & boxes are indicated in **Table 5.6.5**.

Table 5.6.5
AFFECTED ABOVEGROUND SERVICES

Section	Lp	EP	Tsp	Tp	Jbe	JBt	Tr	Py	FL
Elevated	145	-	25	-	40	10	-	-	-

Lp	Light Post	EP	Electric Post
		Tsp	Traffic Signal Post
Tp	Telephone Post	Jbe	Electrical Junction Box
Tr	Transformer	Py	Pylon (electric mast)
FL	Flood Light Post	JBt	Telephone Junction Box

5.6.10 HT-Electric cables Along the Corridor (Underground position)

At several places, 11kV/22kV/33kV power cables belonging to TATA Power Company Ltd. & Reliance Power Company Ltd. are running along & across the proposed alignment in underground position. The list of such cables along with their locations is indicated in **Table 5.6.6, Table 5.6.7(a) & Table 5.6.7(b).** These lines need to be modified/shifted or cabled well in advance of construction along this route.

Table 5.6.6

DETAILS OF AFFECTED TATA CABLE IN BELOW GROUND POSITION

S. No.	Chainage	Affected length (m)	Position with w.r.t. alignment	iption of Cable	sion proposal
1	W-73-E 218	145	Along	Tata Cable	A
2	E-100	9	*Across*	Tata Cable	B
3	E-850	9	Across	Tata Cable	B
4	E-910	9	Across	Tata Cable	B
5	E 923-E 1067	145X2	Along	Tata Cable	A
6	E1287-E1294	7	Along	Tata Cable	A
7	E 1305-E 1312	7	Along	Tata Cable	A
8	E 1330-E 1337	7	Along	Tata Cable	A

S. No.	Chainage	Affected length (m)	Position with w.r.t. alignment	iption of Cable	sion proposal
9	E 1355-E 1382	7	Along	Tata Cable	A
10	E 1387-E 1394	7	Along	Tata Cable	A
11	E 1417-E 1424	7	Along	Tata Cable	A
12	E 2207-E 2220	13	Along	Tata Cable	A
13	E 2222-E 2350	128	Along	Tata Cable	A
14	E-2220	11	Across	Tata Cable	B
15	E-2222	11	Across	Tata Cable	B
16	E 2207-E 2352	145X2	Along	Tata 22Kv	A
17	E 2941-E 3086	145X2	Along	Tata 22Kv	A
18	E 2941-E 3086	145X2	Along	Tata Cable	A
19	E 3587-E 3732	145X2	Along	Tata 22Kv	A
20	E 3587-E 3732	145	Along	Tata Cable	A
21	E 4500-E 4507	7	Along	Tata Cable	A
22	E 4592-E 4614	22	Along	Tata Cable	A

Table 5.6.7(a)

DETAILS OF AFFECTED CABLES of Reliance Energy Ltd IN BELOW GROUND POSITION

11KV

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
1	E 1420 –E 1543	228	Along	A
2	E 1500 –E 1563	63	Along	A
3	E 1953 –E 2025	73	Along	A

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
4	E 2020 –E 2065	45	Along	A
5	E 2029-E 2057	28	Along	A
6	E 2029 –E 2074	48	Along	A
7	E 3990 –E 4250	260	Along	A
8	E 4100 –E 4250	150	Along	A
9	E 3860-E 3890	30	Along	A
10	W-73-E-218	145X2	Along	A
11	E 920-E 1065	145X2	Along	A
12	E 920-E 1010	90	Along	A
13	E -2216	20	Across	B
14	E -2221	20	Across	B
15	E 2941-E 3086	145X3	Along	A
16	E 2870 –E 2940	70X2	Along	A
17	E 3087 –E 3210	123	Along	A
18	E 3300 –E 3580	280	Along	A
19	E 3475 –E 3572	97	Along	A
20	E 2350 –E 2572	223	Along	A
21	E 2573 –E 2755	182	Along	A
22	E 3587 –E 3732	145 X3	Along	A
23	E 1416-E 1423	7X2	Along	A
24	E 4227-E 4234	7	Along	A
25	E -4195	9	Across	B
26	E -4288	9	Across	B
27	E 1280-E 1287	7	Along	A
28	E-80	9	Across	B

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
29	E-100	9X2	Across	B
30	E-374	9	Across	B
31	E -1236	9X3	Across	B
33	E -2357	9	Across	B
34	E 2455-E 2464	9	Along	A
35	E -2572	9	Across	B
36	E 2571-E 2580	9	Along	A
37	E -3572	9	Across	B
38	E -4060	9	Across	B
39	E -4101	9	Across	B
40	E -4102	9	Across	B
41	E 1305-E 1312	7	Along	A
42	E -1456-E 1463	7	Along	A

22 KV

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion proposal
1	E 1582-E 1651	73	Along	A
2	E 2074-E 2167	94	Along	A
3	E 2350-E 2572	222	Along	A
4	E 2850-E 2940	90	Along	A
5	E 3087-E 3150	63	Along	A
6	E 3270-E 3588	280	Along	A
7	E 3366-E 3490	124	Along	A
8	W-73-E 218	145	Along	A
9	E-31-E 176	145X2	Along	A
10	E 922-E 981	59	Along	A
11	E 336-E 343	7	Along	A

12	E 983-E 1087	104	Along	A
13	E 1305-E 1312	7	Along	A
14	E 1330-E 1334	4X2	Along	A
15	E-1330	7X2	Across	B
16	E 1386-E 1393	7	Along	A
17	E 2206-E 2351	145	Along	A
18	E 2224-E 2351	127	Along	
19	E-2332	17	Across	B
20	E-2358	9	Across	B
21	E-2380	9	Across	B
22	E 1416-E 1423	7	Along	A
23	E 4427-E 4434	7	Along	A
24	E 4452-E 4459	7	Along	A
25	E 4476-E 4483	7	Along	A
26	E 4501-E 4508	7	Along	A

TABLE 5.6.7(b)

DETAILS OF AFFECTED RELIANCE CABLE IN BELOW GROUND POSITION

S. No.	Chainage	Affected length (m)	Position w.r.t. to alignment	Diversion proposal
1	W-73-E 218	145X2	Along	A
2	E 923-E 1065	145	Along	A
3	E 1305-E 1313	7	Along	A
4	E 1330-E 1337	7	Along	A
5	E 1355-E 1362	7	Along	A
6	E 1387-E 1394	7	Along	A
7	E 1416-E 1423	7	Along	A
8	E-1702	9	Across	B
9	E 2207-E 2352	145	Along	A

S. No.	Chainage	Affected length (m)	Position w.r.t. to alignment	Diversion proposal
10	E 2941-E 3086	145	Along	A
11	E-3516	9	Across	B
12	E 3587-E 3732	145	Along	A
13	E 4582-E 4606	24	Along	A

5.6.11 At several places, telecom cables of MTNL / TATA Tele Services are also running along & across the proposed alignment in underground position. The likely affected such cables are indicated in **Table 5.6.8 & Table 5.6.9** respectively.

Table 5.6.8
DETAILS OF AFFECTED TELEPHONE CABLE DUCTS IN BELOW GROUND POSITION (MTNL)

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion Proposal
1	W-73-E 218	145X2	Along	A
2	E 920-E 1065	145X2	Along	A
3	E 2208-E 2353	145X2	Along	A
4	E 2941-E 2954	13	Along	A
5	E 2941-E 3086	145	Along	A
6	E 1417-E 1424	7X2	Along	A
7	E 1655-E 1683	7	Along	A
8	E 1676-E 4131	7	Along	A
9	E 4124-E 2152	7	Along	A
10	E 4145-E 4175	7	Along	A
11	E 4168-E 4134	7	Along	A
12	E 4427-E 4434	7	Along	A
13	E 4452-E 4459	7	Along	A
14	E 4477-E 4484	7	Along	A

S. No.	Chainage	Affected Length (in m)	Position wrt Alignment	Diversion Proposal
15	E 4500-E 4507	7	Along	A

Table 5.6.9

DETAILS OF AFFECTED CABLES TATA Tele Services (Underground Position)

S. No.	Chainage	Description of Cables	Affected Length	Position w.r.t. alignment	Location
	Western Segment				
1	W2.6007	OFC	25.00	ACROSS	
2	W2.2645 - W2.0539	4-OFC IN DUCT	210.00	ALONG	STATION AREA
3	W1.4559 - W1.2539	4-OFC IN DUCT	202.00	ALONG	STATION AREA
4	W0.4619 - W0.2419	4-OFC IN DUCT	220	ALONG	RIGHT SIDE
5	W0.3649 - W0.2419	4-OFC IN DUCT	148	ALONG	LEFT SIDE
	Eastern Segment				
1	E 1.055	4-OFC IN DUCT	11	Across	RUNNING SECTION
2	E 1.560	4-OFC IN DUCT	11	Across	RUNNING SECTION
3	E 0.223	4-OFC IN DUCT	11M	Across	B
4	E 0.494 – E 0.760	4-OFC IN DUCT	266m	Along	A
5	E 1.010	4-OFC IN DUCT	3m	Across	B
6	E 1.010 – E 1.028	4-OFC IN DUCT	18m	Along	A
7	E 3.576	4-OFC IN DUCT	2.0m	Across	B
8	E 3.581	4-OFC IN DUCT	3m	Across	B

Detailed proposals for tackling these lines needs to be prepared in consultation with the concerned agencies. However, Tentative provision has been made in cost estimates.

5.7 LAND

5.7.1 The alignment and profile

i) The proposed corridor form Versova to Ghatkopar is fully elevated and is 11.07Kms. long form dead end to dead end. The alignment traverses along Jai Prakash Road, Sir Mathura Das Vasanji Road, Andheri Kurla Road, Andheri Ghatkopar Road, DP Road, Golibar Road and Hirachand Desai Road. Two maintenance depots are being planned for this corridor one at near DN Nagar station with stabling & inter-corridor link with North-South corridor and another depot in Godrej land in the eastern segment.

ii) Development planned prior to MRTS

As discussed in previous paras, under MUIP (Mumbai Urban Infrastructure Project) the roads lying along this corridor are being widened to their full right of way. The road widening /construction activity will be taken up prior to Metro construction and the roads with their full ROW will be available for Metro construction. As per MUIP, the road widening will be carried out on either side equally w.r.t the present road center. Accordingly, the system has been planned and land acquisition requirements have been assessed.

5.7.2 Land Requirement for following major components

- MRTS Structure (including Route Alignment), Station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, Depots, etc.
- Receiving/Traction Sub-stations
- Radio Towers
- Temporary Construction Depots and work sites.

5.7.3 Land required for elevated structures (Other than Stations)

The normal viaduct structure of elevated Metro is about 10 m (edge to edge) wide. Ideally the required right of way is 10m. However, for reasons of safety a clean marginal distance / setback of about 5 m is necessary from either edge of the viaduct (or 10 m on both sides of the center line) wherein no structures are to be located. This is necessary as the traction system is overhead 25 kV ac system with masts fixed on the parapets. Also, it ensures road access ands working space all along the viaduct for working of emergency equipments and fire brigade.

As explained in the earlier chapters the D. P. widths of the roads along which the Metro alignment is passing are more than 20 m except at the following stretches.

(i) Part of J. P. Road to the west of Andheri Metro Station (west of W. Rly. tracks) where D. P. width is 18.4 m and

(ii) Part of Golibar Road (from Sarvodaya Hospital up to L. B. S. Marg). In this critical area we propose two options

a) to set back the building beyond 10 m from the centre as and when the redevelopment proposals are received.
b) to adopt, suitable measures like, screening/covering to mitigate the effects of MRTS system on the structures/people where the clearanceis less than 5m from the station building.
c) Similarly, for safety reasons a belt of 5 m on either side of the station building is required where in no structures are allowed. If the clearance to any structure is less than 5 m, efforts should be made to acquire that building or suitable measures like, screening/covering to mitigate the effects of MRTS system on the structures/people are to be adopted.

The alignment has been planned with a presumption all roads will be widened to D. P. width under MUIP and as such no land acquisition cost is involved for right of way.

In view of the constraints on space on ground floor it is proposed to provide the concourse area exactly below the Station Building at mezzanine level. All the stations including terminal stations are planned with side platforms. Normally, the ideal width required for station building is 28 m. Since, the width of the road where most of the Stations are located is more than 28 m, no land acquisition is envisaged for Stations. The staircase giving access to concourse area from ground will be located on the footpaths at the edge. Some constraints are observed at the station buildings at Andheri and Ghatkopar. The situation is very tight particularly at Ghatkopar where ROW is 18.4 m and building to building space is 22 to 27 m. As a special case the Station Building width is restricted to 20 m at Ghatkopar & attempt is made to locate the staircases within the marginal space available.

5.7.4 Land for Traffic integration

It is proposed to provide traffic integration facilities at all the proposed MRTS Stations. Land for these facilities has been identified and is given in **Table 5.7.1.** The requirement has been worked out keeping in view the traffic demand with full phase network of the Metro.

Table 5.7.1

PROPOSED TRAFFIC INTEGRATION SITES

S. No	Station	Location	Proposed (in sqm)
1.	Versova	Open area behind the metro station	**803**
2.	D N Nagar	Under elevated station concourse	**1,655**
3.	Azad Nagar	Open space in A.H. Wadia School	**2,323**
4.	Andheri	Under elevated station concourse	**84**
5.	WEH	Open space close to station	**1,755**
6.	Chakala	- DO -	**452**
7.	Airport Road	- DO -	**322**
8.	Marol Naka	- DO -	**571**

9.	Saki Naka	- DO -	**525**
10.	Subhash Nagar	- DO -	**346**
11.	Asalpha Road	- DO -	**417**
12.	Ghatkopar	Under elevated station concourse	**120**

Plots are identified for providing parking requirements. However, it was indicated that acquisition of land at all the proposed location may not be possible. So it is suggested that the land may be acquired to the extent possible. Hence, cost of this land has been indicated separately.

5.7.5 Land for Depot

Two sites for locating the proposed depot were examined. One was at Vikhroli, from the large vacant plot owned by M/s Godrej and which is reserved for “Exibition Grounds” in the D. P. Total area of the land is about 20 hectares. Other large open plot is available near the junction of J. P. Road and Link Road near D. N. Nagar. The available land area is about 12.25 hectares. It is reserved as “Sewage Disposal Plant” in the Development Plan. We are of the view that the location near D. N. Nagar is more appropriate and is recommended. However the land at exhibition ground is to be acquired for future use.

5.7.6 Land for Traction and Received Sub station and Radio Towers

Two RSSs are proposed to be located for this corridor . One in D. N. Nagar depot area and another at Marol Naka station. An area of 550 sqm (22X25) has been earmarked at each location. Similarly, two radio towers are also being proposed to be located at these locations occupying an area of 100 sqm (10 m X 10 m) for each radio tower.

5.7.7 Land Requirement for Stations & Running section

The ROW of the roads in eastern segment of the alignment is sufficiently wide excepting near Ghatkopar station. As the alignment is located on the center of the road, no land is required for station building etc., excepting few space for station, traffic integration purposes.

In case of western segment the, the proposed ROW is only 27.45m . Hence at several places due to curves etc., some land is proposed for acquisition required for station buildings, running section etc.

The details of land permanently required for eastern & western segments are given in **Table 5.7.2 & 5.7.3** respectively. The areas identified for acquisition are shown in **Figs.5.7.1 to 5.7.12**(enclosed).

In the stretch between Km.E7.290 and Km. E7.455, for about a length of 165m, the alignment is located off the Golibar Road, away from Sarvodaya hospital. To avoid demolition of important structures a sharp curve of 100m radius is provided. This stretch is passes through private land adjoining the Golibar Road and involves acquisition of about 0.33Ha(165mX20m)of private land on permanent basis. Further, a narrow strip of land lying between the existing Golibar road and the alignment will become redundant. Hence it is proposed to re-align this stretch of Golibar road along the metro alignment with increased ROW, if necessary and the present Goilibar road area can be utilized for rehabilitation of affected people. Hence, permanent land acquisition is not proposed for this stretch. The cost of road re-alignment & rehabilitation has been taken care of in the project cost estimate. A detailed road re-alignment plan will be prepared after, reviewing the DP road alignment at this place.

Table 5.7.2

DETAILS OF LAND PERMANENTLY RE UIRED FOR THE PROJECT- EASTERN SEGMENT

S. No.	Plot No	Location		Area in Sqm	Land owner ship	Proposed Land Use
1	STANP1	Andheri Station	Vacant space/abandoned bldg.	945	Pvt	Station facilities & Traffic Integration
2	STE4P2	Marol Naka	Vacant Space-Commercial	650	Pvt.	RSS & Radio Tower
3	STE6P1	Subash Nagar	Vacant space-Commercial	265	Pvt	Station facilities
4	STE7P1	Asalpha Road	Vacant space-Commercial	400	Pvt	Station facilities
5	STE8P1	Ghatkopar	Res. Built-up	284	Pvt	Station facilities & Traffic Integration
6	STE8P2	Ghatkoper	Com.Buit-up	266	Pvt	-DO-
7		Godrej Land	Vacant -Commercial	200000	Pvt	Maintenance Depot
			Total	202810		

Pvt.Residential 1229 Sqm.
Pvt. Commercial 201581 Sqm

Note :

1. ST- Station ; E-Eastern ; W-Western; AN – Andheri; P- Plot; CD – Construction depot; DP- Maintenance Depot; PD – Property development ;RS-Running Section;

2. STE1P1- Plot NO.1 for 1st eastern station (E1) i.e., WEH Station

Table 5.7.3

DETAILS OF LAND PERMANENTLY RE UIRED FOR THE PROJECT- WESTERN SEGMENT

S. No.	Plot No	Location	Details	Area in Sqm	Land owner ship	Proposed Land Use	Proposed Type of Acquisition	Present land Use
1	STW1P1	Azad Nagar Station	Built-up Commercial	94	Pvt	Station Entry/Exit	Permanent	Commercial
2	STW1P2	- DO-	Vacant space in front of Commercial shops	79	Pvt	- DO-	Permanent	Commercial
3	STW1P3	- DO-	Built-up Residential	16	Pvt	- DO-	Permanent	Residential
4	STW1P4	- DO-	Vacant space in front of Residential Bldg.	110	Pvt	- DO-	Permanent	Residential
5	STW1P5	- DO-	Built-up Commercial	74	Pvt	- DO-	Permanent	commercial
6	STW1P6	- DO-	Vacant space in front of Residential Bldg.	178	Pvt	- DO-	Permanent	Residential
7	STW1P7	- DO-	Vacant space in front of Sports Club(Recreational)	312	Govt.	Stair case	Permanent	Other
8	STW1P9	- DO-	Vacant space in front of Commercial shops	119	Pvt	To maintain safe clearance	TDR	
9	STW1P10	- DO-	- DO-	285	Pvt	Stair case	Permanent	commercial
10	STW1P11	- DO-	- DO-	140	Pvt	To maintain safe clearance	TDR	
11	STW1P12	- DO-	Built-up Residential	187	Pvt	- DO-	TDR	
12	STW1P13	- DO-	Vacant space in front of Commercial shops	216	Pvt	- DO-	TDR	
13	STW1P14	- DO-	Built-up Commercial	116	Pvt	- DO-	TDR	
14	STW1P15	- DO-	Vacant space in side of Sports Club(Recreational)	63	Govt.	- DO-	TDR	
15	STW2P1	D.N.Nagar Station	Vacant space in front of Residential Bldg.	597	Pvt	To maintain safe clearance	TDR	
16	STW2P2	- DO-	Vacant space in front of Commercial shops	190	Pvt	- DO-	TDR	
17	STW2P3	- DO-	Nursery	271	Pvt	- DO-	TDR	
18	STW2P4	- DO-	Built-up Official	74	Govt.	- DO-	TDR	

19	STW2P5	- DO-	- DO-	36	Govt.	- DO-	TDR	
20	STW2P6	- DO-	- DO-	42	Govt.	- DO-	TDR	
21	DEPOT	- DO-	Vacant Area	122500	Pvt		Permanent	
22	STW3P2	- DO-	Built-up Commercial	166	Pvt	To maintain safe clearance	TDR	
23	Sum(1 to 22)		G.Total	125865				
24	Sum(1,2,5,9)		Permanent Commercial (Pvt)	532				
25	Sum(3,4,6,21)		Permanent Residential(Pvt)	122804				
26	Sum(7)		Permanent Other(Govt.)	312				
27	Sum(24,25,26)		Total Permanent	123648				
28	Sum(8 to 20,22)		TDR	2217				

Note :

1. ST- Station ; E-Eastern ; W-Western; AN – Andheri; P- Plot; CD – Construction depot; DP- Maintenance Depot; PD – Property development ;RS-Running Section;

2. STW1P1- Plot NO.1 for 1st Western station (w1) i.e., Azad Nagar

5.7.8 Temporary Construction Depot

5.7.8.1 During construction period, huge quantities of construction materials like reinforcing bars, cement, steel sections, shutters, pre-cast segments etc. are to be stored and sufficient land is required for storage of these materials.

5.7.8.2 Since the area of land being acquired permanently at most of the stations is just sufficiently limited, the land required for construction depots purpose is identified separately, in the vicinity of the stations on temporary acquisition basis. The areas proposed for such purpose in eastern & western segments are indicated in **Table 5.7.4 & 5.7.5** respectively. These sites will be obtained on lease temporarily for the construction period. After completion of construction, these will be handed over back to the land owning agency.

5.7.8.3 Approximately, 1.33 Hectares. of private land is proposed for construction depot purpose in eastern segment. In case of western segment, the construction depots are located in those plots, which are proposed for permanent acquisition. Presently the proposed sites are vacant. The areas are identified based on availability as vacant on date. At the time of construction, depending up on the need % requirements the location and size can be reassessed and temporary land acquisitions can be made accordingly.

Table 5.7.4
PROPOSED CONSTRUCTION DEPOT SITES – EASTERN SEGMENT

S. No.	Plot No	Location	Area in Sq.m	Land Utili ation During Construction	Land Owner ship	Remarks
1	CDAN	Open space of W.Rly	2100	Construction depot for Andheri station	Govt.	Temp.Acquisition
2	CDE1	Open space close to WEH station	1755	Construction depot for WEH station	Pvt. Comm	-Do-
3	CDE2	Construction depot @ Chakala station	1435	Construction depot for Chakala station	Pvt. Comm	-Do-
4	CDE3	Open space close to Airport Road station	1670	Construction depot for Airport Road station	Pvt. Comm	-Do-
5	CDE3A	Open space near Sahar airport	50000	Segment casting yard	Govt.	-Do-
6	CDE4	Open space close to Marol Naka station	2130	Construction depot for Marol Naka station	Pvt. Comm	-Do-
7	CDE5	Open space close to Saki Naka station	2400	Construction depot for Saki Naka station	Pvt. Comm	-Do-
8	CDE6	Open space close to Subash Nagar station	0	Construction depot for Subash Nagar station	Pvt. Comm	Not available. To be identified the time of execution
9	CDE7	Open space close to Asalpha Road station	1837	Construction depot for Asalpha Road station	Pvt. Comm	
10	CDE8	Open space close to Ghatkopar Metro station	0	Construction depot for Ghatkopar Metro station	Pvt. Comm	Not available. To be identified the time of execution
		Total	**63327**			
		Govt.	52100			
		Pvt.Comm	11227			

Table 5.7.5
PROPOSED CONSTRUCTION DEPOT SITES – WESTERN SEGMENT

S. No.	Plot No	Location	Area in Sq.m	Land Utili ation During Construction	Land owner ship	Remarks
1	CD1W1	Open space in School	2530	Construction depot @ Azad Nagar station	Govt.	Proposed for Permanent acquisition for traffic Integration(STW1 P1&3)
2	CD1W1	Open space in Sports club	744	-Do-	Govt.	-Do-

3	CDW2	Land Identified for Maintenance depot	3000	Construction depot @ D.N.Nagar Station	Govt.	Proposed for Permanent acquisition for maintenance Depot(DPP3)
4	CDW3	Open area behind Seven Bungalows Bus depot	4000	Construction depot @ Versova Station	Govt.	Proposed for Permanent acquisition for Property Development (W3PD)
		Total	10274			
Note: Since the construction depots are proposed in the plots proposed for permanent acquisition, separate land acquisition is not required.						

5.7.9 Segment Casting Yard

Large numbers of pre-cast segments are required for construction of elevated structures for which a large open area is required for setting up of casting yard. As far as possible, this area should be close to the site, easily accessible and away from habitation. Considering the various factors, it is proposed to setup the segment-casting yard at the land identified for Maintenance Depot at D.N.Nagar station.

In fact, for a corridor of this length, one yard is sufficient but due to the physical obstruction i.e., W. Rly. tracks it is suggested to provide separate casting yards for Western segment & Eastern Segment.

For Western segment, it can be located in the land identified for maintenance depot at D. N. Nagar. For Eastern segment, the vacant land available near Sahar Airport can be taken as lease/ temporary acquisition basis during construction stage.

5.7.10 Summary of Land Requirements

Abstract of land requirements for different components of this corridor is given in **Table 5.7.6** and are summarized below:

Table 5.7.6

SUMMARY OF LAND RE UIREMENT

S.NO	PERMANENT AC UISITION(Sqm)			TEMPORARY AC UISITION(Sqm)			TDR(Transfer of Development Rights)	REMARKS
	Pvt. Res	Pvt. Comm	Govt.	Pvt. Res	Pvt. Comm	Govt.		
1	1229	201581	NIL	NIL	NIL	NIL	NIL	Stn.entry/ exit,Traffic Integration, RSS, Radio Tower etc. in EASTERN Segment

2	122804	532	312	NIL	NIL	NIL	2217	Stn.entry/ exit,Traffic Integration, Maintenance depot, RSS, Radio Tower etc. in WESTERN Segment
3	NIL	NIL	NIL	NIL	11227	52100	NIL	Construction Depots , Casting yard etc. in EASTERN SEGMENT
4	NIL	NIL	NIL	NIL	NIL	NIL	NIL	Since, located in the locations proposed for permanent acquisition.
Total	**124033**	**202113**	**312**	**0**	**11227**	**52100**	**2217**	
Grand Total		**326458(32.64Ha)**			**63327(6.33Ha)**		**2217**	

5.7.11RELOCATION / RESETTLEMENT

The project involves relocation of few shops, commercial cum residential buildings and hutments along the alignment as discussed in Chapter 10.0. Compensation for relocation of these affected structures shall be paid and it has been considered in the project cost estimate. The alignment has been so chosen, that it remains mostly within the government land. However, between Andheri & Azad Nagar station and between Versova Station & dead end of the alignment. Some private land would be required for acquisition due to limited right of way.

5.7.12 PROPERTY DEVELOPMENT

5.7.12.1General

Like most rail-based mass urban transport systems, this line also, though financially unviable, is economically attractive and needs financial structuring to make it financially viable, as well. Development and commercial utilisation of land and air space along/close to this transport system and its facilities are therefore, considered essential to supplement financial resources for construction and operation of the system.

Economic reforms, globalisation and privatisation have brought enormous changes in financial, economic and employment sectors in the country. Economic growth is targeted at around **6%** per annum. Information technology has led to the drastic changes in the urban life style. Cities, particularly the metros, contribute substantially towards economic growth. Urban population has been doubling almost every 20 years, during the last five decades in India. Markets are growing in numbers and size. Cities are expanding horizontally and vertically. The demand for real estate is accordingly increasing. It is, therefore, considered that real estate, if developed along this corridor, will be popular and will fetch good returns, particularly in view of the fact that practically this entire corridor alignment lies in well developed built up areas.

5.7.12.2Identification of Sites for Property Development

To ensure fast implementation of the proposals and optimization of earnings, the following criteria have been kept in view:

- Land plots to be close to the proposed MRTS corridor,
- Land plots should be vacant and owned preferably by a Government agency.
- Proposed usage to be in conformity with provisions of MPD-2001.
- Availability of adequate infrastructural support and optimum potential for commercial utilization and early high returns.

To supplement financial resources for construction and operation of the system, it is proposed to develop the following sites, near to the station locations for commercial exploitation. In Eastern segment, no suitable land could be identified for property development. In case of western segment, two locations have been identified for property development as below:

1. Versova metro station- The Property development will be done in the air space of the area proposed for acquisition towards traffic integration at Versova station. The area will be about 2000Sqm.

2. D.N.Nagar Maintenance Depot - The Property development will be done in the vacant space left over after providing all the depot facilities at D.N.Nagar and air space above the depot. The area will be about 3000Sqm.

5.7.12.3 Methodology of Property Development

Process of property development requires land, labour, capital, entrepreneurship and management as major inputs. Following steps are involved in the process:

- To obtain land free from all encumbrances with a clear title.
- To obtain clearances of the concerned government and local authorities for proposed usage, ground coverage, FAR, height and other basic controls and availability of essential services like water supply, sewers, electric supply, approach roads, etc.
- To assess demand and optimum usage and expected returns.
- To prepare architectural plans/models and obtain sanctions of concerned authorities.
- To prepare construction plans, structural designs, etc. for implementation.
- To appoint executing agency and create supervising organisation.
- To sell the developed property and realise the proceeds thereof.
- To allow the property on long term lease.

Property development and its transfer can be under taken by MMRDA either by themselves or in collaboration with a builder/developer. Since it involves not only heavy financial investment but also real estate expertise and risk, it is considered better to undertake this activity in collaboration with some established builder/developer of repute on pre-agreed terms regarding individual responsibilities and various related financial aspects.

5.7.12.4 Appointment of Builder/Developer

After selection of property development sites, taking over the land and obtaining preliminary clearances including usage, FAR, ground coverage, height and other basic controls, MMRDA may short list a number of property developers/builders (Indians and Foreigners).

MMRDA may award the right to develop/build and sell the property on its land to a collaborator through a process of short listing followed by open competitive bidding. The bidder who offers highest up-front premium and most attractive terms and time frame may be awarded the work. The builder may book/sell the proposed property to purchasers as the building activity proceeds. The builder/developer will pay MMRDA specific amount of sums on pre-agreed time frame and back his promise by bank guarantees.

5.7.12.5 Requirements of Electric Power

For the purpose of assessing power demand for the proposed commercial development along the corridor, it has been considered that specific power demand will be about 200-W/m^2 of built-up area. This power shall be availed from the respective nearby distribution sub-stations.

5.7.12.6 Property Development in D.N.Nagar Depot Area

The land identified for depot at DN Nagar is limited and the approach ramp for ascending /descending the alignment from elevated position to ground and then to elevated position is not available. If, such a ramp is located on JP road, it would block the cross roads and occupies more space on ground and becomes a physical barrier on JP Road for the developments on either side. Hence, the depot is proposed in elevated position.

In the depot, the track and it's related facilities are planned in elevation position. Other facilities such as material store, staff office, water tanks etc. are planned at grade. Due to the supporting structural arrangement of the elevated depot, the feasibility of utilizing the ground portion can be ascertained only after detailed design of the depot. The inter corridor link between East-West & North- South corridors would occupy some space above the depot. The rail level in the depot will be about 12m above the ground level and the inter-corridor link line will be at a height of about 20m form the existing ground level. Hence, space above 25m from the ground level will be available for commercial exploitation, subjected to prevailing building bye-laws in terms of FAR/FSI etc.

Chapter 6

STABLING-CUM-INSPECTION DEPOTS

6.1 INTRODUCTION

Details of "Versova-Andheri-Ghatkoper", the East West corridor of Mumbai MRTS are as below:

S. No.	Parameter	EW Corridor
1	**Gauge** (Nominal)	1435 mm
2	Route length	11.07 Km

This report covers following aspects of D N Nagar depot based on the details at **Annexure-I**: -

- Conceptual design and layout of Stabling Shed, Inspection shed, minor repairs and cleaning of Rolling Stock.
- Operational and functional safety requirements
- Ancillary buildings for other maintenance facilities
- Electrical & Mechanical Services, Power supply and Distribution system.
- Water Supplies, Drainage & Sewerage.
- This report provides conceptual design and will only work as a guide for detailed design later.

6.2 MAINTENANACE PHILOSOPHY

The main outlines of the philosophy followed are:

- ➢ Monitoring of the performance of equipment by condition monitoring of key parameters. The concept is to evolve the need based maintenance regime, which can be suitably configured in the form of schedules like weekly/15 days check, "45 days check", annual check, "IOH" and "POH".
- ➢ Labour intensive procedures will be kept to the minimum. More automation with state of the art machinery to ensure quality with reliability.
- ➢ Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.
- ➢ Energy conservation shall be given due attention

6.3 LOCATION OF THE DEPOT & ITS VARIOUS AUXILLARY BUILDINGS

The D N Nagar Depot is planned at an elevated level as space for providing ramp is not available to construct the depot at ground level. A two level depot is providing in Bangkok also. The Stabling Shed, Inspection Shed, Blow Down Plant, Interior Cleaning Plant, Automatic Washing Plant, Emergency Building, Tower Wagon Shed, ETU Workshop are planned on the deck. Some auxiliary buildings are proposed at ground level under the Deck. These buildings will be DCOS Store, Time &Security Offices, Light Vehicle parking area, Depot Substation, Canteen, Workshop Manager Office & P. Way Office. Material Transfer Lift is planned for transfer of materials from ground to deck & vice versa. Balance space can be used for housing of staff & property development. The depot layout is indicated in **Fig. 6.1**.

6.4 APPROACH OF MAINTENANCE FOR ROLLING STOCK IN D N NAGAR DEPOT OF MUMBAI MRTS

D N Nagar Depot will be used for stabling of Rolling Stocks , their cleaning ,inspections and minor repairs. These Rakes will be operational on **Versova-Andheri-Ghatkopar** section of Mumbai MRTS.

For major repairs, IOH, POH and wheel reprofiling works, the mothershed workshop located at the end of NS Corridor at MITHCHOWKI is to be used by transferring rakes through Rake Transfer Line.

Rolling Stocks will approach from Versova Station to the Depot.

6.5 ROLLING STOCK MAINTENANCE NEEDS:

The following maintenance schedule has been envisaged for conceptual design of depot assuming 350 km of running per train per day.

Type of Schedule	Interval	Work content	Locations
Daily	Daily	Check on the train condition and function at every daily service completion. Internal cleaning / mopping of floor and walls with vacuum cleaner.	Stabling Bays
Weekly check	7 Days	Check on the safety and reliability of critical equipment, General visual inspection, testing of systems	Inspection Bays
“A” Service Check	5,000 Km (15 days)	Detailed inspection of “weekly Check” tasks plus testing of systems, replacement of oils & lubricants and consumables	Inspection Bays
“B” Service Check	15,000 Km (45 days)	Detailed inspection of ‘A’ type tasks plus items at multiples of 15,000 Km (‘B’ type tasks)	Inspection Bays

Intermediate Overhaul (IOH)	300,000 Km (3 Years)	Check and testing of all sub-assemblies (Electrical + Mechanical). Replacement of parts and rectification, trial run	Workshop
Periodical Overhaul (POH)	600,000 Km (6 Years)	Dismantling of all sub-assemblies, bogies, suspension system, traction motor, gear, control equipment, air-conditioning units etc. Checking repair and replacement as necessary. Inspection and trial	Workshop

6.5.1 Washing Needs of Roling Stock

The Metro trains are maintained to a high degree of cleanliness and therefore needs the following schedules

S. No.	Kind of Inspection	Maint. Cycle	Time Reqd. for Checking	Maintenance Place
1.	Outside Cleaning (wet washing on automatic washing plant)	3 Days	10 mins	Single Pass through Automatic washing plant of Depot
2.	Outside heavy Cleaning (wet washing on automatic washing plant and Front Face, Vestibule/Buffer area, Floor, walls inside/outside and roof. Manually)	30 days	3 Hrs	(Automatic washing Plant & washing line)

6.5.2 Operational Features

The rake induction and withdrawal to open line will be primarily from the stabling shed. Movement from depot to the open line is so planned that the headway of open line is not affected. Simultaneous receipt and dispatch of trains from depot to open line is not feasible in the present site constraint. Either of the two activities will be done effectively without effecting the train operation on the main line. The stabling as well as the Inspection lines would be interlocked with the open line thereby induction of train from the stabling and Inspection lines would be safe and without loss of time. There would be transfer track on the incoming line to facilitate the placement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear.

An emergency line will be provided from which an emergency rescue vehicle may be dispatched to open line in the event of emergency if necessary.

As per **Annexure –I**, taking into consideration the rake requirement (which is 20 rakes) on this corridor for the horizon year 2031, 11 rakes shall be stabled in the stabling shed, 2 rakes will be under inspection in Inspection shed, 1 in the Interior Cleaning Plant for maintenance and 4 rakes shall be stabled at the termination stations. 2 rakes will be engaged in its heavy repair and maintenance in the Workshop. So, a minimum of 11 stabling lines will suffice the requirements.

The scheduled inspections shall be carried out during the day off peak and night. One & half inspection lines are used for weekly/15 days schedule per day for 3 rakes. So in 7 days 21 rakes are checked on 1 & ½ lines. 'B' & 'C' check requires half the day, so ½ inspection line is for "B"&"C" check. ½ Inspection line will be used for 20 rakes "B" & "C" check. And this ½ line is vacant for 25 days. So, a minimum of 2 inspection lines are planned.

6.6 INFRASTRUCTURE FACILITIES PLANNED AT D N Nagar Depot:

6.6.1 Design of Inspection Shed Capacity at D N Nagar Depot

Following facilities shall be provided to include the ability to carry out the inspection, of the following equipments of rolling stock fleet:

- Electrical components;
- Electronics; PA/ PIS
- Mechanical components;
- Batteries;
- Rolling stock air conditioning;
- Brake modules;
- Bogie; traction motor
- Vehicle doors, windows and internal fittings.

Each of Inspection shed lines will be able to cater one rake during the day's off peak and one at night time when all the rakes return to the depot. Following are the design calculations of for the Inspection shed line requirements.

S. No.	Schedule	Designed capacity (4 car length)	No. of lines for Designed capacity
1	Daily safety check on stabling lines	11 rakes	11
2	Weekly/15 days Schedule	21 rakes	1line during day & night+1 line only during night (with sunken floor)
3	45 days Schedule	45 rakes	1 line during day (with sunken floor)

4	Unscheduled Line	Unscheduled Maintenance	1 line (interior cleaning line can be used in day time or the sunken floor line in the Unscheduled workshop.)

An Inspection shed consisting of two lines & one bay in between the lines of 160m x 15m is planned for the depot. The Inspection shed bay will have two inspection lines with sunken floor. The floor will be sunken by 1100mm. The centerline of both the tracks will be 8000mm apart. The centerline of tracks would be at a distance of 3500mm from the columns of shed. Roof Inspection platforms supported on the columns shall be provided. There would be lighting below the rail level to facilitate the under frame inspection. 415V 3 phase 50 Hz, 230V 1 phase 50 Hz AC supply and pneumatic supply shall also be made available on each inspection shed columns.

6.6.2 Stabling Lines in Depot

In the yard 11 number 6-car length-stabling lines are planned at D N Nagar Depot. Two (2) rakes would be housed in the inspection shed. The length of 6 cars Rolling Stock is approx 133.88m. Stabling lines are designed for 160m lengths or more to cater for provision of the friction buffer stops and the signaling interlocking needs, assuming the speed of the Rolling Stock in the depot to be 25 kmph. It is recommended to cover the stabling lines.

The space between stabling lines shall be sufficient to include pathway to be constructed between each track to provide access for internal train cleaning.

6.6.3 Automatic Coach Washing Plant

Provision is made for Rolling Stock exterior surfaces to be washed using a fully automated Train Washing System, with a throughput capacity of approximately six trains per hour. This shall be accommodated in the 30m x 10m area. As per the site constraints, direct entry of train from Train Wash Plant to the stabling shed is not possible. This movement would be through Z Shunting.

6.6.4 Washing Apron

Monthly heavy Cleaning of interior walls, floors, seats, windows glasses etc, outside heavy Cleaning, Front/ rear Face, Vestibule/ Buffer area, outside walls and roof shall be done manually in the interior cleaning plant. Outside Heavy Cleaning Rolling Stock is in 30 days maintenance schedule, requiring 3hrs for 1 rake.

6.6.5 Power Supplies

Power supply arrangement for depot is to be made separately to take care of operational as well as yard lighting load. An auxiliary substation has been planned for catering to the power supply requirement of the whole depot and workshop. Details of connected load feeder shall be worked out. Taking diversity factor of 0.5 the maximum demands shall be computed.

6.6.6 Standby Power Supply

The standby power supply is proposed through DG set with AMF panel. The capacity of DG set will be adequate to supply all essential loads without over loading. This will also be housed in the Substation.

6.6.7 Water Supply, Sewerage and Drainage Works

In house facilities such as tube wells shall be developed or sufficient supply from BMC to be ensured for the water supply of the entire depot cum workshop. Sewerage, storm water drainage shall be given due care while designing the depot for efficient system functioning. Past records of Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphasis to charge the under ground reserves.

6.6.8 Unscheduled Workshop

This workshop will have two lines - one will be at floor level and the other will have a sunken floor same as the Inspection line in the Inspection shed. The latter line will be used for unscheduled attention of Rolling Stock.

Vehicles like diesel locomotive, electric tractor, tower wagons etc shall be housed and given required inspection attention on the former floor level line. This Unscheduled workshop will be built adjacent to the Inspection shed. However for the heavy lifting needs, these vehicles may be taken to main workshop.

6.6.9 Watch Towers

There shall be provision of 2 no. of watch towers for the vigilance of depot activities.

6.6.10 Shed and Buildings

The shed and buildings normally provided in the depot with their sizes and brief functions are indicated in **Annexure-II**. Some of these buildings are not depicted on the layout drawing. At the detailed design stage depending upon the land availability, the decision to have these buildings can be taken. These can then be architecturally and functionally grouped.

6.6.11 Plant And Machinery

Requirement of major plants and machinery, which are vital for operational needs, is given in **Annexure-III**. Total cost incurred in Machines & Plants will be approximately Rs. 40 Cr.

ANNEXURE-I

Brief details guiding the design of Stabling-cum-Inspection depot of MUMBAI MRTS (Versova-Andheri-Ghatkopar)

1.1 SALIENT FEATURES OF ROLLING STOCK:

S. No.	Parameter	(East - West) LINE - 1
1	**Vehicle dimensions**	
	Length (including coupler)	DT-M-T-M-M-DT : 133880 mm
	Width	3200mm
	Height	4118mm
2	Coach construction	Lightweight stainless steel body
3	Tare Weight	DT (42.0T), T (42.0T), M (42.0T)
4	Axle load	17T per axle
5	Propulsion system	3 phase drive system with VVVF control
6	Type of traction supply	25KV AC Overhead collection

1.3 RE UIREMENT OF COACHES for Versova- Ghatkopar Corridor

(Line-1 Route Length: 11.07 km)

Year	Head way	Cars	Rake requirement				No of Cars	Train Composition
			Bare	Traffic Reserve	R&M	Total Rakes		
2011	5	4	11	1	2	14	56	DT-M-M-DT
2021	4	4	13	1	2	16	64	DT-M-M-DT
2031	3	4	17	1	2	20	80	DT-M-M-DT

ANNEXURE-II

LIST OF BUILDINGS FOR D N Nagar Depot

S. No.	Name of Building	Si e	Brief Function
1	**Inspection Shed** Associated sections **Sun shade roof**	160 x 15m 60 x 8 m 160 x 57m	Designed for the servicing of 126cars for 7day schedule & 270 cars for 45 day schedule inspections. Rooms d/ storey for carrying out the inspection activity For stabling 11 rakes of 6 cars each.
2.	DCOS Stores & Offices including Goods Platform with Ramp	42.5 x 42.5m	(i) Stocking of spares for regular & emergency requirement including consumable items. (ii) This store caters for the requirement of depot for rolling stock & other disciplines. (iii) To be provided with computerized inventory control. Loading/ Unloading of material received by road.
3.	Elect. Substation	25x22 m	To cater for normal and emergency power supply for depot, workshop, service and all other ancillary buildings, Essential power supply for essential loads and security light.
4.	ETU Shed cum Traction repair depot & E&M repair shop	80 x 30 m (partly double storey)	Stabling and routine maintenance of shunting engine, tower wagon etc. & Traction maintenance depot For maintenance of lifts / escalators and other General service works.
5.	Cycle & Scooter Stand	25 x 6 m	To park cycles and Scooter
6	Auto Coach washing plant	30 x10 m	For automatic washing of coaches washing apron is for collection of
7	Washing Apron	140x 6.5m	Dripping water and its proper drainage.
8	Blow down plant	31 x 14m	
10.	P. Way Office,	80 x 20m	For Track maintenance
11.	Security office & Time Office Garages (4 Nos)	15 x 8m Approx 6 x 8m	For security personnel. For time Punching For parking vehicle jeep, truck etc.

S. No.	Name of Building	Si e	Brief Function
12.	Check post (2 Numbers)	5 x 3	For security check of incoming / outgoing staff material and coaches.
13.	Watch tower (2 Nos.)	3.5x2.5	For security of the depot especially during nighttime.
14.	O.H raw water Tank	1,00,000 Ltrs Capacity	Storage of water, capacity 1,00,000 litres each.
15.	Pump house Bore well	7.3x5.4 200 mm	Submersible type pump planned with 200-mm diameter bore well.
16.	Work shop Manager Office	30x20m	Office of Depot in charge
17	ATP& ATO Room	4x5 m	To keep equipments of ATP/ATO.
18	Waste Water Treatment Plant	12x6m	For treating the discharge waters of the depot and remove the oil, acids etc. before discharging, with U/G tank.
19	Canteen	400 sqm	To cater staff of depot and workshop. Obligatory as per statutory requirements.
20.	Compressor room 1 no	12 x 6m	To supply pneumatic air to servicing shed

<u>Note</u>

1 Some of these buildings are not depicted on the layout map. Depending on the administrative decision, this shall be suitably done at the detailed design stage incorporating the site topography, architectural nitty gritty and minor adjustment in sizes looking to the available land.

2 Some of the buildings like stabling shed; security office etc shall be pre-engineered structure. The decision in this regard may be taken at the detailed design stage.

ANNEXURE-III

M&P required for Depot for VARSOVA – ANDHERI – GHATKOPER SECTION

S No.	Equipment
1	Under floor Pit wheel lathe withChip crusher and conveyor for lathe on pit. &Winch capstan for under floor wheel lathe
2	Synchronized pit jacks for two car lifting consisting of 8 jack system with Mobile lifting jacks-12& 15T
3	Turntable for bogies
4	Automatic Washing plant for Metro cars.
5	Diesel Shunting Engine
6	Electric bogie tractor for pulling cars and bogies inside workshop
7	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc
8	Cherry picker/ Snorkel. High lift platform type vehicle to rach viaduct and OHE from road
9	Turn table for one car
10	Accommodation bogie 2 car sets for Metro Cars
11	Jib Crane
12	Mobile portal type A,B & Jib Crane,Mobilejib crane (overhang type)
13	Car body stands
14	Underframe & Bogie blowing plant
15	Vertical carousel storage system
16	Bogie cleaning plant
17	Rail fed Bogie wash plant
18	Ultrasonic cleaning tank
19	Ultrasonic machine for cleaning electronic equipment
20	Welding equipments (Mobilewelding, oxyacetelene, fixed arc welding)
21	Set of machine tools(one radial drilling machine, one universal milling machine, two slide lathes, one panel sawing machine, one guillotine shears, one cutting machine.
22	Mobile safety steps
23	Mobile lifting table
24	Work lift platform
25	Fork lift tractor
26	Pallet trucks
27	Minor equipment and collective tools
28	Electric and pneumatic tools
29	Measuring and testing equipment
30	Axle shaft inspection station
31	Tool kits
32	Floor cleaning machine
33	EMU battery charger

34	Battery Charger (for road vehicles)
35	Water de-mineralizing plant (Distillation plant)
36	Bearing puller & press
37	Road vehicles (pickup van/ truck)
38	Industrial furniture
39	Storage racks
40	High-pressure washing pump for front and rear end cleaning of cars.
41	Simulator with 3 degrees of freedon on motion for the modern rolling stock, to train the drivers.
42	Cleaning booth for TM
43	Transformer oil purification plant
44	Painting booth for separate parts
45	Induction heater
46	Vertical boring machine
47	Press for wheel fitting and removal
48	Surface wheel lathe
49	Axle journal turning and burnishing lathe
50	Special jigs and fixtures and test benches for Rolling stock

CHAPTER 7

TRAIN OPERATION

7.1 Operation Philosophy

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections
- Economical & optimum train service frequency not only during peak period (3 minutes Headway), but also during off-peak period (15 minutes headway),
- A short train consist (4 coaches) with high frequency service to be suitably increased to 6 coaches and 8 coaches as the transport demand picks up. Basic suit selected is one motor coach and one Trailer coach.
- multi-tasking of train operation and maintenance staff.

7.2 Stations

Mumbai Metro Rail System consists of three lines. Line 1 – Varsova - Andheri-Ghatkopar Section is of the length of 12 kms with 12 stations. List of stations for Line-I is given in **Table 7.1**.

TABLE 7.1
List of Stations Line-I
Varsova ⇆ to Ghatkopar

Sr. No.	NAME OF STATION	Remarks
1.	Varsova	ELE
2.	Lokhandwala	ELE
3.	DN Nagar	ELE
4.	Andheri Metro	ELE
5	Weh	ELE
6.	Chakala	ELE
7.	JB nagar	ELE
8.	Marol Naka	ELE
9.	Saki Naka	ELE
10.	Santosh Nagar	ELE
11.	Alalapha	ELE
12.	Ghatkopar	ELE

7.3 TRAIN OPERATION PLAN

- The salient features of the proposed train operation plan are:

  - Running of services for 19 hours of the day (5 AM to Midnight) with a station dwell time of 30 seconds,
  - Make up time of 5-10% with 8-12% coasting.
  - Scheduled speed of 32 kmph.

7.3.1 Traffic Demand

Peak hour peak direction traffic demands (PHPDT) for different years for the purpose of planning are indicated in the **Table 7.2**.

TABLE 7.2
Peak hour peak direction traffic (PHPDT) Demand

LINE – 1	YEAR		
	2011	2021	2031
Varsova – Andheri - Ghatkopar Corridor	31126	39316	50912
Considering 60% traffic demand for stand alone section	15563	23590	30547

The above demand precludes use of Light Rail Vehicle. Considering the future expected population increase in a city like Mumbai, the use of Mass Rapid Transit Rail Vehicle of medium capacity has been considered.

7.3.2 Train formation

To meet the above projected traffic demand, the possibility of running trains with composition of 4 car, 6 car, and 8 car with different headway of 2 minutes to 15 minutes has been examined .

The basic unit of 4 car train comprising of DTC-MC-MC-DTC similar to Delhi Metro configuration has been selected because of following considerations: -

(I) Availability of Standard design with proven performance.
(II) Matching of varying hourly traffic demand with Passenger Carrying Capacity of Trains having 4 car or 6 car composition for different headways.

7.3.2.1 Composition

Car composition adopted for year 2011, 2021 & 2031 is given in **Fig 7.1 & 7.2**

4 Car Train Composition DTC + MC + MC + DTC
6 Car Train Composition DTC + MC + TC + MC + MC + DTC
8 Car Train Composition DTC + MC + TC + MC +TC+ MC + MC + DTC

DTC : Driving Trailer Car
MC : Motor Car
TC : Trailer Car

7.3.2.2Capacity

DTC : 282 passenger (Sitting-43, Crush Standing –239)
TC /MC : 307 passenger (Sitting-50, Crush Standing –257)
4 Car Train ; 1178 passenger (Sitting-186,Crush Standing –992)
6 Car Train : 1792 passenger (Sitting-286, Crush Standing –1506)
8 Car Train : 2408 passenger (Sitting-386, Crush Standing –2020)

The above capacities are @ 6 standees per square meter.

7.3.3 Train Operation Plan

Based on the above consideration, the Train operation plan (headway and train composition) for the year 2011, 2021 and 2031 are given as under-

- **Year 2011**

  The operation on Line 1- Varsova – Andheri - Ghatkopar Corridor is planned with **4-car trains at 5 minutes headway** the first year of operation i.e. **2011** with Peak Hour Peak Direction Capacity of **14136** (Graph-1). The capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on few inter station section, but will avoid excessive under loading on most of the sections.

- **Year 2021**

  The operation on Line 1- Varsova – Andheri - Ghatkopar Corridor is planned with **4-car trains at 4 minutes** headway for the year of operation i.e. **2021** to meet the Peak Hour Peak Direction demand of **23590** (Graph-2). The capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on three inter station sections, but will avoid excessive under loading on most of the sections.

- **Year 2031**

  The operation on Line 1- Varsova – Andheri - Ghatkopar Corridor is planned with **4 - car trains at 3 minutes** headway for the year of operation i.e. **2031** to meet the Peak Hour Peak Direction Demand of **30547** (Graph-3). The capacity planned is less than the peak demand. This optimum capacity decided might slightly cause over crowding on some inter station sections, but will avoid excessive under loading on most of the balance sections.

In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by either varying the rake composition or adjusting the Headway .The PHPDT capacity provided on both the corridors in different years is given in **Table 7.3**

TABLE 7.3
CAPACITY PROVIDED
Varsova – Andheri – Ghatkopar Corridor

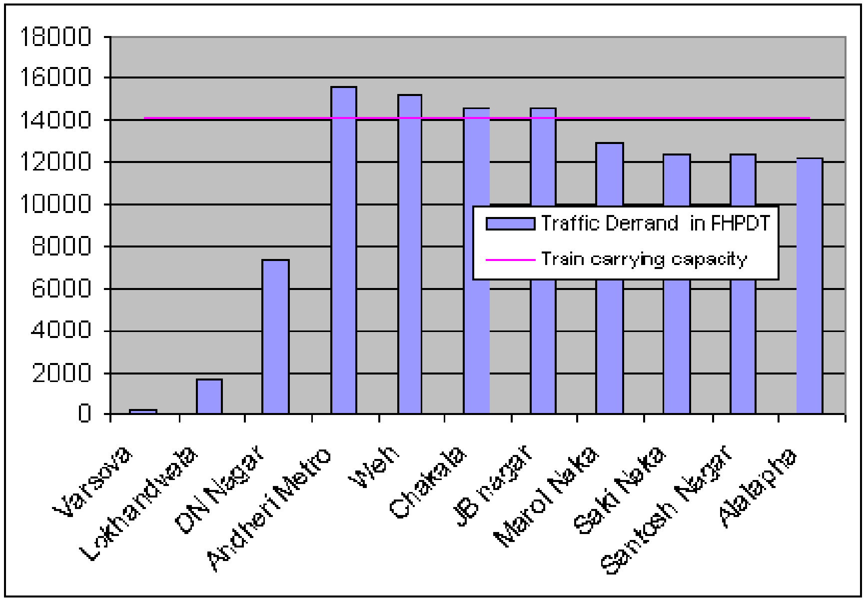
Year	**2011**	**2021**	**2031**
Cars/trains	**4**	**4**	**4**
Head way (Minutes)	**5**	**4**	**3**
PHPDT Demand	**15563**	**23590**	**30547**
PHPDT Capacity Available	**14136**	**17670**	**23560**

Line - 1
Varsova to Ghatkopar Corridor

PHPDT FOR YEAR 2011

4 car train, Headway 4 min

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity
1	Varsova	D N Nagar	183	14136
2	DN Nagar	Azad Nagar	1675	14136
3	Azad Nagar	Andheri	7416	14136
4	Andheri	Weh	15563	14136
5	Weh	Chakala	15242	14136
6	Chakala	Airport Road	14610	14136
7	Airport Road	Marol Naka	14613	14136
8	Marol Naka	Saki Naka	12905	14136
9	Saki Naka	Subhash Nagar	12389	14136
10	Subhash Nagar	Alalapha Road	12389	14136
11	Alalapha Road	Ghatkopar	12223	14136
	TOTAL			



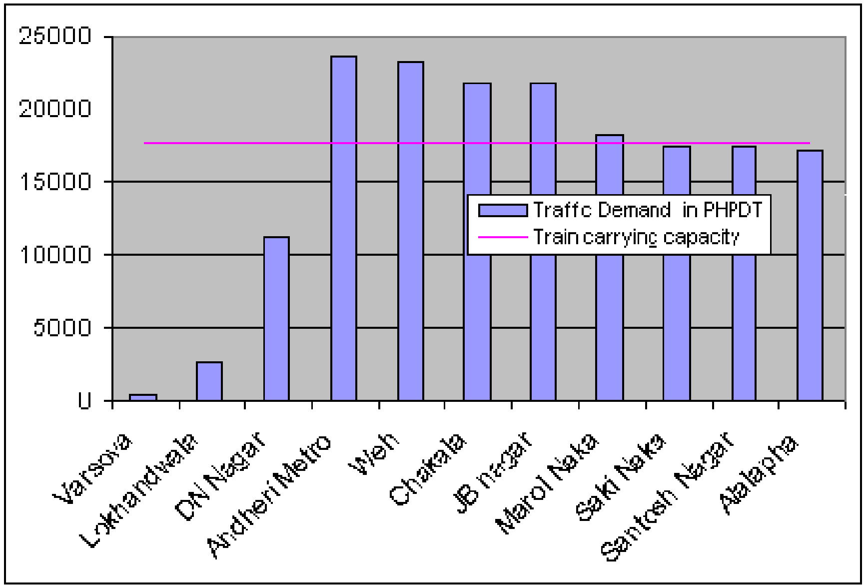
*** Considering 50% traffic demand for stand alone section**
Graph-1

Line - 1
Varsova to Ghatkopar Corridor

PHPDT FOR YEAR 2021

4 car train, Headway 4 min

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity
1	Varsova	DN Nagar	365	17670
2	DN Nagar	Azad Nagar	2642	17670
3	Azad Nagar	Andheri	11342	17670
4	Andheri	Weh	23590	17670
5	Weh	Chakala	23215	17670
6	Chakala	Airport Road	21754	17670
7	Airport Road	Marol Naka	21762	17670
8	Marol Naka	Saki Naka	18224	17670
9	Saki Naka	Subhash Nagar	17410	17670
10	Subhash Nagar	Alalapha Road	17410	17670
11	Alalapha Road	Ghatkopar	17161	17670
	TOTAL			



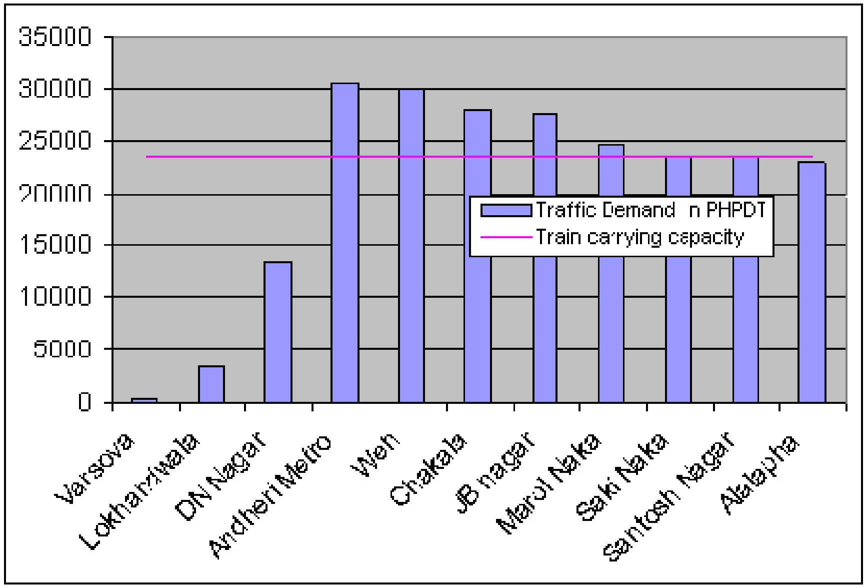
*** Considering 60% traffic demand for stand alone section**
Graph-2

Line - 1
Varsova to Ghatkopar Corridor

PHPDT FOR YEAR 2031

4 car train, Headway 4 min

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity
1	Varsova	DN Nagar	430	23560
2	DN Nagar	Azad Nagar	3348	23560
3	Azad Nagar	Andheri	13525	23560
4	Andheri	Weh	30547	23560
5	Weh	Chakala	30051	23560
6	Chakala	Airport Road	27960	23560
7	Airport Road	Marol Naka	27696	23560
8	Marol Naka	Saki Naka	24523	23560
9	Saki Naka	Subhash Nagar	23486	23560
10	Subhash Nagar	Alalapha Road	23486	23560
11	Alalapha Road	Ghatkopar	23026	23560
	TOTAL			



*** Considering 60% traffic demand for stand alone section**

Graph-3

7.3.4 Train frequency

a) The train operation plan provides for 5-minute headway during peak hours and 15 minutes headway during lean hours to keep the services attractive in the year 2011.

b) In the year 2021, train headway is planned at 4 minutes during peak hours and 12 minutes during lean hours.

c) Peak time train headway is proposed to be reduced to 3 minutes in the year 2031 while lean time headway is kept at 10 minutes.

d) No, services are proposed between 00.00 hrs. to 5.00 hrs. which are reserved for maintenance of infrastructure and rolling stock.

7.3.5 Hourly Train Operation plan

The hourly distribution of daily transport capacity and the directional split is presented in **Table 7.4, 7.5 and 7.6** for years **2011, 2021 and 2031** respectively.

The number of trains proposed to be operated daily during different hours in each direction for the year 2011 (first year of operation) for each section of the network is presented in **Table 7.7**

The number of trains proposed to be operated daily for each section for the year 2021 and 2031 is presented in **Table 7.8 & 7.9** respectively.

7.3.6 Hourly capacity

Based on daily train operation plan, figures of Peak Hour Peak direction capacity have been worked out for every hour of the day for operation in year 2011, 2021 and 2031. Peak Hour Peak direction capacity have been indicated for every hour of day for line 1 in **Table 7.10, 7.11 & 7.12.**

TABLE 7.4

Hourly Distribution of Transport Capacity and Directional Split
(YEAR - 2011)
4 Car, 5 Minutes Headway

Time of Day	% of Daily Traffic Capacity	Directional Split	
		To Ghatkoper	To Versova
5 to 6	3.09%	55%	45%
6 to 7	3.70%	55%	45%
7 to 8	**6.17%**	**55%**	**45%**
8 to 9	**7.41%**	**55%**	**45%**
9 to 10	**7.41%**	**55%**	**45%**
10 to 11	**7.41%**	**55%**	**45%**
11 to12	**6.17%**	**55%**	**45%**
12 to 13	3.70%	55%	45%
13 to 14	3.70%	55%	45%
14 to 15	3.70%	55%	45%
15 to 16	3.70%	55%	45%
16 to 17	**6.17%**	**55%**	**45%**
17 to 18	**7.41%**	**55%**	**45%**
18 to 19	**7.41%**	**55%**	**45%**
19 to 20	**7.41%**	**55%**	**45%**
20 to 21	**6.17%**	**55%**	**45%**
21 to 22	3.70%	55%	45%
22 to 23	3.09%	55%	45%
23 to 24	2.47%	55%	45%

TABLE 7.5

Hourly Distribution of Transport Capacity and Directional Split
(YEAR - 2021)
4 Car, 4 Minutes Headway

Time of Day	% of Daily Traffic Capacity	Directional Split	
		To Ghatkoper	To Versova
5 to 6	2.58%	53%	47%
6 to 7	3.09%	53%	47%
7 to 8	**6.19%**	**53%**	**47%**
8 to 9	**7.73%**	**53%**	**47%**
9 to 10	**7.73%**	**53%**	**47%**
10 to 11	**7.73%**	**53%**	**47%**
11 to12	**6.19%**	**53%**	**47%**
12 to 13	3.09%	53%	47%
13 to 14	3.09%	53%	47%
14 to 15	3.09%	53%	47%
15 to 16	3.09%	53%	47%
16 to 17	**6.19%**	**53%**	**47%**
17 to 18	**7.73%**	**53%**	**47%**
18 to 19	**7.73%**	**53%**	**47%**
19 to 20	**7.73%**	**53%**	**47%**
20 to 21	**6.19%**	**53%**	**47%**
21 to 22	5.15%	53%	47%
22 to 23	3.09%	53%	47%
23 to 24	2.58%	53%	47%

TABLE 7.6

Hourly Distribution of Transport Capacity and Directional Split
(YEAR - 2031)
4 Car, 3 Minutes Headway

Time of Day	% of Daily Traffic Capacity	Directional Split	
		To Ghatkoper	To Versova
5 to 6	2.65%	52%	48%
6 to 7	4.42%	52%	48%
7 to 8	**5.31%**	**52%**	**48%**
8 to 9	**6.64%**	**52%**	**48%**
9 to 10	**8.85%**	**52%**	**48%**
10 to 11	**6.64%**	**52%**	**48%**
11 to12	**5.31%**	**52%**	**48%**
12 to 13	4.42%	52%	48%
13 to 14	4.42%	52%	48%
14 to 15	4.42%	52%	48%
15 to 16	4.42%	52%	48%
16 to 17	**5.31%**	**52%**	**48%**
17 to 18	**6.64%**	**52%**	**48%**
18 to 19	**8.85%**	**52%**	**48%**
19 to 20	**6.64%**	**52%**	**48%**
20 to 21	**5.31%**	**52%**	**48%**
21 to 22	4.42%	52%	48%
22 to 23	2.65%	52%	48%
23 to 24	2.65%	52%	48%

TABLE 7.7

Hourly Train operation plan
(YEAR - 2011)
4 Car, 5 Minutes Headway

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	12	5	5
6 to 7	10	6	6
7 to 8	**6**	**10**	**10**
8 to 9	**5**	**12**	**12**
9 to 10	**5**	**12**	**12**
10 to 11	**5**	**12**	**12**
11 to12	**6**	**10**	**10**
12 to 13	10	6	6
13 to 14	10	6	6
14 to 15	10	6	6
15 to 16	10	6	6
16 to 17	**6**	**10**	**10**
17 to 18	**5**	**12**	**12**
18 to 19	**5**	**12**	**12**
19 to 20	**5**	**12**	**12**
20 to 21	**6**	**10**	**10**
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
Total No. of trains per direction per day		**162**	**162**

Rake formation : 4 cars

TABLE 7.8

Hourly Train operation plan
(YEAR - 2021)
4 Car, 4 Minutes Headway

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	12	5	5
6 to 7	10	6	6
7 to 8	**5**	**12**	**12**
8 to 9	**4**	**15**	**15**
9 to 10	**4**	**15**	**15**
10 to 11	**4**	**15**	**15**
11 to12	**5**	**12**	**12**
12 to 13	10	6	6
13 to 14	10	6	6
14 to 15	10	6	6
15 to 16	10	6	6
16 to 17	**5**	**12**	**12**
17 to 18	**4**	**15**	**15**
18 to 19	**4**	**15**	**15**
19 to 20	**4**	**15**	**15**
20 to 21	**5**	**12**	**12**
21 to 22	6	10	10
22 to 23	10	6	6
23 to 24	12	5	5
Total No. of trains per direction per day		**194**	**194**

Rake formation : 4 cars

TABLE 7.9

Hourly Train operation plan
(YEAR - 2031)
4 Car, 3 Minutes Headway

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	10	6	6
6 to 7	6	10	10
7 to 8	**5**	**12**	**12**
8 to 9	**4**	**15**	**15**
9 to 10	**3**	**20**	**20**
10 to 11	**4**	**15**	**15**
11 to12	**5**	**12**	**12**
12 to 13	6	10	10
13 to 14	6	10	10
14 to 15	6	10	10
15 to 16	6	10	10
16 to 17	**5**	**12**	**12**
17 to 18	**4**	**15**	**15**
18 to 19	**3**	**20**	**20**
19 to 20	**4**	**15**	**15**
20 to 21	**5**	**12**	**12**
21 to 22	6	10	10
22 to 23	10	6	6
23 to 24	10	6	6
Total No. of trains per direction per day		**226**	**226**

Rake formation : 4 cars

TABLE 7.10
Hourly Capacity Provided
(YEAR - 2011)
4 Car, 5 Minutes Headway

Time of Day	No of Trains per Hour	PHPDT capacity Available
5 to 6	5	5890
6 to 7	6	7068
7 to 8	**10**	**11780**
8 to 9	**12**	**14136**
9 to 10	**12**	**14136**
10 to 11	**12**	**14136**
11 to12	**10**	**11780**
12 to 13	6	7068
13 to 14	6	7068
14 to 15	6	7068
15 to 16	6	7068
16 to 17	**10**	**11780**
17 to 18	**12**	**14136**
18 to 19	**12**	**14136**
19 to 20	**12**	**14136**
20 to 21	**10**	**11780**
21 to 22	6	7068
22 to 23	5	5890
23 to 24	4	4712

TABLE 7.11
Hourly Capacity Provided
(YEAR - 2021)
4 Car, 4 Minutes Headway

Time of Day	No of Trains per Hour	PHPDT capacity Available
5 to 6	5	5890
6 to 7	6	7068
7 to 8	**12**	14136
8 to 9	**15**	17670
9 to 10	**15**	17670
10 to 11	**15**	17670
11 to12	**12**	14136
12 to 13	6	7068
13 to 14	6	7068
14 to 15	6	7068
15 to 16	6	7068
16 to 17	**12**	14136
17 to 18	**15**	17670
18 to 19	**15**	17670
19 to 20	**15**	17670
20 to 21	**12**	14136
21 to 22	10	11780
22 to 23	6	7068
23 to 24	5	5890

TABLE 7.12
Hourly Capacity Provided
(YEAR - 2031)
4 Car, 3 Minutes Headway

Time of Day	No of Trains per Hour	PHPDT capacity Available
5 to 6	6	7068
6 to 7	10	11780
7 to 8	**12**	14136
8 to 9	**15**	17670
9 to 10	**20**	23560
10 to 11	**15**	17670
11 to12	**12**	14136
12 to 13	10	11780
13 to 14	10	11780
14 to 15	10	11780
15 to 16	10	11780
16 to 17	**12**	14136
17 to 18	**15**	17670
18 to 19	**20**	23560
19 to 20	**15**	17670
20 to 21	**12**	14136
21 to 22	10	11780
22 to 23	6	7068
23 to 24	6	7068

7.3.7 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for year 2011, 2021 and 2031 are given in **Table 7.13**

TABLE 7.13
Vehicle Kilometer
(I) Line 1-Varsova to Ghatkopar Corridor

Year	**2011**	**2021**	**2031**
Section Length	12	12	12
No of cars per Train	4	4	4
No of working Days in a year	340	340	340
Number of Trains per day each Way	162	194	226
Daily Train -KM	3888	4656	5424
Annual Train - KM (10^5)	13.22	15.83	18.44
Annual Vehicle - KM (10^5)	**52.88**	**63.32**	**73.77**

7.4 Year wise rake Requirement

Based on Train formation and headway as decided above to meet Peak Hour Peak Direction Traffic Demand in different years, Rake requirement has been tabulated in **Table 7.14**

Requirements of coaches for Line 1 – Varsova - Andheri-Ghatkopar Section is calculated based on following assumptions-

Assumptions -

1. Train Composition planned as under
   4Car Train Composition DTC + MC + MC + DTC
   6 Car Train Composition DTC + MC + TC + MC + MC + DTC
2. Train Capacity DTC = 282 (Passengers)
   MC/ TC = 307 (passengers)
   4 Car Train = 1178 passengers
   6 Car Train = 1792 passengers
3. Coach requirement has been calculated based on headway during Peak hours.

Mumbai Metro
Table –7.14
Rake Requirement
LINE - 1 (Varsova-Andheri-Ghatkopar Corridor)

Train Capacity	**4 Car**	**1506**	**1178**
	6 Car	**2290**	**1792**
	8 Car	**3074**	

Assumed Schedule Speed 32 kmph

Year 2011

Section	DISTANCE KMS	PHPDT			HEADWAY MIN	RAKE REQUIREMENT			TOTAL No of Rakes	RAKE CONSIST	NO OF CARS
		Projected Max. PHPDT demand	Train Capacity	Maximum PHPDT capacity available		BARE	TRAFFIC RESERVE	R&M			
Varsova-Andheri-Ghatcopar	12	18675.6	1178	**14136**	5	11	1	2	**14**	4 Car	56

Year 2021

Section	DISTANCE KMS	PHPDT			HEADWAY MIN	RAKE REQUIREMENT			TOTAL No of Rakes	RAKE CONSIST	NO OF CARS
		Projected Max. PHPDT demand	Train Capacity	Maximum PHPDT capacity available		BARE	TRAFFIC RESERVE	R&M			
Varsova-Andheri-Ghatcopar	12	23589.6	1178	**17670**	4	13	1	2	**16**	4 Car	64

Year 2031

Section	DISTANCE KMS	PHPDT			HEADWAY MIN	RAKE REQUIREMENT			TOTAL No of Rakes	RAKE CONSIST	NO OF CARS
		Projected Max. PHPDT demand	Train Capacity	Maximum PHPDT capacity available		BARE	TRAFFIC RESERVE	R&M			
Varsova-Andheri-Ghatcopar	12	30547.2	1178	**23560**	3	17	1	2	**20**	4 Car	80

Year	2011	2021	2031
Headway	5	4	3
Cars Reqd	56	64	80
Rakes Reqd	14	16	20

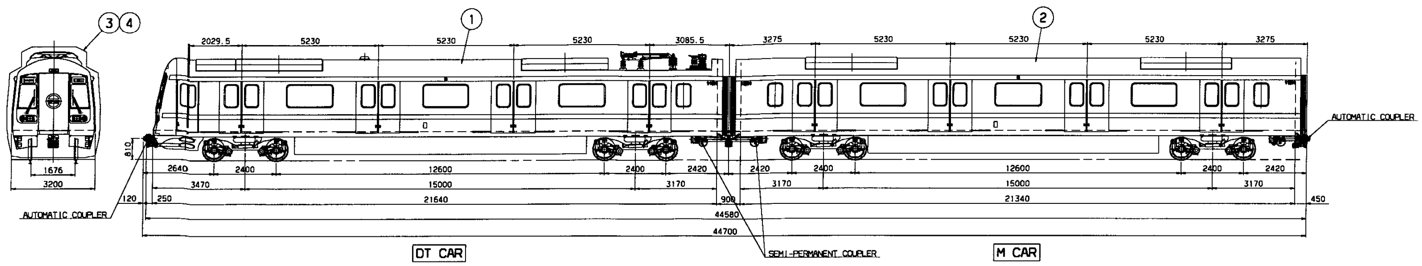
Assumption: Schedule speed is taken as 32 kmph because of sharp curves and steep gradients and being !M+1T combination
Turn round time is taken as 6 min per trip

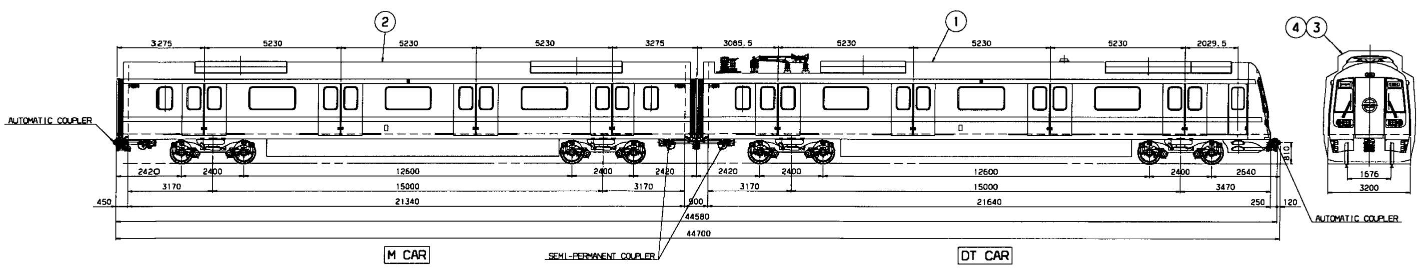
4. Traffic reserve is taken as one train per section to cater to failure of train on line and to make up for operational time lost.
5. Repair and maintenance has been estimated as 8 % of total requirement (Bare +Traffic Reserve) based on IOH & POH interval of 3 and 6 years.
6. The calculated number of rakes in fraction is rounded off to next higher number.
7. Schedule speed is taken as 32 Kmph because of presence of Sharp curves and steep gradients
8. Turn round time is taken as 3 min at terminal stations.

7.5 Cost Estimate

For estimation of cost per coach, cost of DMRC EMU has been taken as reference because the coach planned for Mumbai Metro is of the same size. For DMRC, 60 coaches have been imported and 180 coaches are planned for assembling / manufacturing in BEML, Bangalore. Accordingly various venders for Electrical Systems, PA/PIS, Air conditioner etc are being developed .It is expected that with little investment BEML may become a Centre for assimilation of technology for design & manufacture of modern metro rolling stock and will be able to manufacture and supply coaches for future metros.

Accordingly cost for coaches of Mumbai metro has been worked out assuming that certain sub-system and assemblies will be manufactured indigenously in India and partial components will be imported. In case coaches are to be imported the cost may vary. The cost estimate is given in chapter 10.

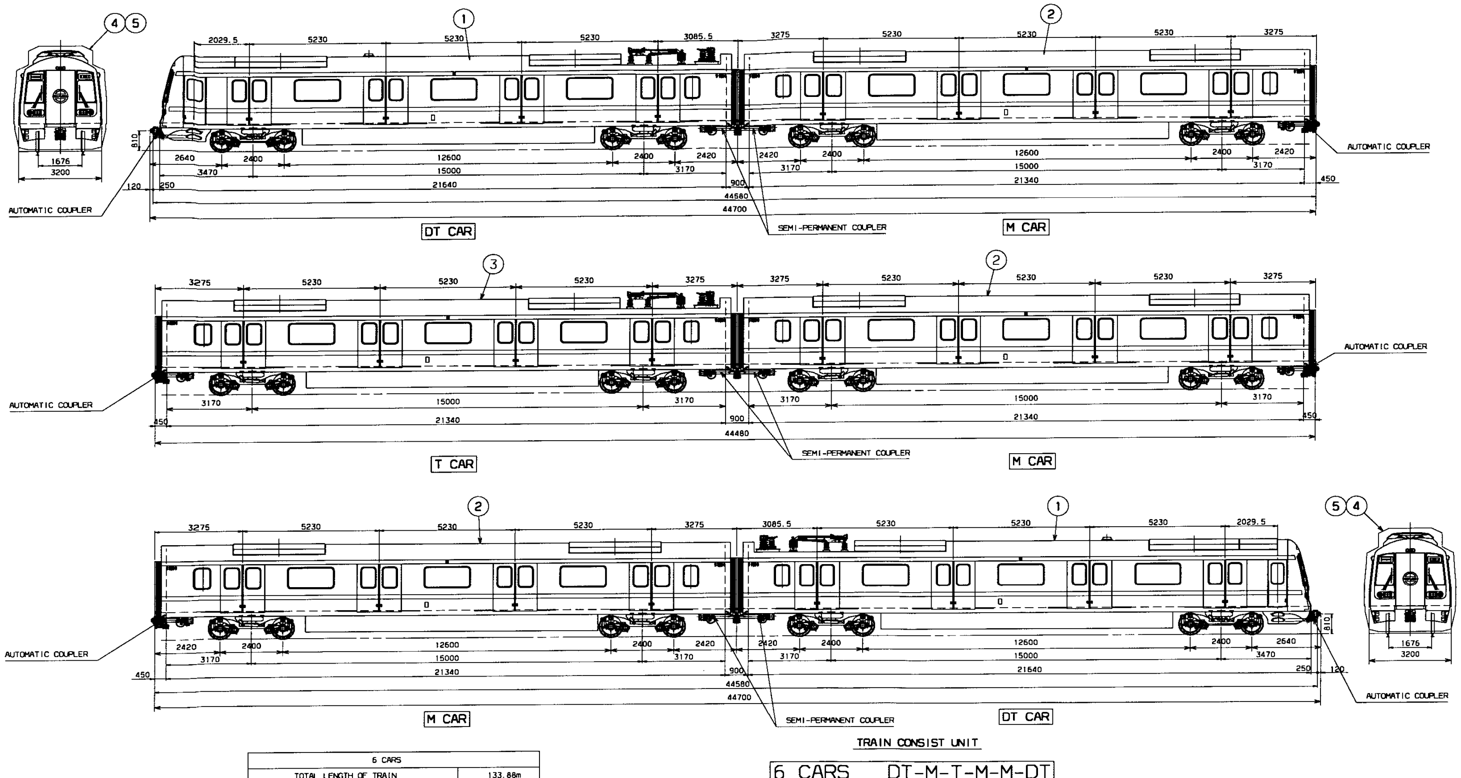




4 CARS		
TOTAL LENGTH OF TRAIN		89.4m
TOTAL PASSENGER CAPACITY	SEATED	186 PERSONS
	STANDEES(8PERSONS/m²)	1320 PERSONS
	TOTAL	1506 PERSONS

TRAIN CONSIST UNIT

4 CARS	DT-M-M-DT



6 CARS		
TOTAL LENGTH OF TRAIN		133.88m
TOTAL PASSENGER CAPACITY	SEATED	286 PERSONS
	STANDEES(8PERSONS/m²)	2004 PERSONS
	TOTAL	2290 PERSONS

M&P recommended list for Depot for VARSOVA – ANDHERI – GHATKOPER SECTION

Sr No.	Equipment
1	Under floor Pit wheel lathe withChip crusher and conveyor for lathe on pit. &Winch capstan for under floor wheel lathe
2	Synchronized pit jacks for two car lifting consisting of 8 jack system with Mobile lifting jacks-12& 15T
3	Turntable for bogies
4	Automatic Washing plant for Metro cars.
5	Diesel Shunting Engine
6	Electric bogie tractor for pulling cars and bogies inside workshop
7	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc
8	Cherry picker/ Snorkel. High lift platform type vehicle to rach viaduct and OHE from road
9	Turn table for one car
10	Accommodation bogie 2 car sets for Metro Cars
11	Jib Crane
12	Mobile portal type A,B & Jib Crane,Mobilejib crane (overhang type)
13	Car body stands
14	Underframe & Bogie blowing plant
15	Vertical carousel storage system
16	Bogie cleaning plant
17	Rail fed Bogie wash plant
18	Ultrasonic cleaning tank
19	Ultrasonic machine for cleaning electronic equipment
20	Welding equipments (Mobilewelding, oxyacetelene, fixed arc welding)
21	Set of machine tools(one radial drilling machine, one universal milling machine, two slide lathes, one panel sawing machine, one guillotine shears, one cutting machine.
22	Mobile safety steps
23	Mobile lifting table
24	Work lift platform
25	Fork lift tractor
26	Pallet trucks
27	Minor equipment and collective tools
28	Electric and pneumatic tools
29	Measuring and testing equipment
30	Axle shaft inspection station
31	Tool kits
32	Floor cleaning machine
33	EMU battery charger
34	Battery Charger (for road vehicles)
35	Water de-mineralizing plant (Distillation plant)
36	Bearing puller & press
37	Road vehicles (pickup van/ truck)
38	Industrial furniture
39	Storage racks
40	High-pressure washing pump for front and rear end cleaning of cars.
41	Simulator with 3 degrees of freedon on motion for the modern rolling stock, to train the drivers.
42	Cleaning booth for TM
43	Transformer oil purification plant

44	Painting booth for separate parts
45	Induction heater
46	Vertical boring machine
47	Press for wheel fitting and removal
48	Wheel lathe
49	Axle journal turning and burnishing lathe
50	Special jigs and fixtures and test benches for Rolling stock

CHAPTER 8

POWER SUPPLY ARRANGEMENTS

8.1 POWER RE UIREMENTS

Power supply is the lifeline of Metro System

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signalling & telecom, fire fighting etc), workshops & depots and other maintenance infrastructure within premises of metro system. The power requirements of a metro system are determined by peak-hour demands of power for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following requirements: -

(i) Specific energy consumption of rolling stock – 70KWh/1000 GTKM
(ii) Regeneration by rolling stock – 30%
(iii) Elevated/at –grade station load – initially 250KW, which will increase to 350 KW in the year 2031
(iv) Depot auxiliary load - initially 2000KW, which will increase to 2500 KW in the year 2031.

Keeping in view the train operation plan the demand of auxiliary and traction power, power requirements projected for the year 2011, 2021 and 2031 are summarized in **Table 8.1** below: -

Table 8.1
Power Demand Estimation (MVA)

Corridor		**Year**		
		2011	**2021**	**2031**
Versova – Ghatkopar section	Traction	7	9	12
	Auxiliary	6	8	9
	Total	**13**	**17**	**21**

The detailed calculations of power demand estimation are attached at **Annexure 8.1.**

8.2 NEED FOR HIGH RELIABILITY OF POWER SUPPLY

The proposed Mumbai metro system is being designed to handle about 60,000 passengers per direction during peak hours when trains are expected to run at 3 minutes intervals. Incidences of any power interruption, apart from affecting train running, will cause congestion at stations. Interruption of power at night is likely to cause alarm and increased risk to traveling public. Lack of illumination at stations, non-visibility of appropriate signage, disruption of operation of lifts and escalators is likely to cause confusion, anxiety and ire in commuters, whose tolerance level are low on account of stress. Effect on signal and communication may affect train operation and passenger safety as well. Therefore, uninterrupted power supply is mandatory for efficient metro operations.

To ensure reliability of power supply, it is essential that both the sources of Supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 132 or 66kV or 33kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority itself.

8.3 SOURCES OF POWER SUPPLY

The high voltage power supply network of Mumbai city was studied in brief. The city has 220kV, 33/22kV and 11kV network to cater to various types of demand in vicinity of the proposed corridor. Series of meetings were held with M/s Reliance Energy Limited (Licensee of the area) to finalise the Input Power Supply sources & Supply Voltage.

M/s Reliance indicated during discussions that their 33kV network is also highly reliable and MRVC is also taking power at 33/22 kV for setting up 25kV Traction Sub-stations. Taking power at 220kV voltage level will not be economical, when 33kV supply meets reliability requirements. Keeping in view the reliability requirements, two 33/25kV Receiving Sub-stations (one as stand by) are proposed to be set up (one at depot and other at Marol Naka). This is an economical solution without compromising reliability. Based on the discussions with Reliance Energy Ltd., it is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations at 33kV voltage through cable feeders as indicated in **Table 8.2.**

Table 8.2
Sources of Power Supply

S. No	Corridor	Grid sub-station of Reliance Energy Ltd. (Input voltage)	Location of RSS of Metro Authority	Approx. length of 33kV cables
1.	Versova - Ghatkopar section	Versova Receiving sub-station (220/33kV)	Depot	1km. (Double circuit)
2.		Arrey Receiving sub-station (220/33kV)	Marol Naka	3km. (Double circuit)

The summary of expected power demand at various sources is given in **Table 8.3.** M/s Reliance Energy Ltd have confirmed availability of requisite power and 2x 33kV bays at their above sub-stations vide letter no. Mktg/SCZ/3350/2004 dated 13.09.2004 **(Annexure 8.2)**

Table 8.3
Power Demand projections for various sources

Corridor	Input Source	Peak demand – Normal (MVA)		Peak demand* – Emergency (MVA)	
		Initial Year (2011)	Year (2031)	Initial Year (2011)	Year (2031)
Versova Ghatkopar section	Versova RSS				
	Traction	4	7	7	12
	Auxiliary	3	5	6	9
	Sub-total (A)	**7**	**12**	**13**	**21**
	Arrey RSS				
	Traction	3	5	7	12
	Auxiliary	3	4	6	9
	Sub-total (B)	**6**	**9**	**13**	**21**
	TOTAL (A B)	**13**	**21**	**13**	**21**

* Incase of failure of other source of power

The 33kV power supply will be stepped down to 25kV single phase for traction purpose at the two RSSs of metro authority and the 25kV traction supply will be fed to the OHE at viaduct through cable feeders. The 33kV power supply received directly from Reliance Energy RSS will be distributed along the alignment through 33kV Ring main cable network for feeding auxiliary loads (Refer power supply schematic drawings no. BM/PS/GA/001/R0). These cables will be laid in dedicated ducts along the viaduct. If one RSS trips on fault or input supply failure, train services can be maintained from other RSS. A 25kV power supply link is proposed between the Metro and Western Railway at Andheri SSP as shown in the drawing. This link will be used to pull trains to various stations when both the RSSs fail. However, in case of total grid failure, all trains may come to a halt but station lighting & other essential services can be catered to by stand-by DG sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well.

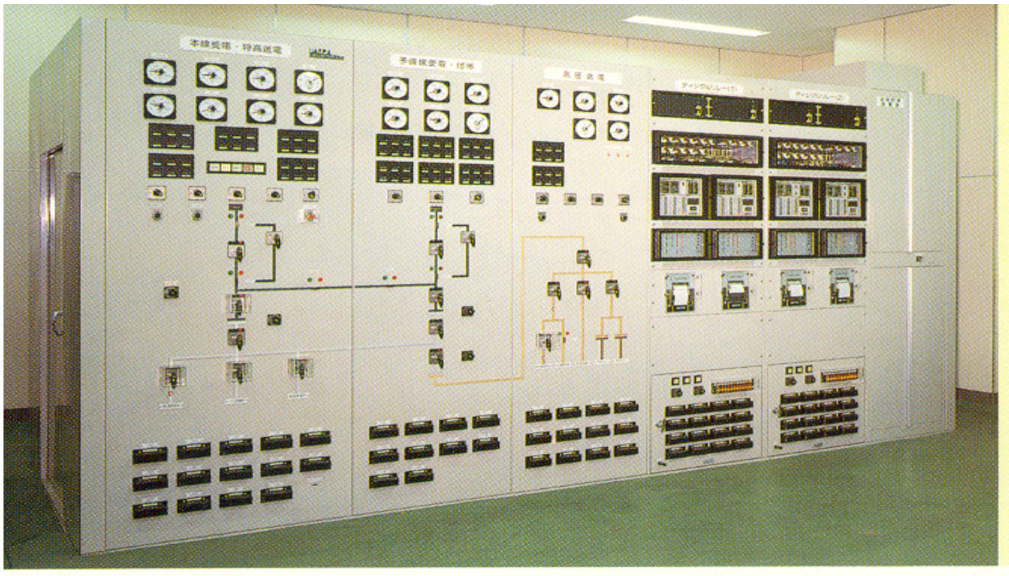
Typical High Voltage Receiving Sub-station

The 33kV cables will be laid through public pathways from Reliance Energy Sub-stations to RSSs of Metro Authority. Each RSS shall be provided with 2 nos. (one as standby) 33/25kV, 21.6 MVA single phase traction transformers for feeding to traction loads, being the standard design. This arrangement would also ensure that the system caters to additional power supply requirements in case of likely extensions of the corridors at either end. Depot RSS can also be used for feeding 25kV traction supply to Charkop - Colaba corridor.

Indoor type 33kV switchgear and outdoor type 25kV switchgear is proposed for each RSS to be located in approx. 50m x 50m (2500 sq. m) land plot. Gas Insulated Switchgear (GIS), though requires less space (approximately half) & reduced maintenance, is not proposed because of high capital cost.

8.4 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS & DEPOT

Auxiliary sub-stations (ASS) are to be provided at each station. A separate ASS is required at depot. The ASS will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 350 kW for elevated stations. Accordingly, two dry type cast resin transformers (33/0.415kV) of 400 kVA capacity are proposed to be installed at the stations (one transformer as standby). Depot ASS will also be provided with 2x2000 kVA auxiliary transformers.



Typical Indoor Auxiliary Sub-station

8.5 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

25kV ac traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Booster Transformer and Return Conductor (BT/RC) System is proposed for EMI mitigation. Concrete structures of elevated viaducts are not good electrical earths and therefore, Earthing and Bonding of the traction system shall be in accordance with the latest standards EN50122-1, IEEE80 and other relevant standards. Two earth conductors – Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC), are proposed to be laid along with elevated via duct and all the metallic structures, structural reinforcement, running rails etc will be connected to these conductors to form an equiv-potential surface & a least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25kV OHE and the elevated viaduct. Similar arrangements have been adopted on Delhi Metro as well.

Detailed specifications of equipments e.g. power cables, transformer, switchgear, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecomm, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.

8.6 RATING OF MAJOR E UIPMENT

25kV ac Overhead Equipment (OHE) shall comprise 150sqmm HD-copper contact wire and 65 sq. mm Cd-copper catenary wire. Return conductor (RC) shall be All Aluminum Conductor (AAC) of 233sqmm cross section. From safety considerations, Hydraulic type Anti-Tensioning Device (ATDs) are proposed on mainlines which does not require use of balance weight for tensioning of OHE conductors.

Based on emergency demand expected at each RSS as shown in **Table 8.3**, 2 nos. 33/25kV traction transformers of 21.6 MVA capacity shall be provided at each RSS, being standard design (one to be in service and second one to serve as standby). The 33kV incoming cable shall be 3-phase single core XLPE insulated with 500mm^2 Copper conductor to meet the normal & emergency loading requirements and fault level of the 33kV supply.

33kV and 25kV switchgear shall be rated for 1250 A, being standard design. 33kV cable ring network shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations and accordingly 3 core x 200 mm^2 copper conductor XLPE insulated 33kV cable is proposed for ring main network.

Adequate number of cables are required for transfer of traction power from Metro's RSS to 25kV OHE. Single-phase XLPE insulated cables with 240mm^2 copper conductor are proposed for traction power. Based on current requirements, 2 cables are required for each of the four circuits to feed power to OHE.

The above capacities of transformers, switchgear, cables etc. have been worked out based on the conceptual design. Therefore, these may be reviewed for better accuracy during design stage of project implementation.

8.7 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide a standby DG set of 100 KVA capacity at the stations to cater to the following essential services:

(i) Essential lighting
(ii) Signaling & telecommunications
(iii) Fire fighting system
(iv) Lift operation
(v) Fare collection system

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

8.8 SUPERVISORY CONTROL AND DATA AC UISITION (SCADA) SYSTEM

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fibre provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 33kV ac switchgear, transformers, 25kV ac switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

8.9 ENERGY SAVING MEASURES

Energy charges of any metro system constitute a substantial portion of its operation & maintenance (O & M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement during initial years of operation. Subsequently, traction power consumption increases with increase in train frequency/composition in order to cater more traffic. The proposed system of Mumbai Metro includes the following energy saving features:

(i) Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.

(ii) Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25kV ac OHE to be consumed by nearby trains.

(iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100% of load) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc).

(iv) Machine-room less type lifts with gearless drive have been proposed with 3-phase VVVF drive. These lifts are highly energy efficient.

(v) The proposed heavy-duty public services escalators will be provided with 3-phase VVVF drive, which is energy efficient & improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by passengers.

(vi) The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc) have been incorporated in the system design.

(vii) Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

8.10 ELECTRIC POWER TARIFF

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25-35% of total annual working cost. Therefore, it is the key element for the financial viability of the Project. The annual energy consumption is assessed to be about 30 million units in initial years (2011), which will double by horizon year 2031. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff be kept at a minimum in order to contain the O& M costs. Therefore, the power tariff for Mumbai Metro should be at effective rate of purchase price (at 33kV voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. This is expected to be in the range of Rs. 2.50-2.75 per unit. It is proposed that Government of Maharashtra takes necessary steps to fix power tariff for Mumbai Metro at “No Profit No Loss” basis. Financial analysis has been carried out based on this tariff (Rs. 2.75 per unit) for the purpose of finalizing the DPR. Similar approach has been adopted for Delhi Metro.

Annexxure 8.1

POWER RE UIREMENTS	VERSOVA - GHATKOPAR SECTION		
	Year 2011	**Year 2021**	**Year 2031**
Traction power requirements			
Motor coach-tare weight	42T	42T	42T
Motor coach-passenger carrying capacity	392	392	392
Trailer coach-tare weight	42T	42T	42T
Trailer coach-passenger carrying capacity	361	361	361
No of cars	4(2M+2T)	4(2M+2T)	4(2M+2T)
Passenger weight	97.9T	97.9T	97.9T
Total Train weight	263.9T	263.9T	263.9T
Section length	11.07KM	11.07KM	11.07KM
Headway	5.0mts	4.0mts	3.0mts
Specific Energy consumption	70 KWhr/1000 GTKM	70 KWhr/1000 GTKM	70 KWhr/1000 GTKM
No. of trains/hr in both directions	24	30	40
Peak traction power requirement	6.7MW	8.3MW	11.1MW
Less Regeneration @30%	2.0MW	2.5MW	3.3MW
Depot power requirements	2.0MW	2.5MW	3.5MW
Total traction power requirement	6.7MW	8.3MW	11.3MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf	**7MVA**	**9MVA**	**12MVA**
Station aux power requirements			
Elevated/at-grade station--power consumption	0.25MW	0.30MW	0.35MW
No. of elevated/at-grade stations	12	12	12
Total Station Aux Power requirement	3.0MW	3.6MW	4.2MW
Depot Aux power requirement	2.0MW	2.50MW	3.0MW
Total Aux Power requirement	5.0MW	6.10MW	7.2MW
Total aux power requirement (MVA) assuming 5% energy losses and .85 pf	**6MVA**	**8MVA**	**9MVA**
Total traction & aux power requirement (MVA)	**13MVA**	**17MVA**	**21MVA**

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Mumbai 400 055

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www.rel.co.in

Mktg/SCZ/3350/2004

13th September,2004

Mr. Anil Kumar,
Dy Chief Engineer,
Delhi Metro Rail Corporation,
NBCC Place,
Bhisma Pitamah Marg,
Pragati Vihar,
New Delhi 110003.
Sir,

Sub: Power supply for the proposed Mumbai Metro's Phase I.

Thank You for your visit to our office on Monday 6th Sept 04 along with Mr. Gangurde of MMRDA.

As discussed we shall be in a position to supply you your complete requirements of power for construction ,commercial and traction purposes.

As desired two bays each of 20 MVA at 33 kV will be provided for the purpose at our 220kV/33kV Receiving Stations at Versova and Aarey.

We understand that your power requirements will be as below:

Year	Load	Location
2008	20 MVA	Versova and Aarey
2015	25 MVA	Versova and Aarey
2021	40 MVA	Versova and Aarey

We also understand that the 33KV three phase power supply will be converted to 25 kV single phase AC at your end. During the meeting you indicated that your electrical distribution system will be designed to address the issue of unbalanced loading. However, you are requested to provide us the detailed information in order to enable us to work out our protection system.

On receipt of your confirmation, we shall finalise the terms and conditions of supply.

We look forward to an ongoing and mutually beneficial relationship.

Thanking You,

Yours truly,

Suresh Malkani 13/9

Suresh Malkani.

Registered Office Reliance Energy Centre, Santa Cruz (E), Mumbai 400 055

Energy is life

Chapter – 9

ENVIRONMENTAL IMPACT ASSESSMENT

9.1 ENVIRONMENTAL BASELINE DATA

The main aim of the study is to ascertain the existing baseline conditions and assess the impacts of all the factors as a result of the proposed corridor during its operation and construction in phases. The changes likely to occur in different components of the environment viz. Natural Physical Resources, Natural Ecological (or Biological) Resources, Human/Economic Development Resources (Human use values), Quality of life values (socio-economics), would be studied and assessed to a high degree of accuracy. The area of study include Hydrology, Surface Water Quality, Air Quality, Soils, Noise, Geology, Socio- economics, archaeological /historical monuments etc.

The information presented in this section stems from various sources such as reports, field surveys and monitoring. Majority of data on water quality, vegetation, and air and noise quality was collected during field studies in June 2004 & September 2004. This data has been further utilized to assess the incremental impact if any due to the project. The development / compilation of environmental baseline data is essential to assess the impact on environment due to the project. The study area is the metro corridor from Versova to Ghatkopar.

9.1.1 General Environment

Mumbai (Bombay) is located (Latitude 18'54"N, Longitude 72'49"E) in Maharashtra State and is the principal Indian port on the Arabian Sea. The original city is confined by its island location. Mumbai's central business district, comprising most of the commercial and business centres and government offices, is located in the extreme southern part of the city. Mumbai harbour is to the east of the city. The commercial Fort area lies to the south of the island while the commercial, residential and industrial areas are located north of the Fort area. The mean elevation of Mumbai is 11 m above mean sea level. The metropolis covers an area of 603 km^2 of which Greater Mumbai covers 438 km^2.

Mumbai has a tropical savanna climate; mean humidity ranges between 57-87 per cent. The annual mean temperature is 25.3^oC rising to a monthly maximum of 34.5^oC in June and with a minimum of 14.3^oC in January. Total annual mean precipitation is 2,078 mm with 34 per cent (709 mm) falling in the month of July. Due to the summer monsoons, maximum sunshine occurs in winter (291 hours in January). In the winter the predominant wind direction is northerly (NW-NE). However, in the monsoon season westerly and southerly winds predominate. There is virtually always a sea breeze during the day with mean wind speeds between 5-8 km/hour.

9.1.2 Water and Soil

The water and soil samples have been tested for chemical analysis. The results so obtained are summarised in **Tables 9.1 and Table 9.2.** Most of the parameters are within the permissible limits. It could be concluded that the seawater is having high BOD, COD contents and it also contains the heavy metals. The texture of soil is mainly sandy. The higher concentration of phosphate and organic matter is an indication of good fertility value. As metro will be above ground, it will not be in contact with soil and water. Hence soil and underground water are unlikely to undergo any deteriorating effect due to proposed MRTS structures and foundation.

Table 9.1
CHEMICAL ANALYSIS OF WATER SAMPLES

S. No.	Parameter	Sample Locations			
		Near Andheri station	Near Seven bungalows area	Sea water sample at Varsova	Near Sarvodaya Hospital
1	Total Suspended Solids (mg/l)	5.6	3.8	421.2	3.9
2	BOD (mg/l)	ND	ND	21	<2
3	pH	8.14	7.68	7.85	8.1
4	Chloride, Cl (mg/l)	144	35.96	16000	167.83
5	Total dissolved solids (mg/l)	449	288.94	27009	692.4
6	Sulphate, SO4 (mg/l)	38	14.93	2000	65.67
7	Fluorides (as F) (mg/l)	0.61	0.29	2.12	0.67
8	Nitrates as NO3 mg/l	0.41	18.78	1.47	ND
9	Alkalinity, mg/L	191.81	215.78	100	275.72
10	Total Hardness, mg/L	287.71	267.73	5320	335.66
11	Turbidity	3	2	40	1
12	COD, mg/L	ND	ND	72	4
13	DO, mg/L	7.5	6	4.5	5.3
14	Chromium, mg/L	ND	ND	ND	ND
15	Cadmium, mg/L	ND	ND	0.1	ND
16	Copper, mg/L	ND	ND	0.14	ND
17	Zinc, mg/L	0.18	ND	2.34	0.09
18	Arsenic, mg/L	ND	ND	ND	ND

ND - Not Detectable

Table 9.2
PHYSIO-CHEMICAL CHARACTERISTICS OF SOILS

S.No.	Sample /Parameter	Sampling locations		
		Near Andheri station	Near seven bungalows area/ Varsova	Near Starplus office
1	pH	7.45	8.15	7.85
2	Texture			
	Sand (%)	97.474	93.66	73.59
	Silt (%)	0.16	0.22	14.37
	Clay (%)	2.37	6.12	12.04
3	Nitrogen (kg/hectare)	3134.84	1900	623
4	Phosphorus (kg/ha)	70.15	70.22	30.83
5	K (meq/100gm)	0.8	1.38	1.09
6	Ca (meq/100gm)	15.23	46.3	9.16
7	Mg (meq/100gm)	5.9	4.04	1
8	Na (meq/100gm)	1.31	2.47	2.77
9	Organic matter (%)	5.13	5.64	1.81

Maharashtra Pollution Control Board (MPCB) is monitoring the sea water quality at various locations once in a month including a location at Versova. The characteristics of the sea water quality during 1998-99 (Latest as provided by MPCB) is presented in **Table 9.3** as below:

TABLE 9.3
Characteristics of Sea water quality near Versova monitored by MPCB

S. No	Parameter	Min.	Max.	Average
1	BOD (mg/l)	5	19	**9.95**
2	COD, mg/L	128	348	**235**
3	TSS (mg/l)	44	52	**47**
4	pH Value	7.3	8.1	**7.78**
5	DO, mg/L	3.6	5	**4.35**

Source : MPCB annual report 1998-99

Based on the above table it can be concluded that the parameters monitored for seawater sample near Varsova station is having their usual characteristics with high TDS, Chlorides. Also the seawater contains the heavy metals and BOD, which indicates the pollution of seawater due to various discharges.

9.1.3 Forestry

Tree survey was carried out along the proposed alignment. No forest area exists along the project alignment or its corridor. Most of the trees were planted along the roads on both the sides in the path. No plantation of trees at the centre have been observed through out the project alignment along the road. The main species observed are babool, Pipal, , Ashok,, Bakaan, Neem and other types of tress etc. No rare or endangered species of trees have been noticed during field studies**..** Most of the trees contain the girth size of about 30cm and more. No cutting of trees due to Metro project is anticipated in Eastern segment, as MMRDA is widening the road from Andheri (east) to Ghatkopar station. The average numbers of trees are 11.2per km. An inventory of trees, likely to be lost on the western segment is presented in **Table 9.4**

Table 9.4: LOSS OF FLORA
WESTERN SEGMENT

S No	From – To	Location of tress		
		Left	Right	Total
1	Ch 0.00 -Ch 232.183	7	6	13
2	Ch 232.183 -Ch 482	8	8	16
3	Ch 482 -Ch 722	3	5	8
4	Ch 722 - Ch 1032	3	4	7
5	Ch 1032 - Ch 1313	2	2	4
6	Ch 1313 - Ch 1530 (bus stop)	1	3	4
7	Ch 1530 (bus stop) - ch 1830 (Indian oil Nagar)	7	5	12
8	Ch 1830 (Indian oil Nagar) - Akhand Jyoti Appts. (Ch. 2080)	0	9	9
8	Anand Jyoti Appts.- (Ch. 2080) - Ch 2332 (Ambedkar Nagar)	4	5	9
9	Ch 2332 (Ambedkar Nagar) - Ch 2632(Elershine Bunglows)	6	4	10
10	Ch 2632(Elershine Bunglows) - Ch 2832 (Depot line)	4	2	6
11	Ch 2832 (Depot line) - Ch 3170(Thaker sweets)	7	3	10
12	Ch 3170 (Thaker sweets) – Ch 3.629km (pink Appts.)	7	2	9
	TOTAL	**59**	**58**	**123**

- -Near railway station crossing from East to West of Andheri in the middle .
- All the changes mentioned above carries negative sign considering Ch. 0.00 is the centreline of the Andheri station. towards Versova .

9.1.4 Air uality

The atmospheric concentrations of air pollutants show a rising trend. As a part of this study ambient air quality monitoring (AAQM) has been carried out by setting up ambient air quality monitoring stations through mobile van at four locations as shown in **Table 9.5** for the parameters SPM, CO, SO_2, HC, and NOx. The results so obtained are reported below. The ambient air quality data indicates much higher values of suspended particulate matter (SPM) at these locations except at Versova station, than the prescribed limits established by CPCB. The lesser values at Versova station is observed due to less traffic with in that area and also near the sea shore side. The SPM values at Chruch location in Andheri east is due to severe traffic congestion and load. However, in case of the values of SO_2, NOx and CO, the observed values are within the permissible limits. In overall it can be concluded that the project alignment is moderately polluted, may be due to more traffic etc.,

Table 9.5
AIR UALITY AT PROJECT SITE (μg/ m^3)

S.No.	Location	SPM g/m^3	HC mg/m^3	NOx g/m^3	SO_2 g/m^3	CO mg/m^3
1	Near Andheri Sports club	412-475	Traces-1.78	24-28	37-47	Traces - 2.8
	Average (24 hour)	444	0.96	42	26.4	1.53
	% Variation from standard	23%	---	---	--	---
2	Near Seven bunglows area	308-358	Traces-1.8	26-34	15-19	Traces-1.8
	Average (24 hour)	334	0.86	29	15.5	1.48
	% Variation from standard	----	---	---	---	--
3.	Near Proposed varsova station	111-152	Traces - 1.23	11-23	14-16	Traces - 1.72
	Average (24 hour)	131	0.8	16.5	13	1.4
	% Variation from standard	**---**	**---**	**---**	**---**	**---**
4.	Near Church on Andheri (East)	420-450	Traces – 1.5	25-44	8-16	Traces –2.2
	Average (24 hour)	435	0.75	37.9	11.5	1.1
	% Variation from standard	**21%**	**---**	**---**	**---**	**---**
5..	On J. V. Road (Meghdoot hotel) near Ghatkopatr post office.	350-370	Traces-0.86	20-35	7.5-9.0	Traces – 1.5

	Average (24 hour)	360	0.43	28.7	8.0	0.75
	% Variation from standard	**---**	**---**	**---**	**---**	**---**
Prescribed limit		**360 g/m^3**	**---**	**80 g/m^3**	**80 g/m^3**	**4mg/m^3**
Average value of parameter of above locations		**340 g/m^3**	**0.8mg/m^3**	**30.8 g/m^3**	**14.88 g/m^3**	**1.25mg/m^3**

Note: * SPM values are high due to dusty atmosphere

Maharashtra Pollution Control Board (MPCB) along with Mumbai Municipal Corporation is monitoring the air quality status at various locations and one of the location is in Andheri. The monitoring results during 2002-03 (Latest as provided by MPCB) are presented in the **Table 9.6**as given below:

Table 9.6 : Monitoring results made by MPCB during 2002-03

Monitoring parameter	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Jan-03	Feb 03	Mar 03	Average
SO_2	15	6	**10**	6	9	15	33	44	41	45	31	34	**24.65**
NO_x	31	14	**32**	19	26	31	56	90	89	87	81	79	**52.9**
SPM	237	136	**108**	209	203	131	237	250	312	279	305	352	**229.9**

Source : MPCB report 2002-03

Hence it can be concluded that the parameters monitored for air quality values at above locations monitored by RITES along the project alignment are comparable to the monitoring results carried by MPCB for the month of June, that the increase in monitored parameters may be due to increase in traffic in two years.

9.1.5 Seismicity

The project area falls in **Zone-IV** of Seismic Zoning Map of India. The India Meteorological Department (IMD) has considered suitable seismic factor of adequate for design purpose for Civil Engineering structures. This factor needs to be appropriately incorporated while finalising civil designs.

9.1.6 Noise

Noise levels were measured at different places along the alignment at 2.0-m away from source as per standard practice. The noise levels measured at different locations are summarised in **Table 9.7.** It is observed that the noise levels recorded at various places are higher than prescribed permissible levels of 55-dBA (day) and 45dBA (night) for residential area.

Table 9.7
NOISE LEVELS ALONG THE ALIGNMENT DB(A)

Location	L_{eq}	L_{max}	L_{10}	L_{50}	L_{90}	L_{min}	L_{day}	L_{night}	L_{DN}
Near Andhri Sports club	68.6	74	75.3	74.3	70.18	58	70.9	64	74.4
Near Seven bunglows area	69	74	74.6	73.5	69.8	56	71	63	73.4
Near Proposed Versova station	62.6	68	69.3	64.5	61.1	52	66.9	55	65.6
Near Church on Andheri (East)	75.5	78	72.5	78.4	72.14	62.5	74.56	69	78
On J. V. Road near Ghatkopatr post office	68	72	73.5	72.4	67.8	58	59	61	71

Note: $L_{10,}$ L_{50} and L_{90} are the sound level, which is exceeded 10%, 50% & 90% of the total time

9.2 SOCIO ECONOMIC PROFILE

A detailed socio-economic study has been carried out for Versova to Ghatkopar corridor. The study is conducted through socio – economic survey by field visit and analysis.

9.2.1 Dislocation Due to the Proposed Corridor: In order to keep acquisition of private land to the barest minimum, the alignment has been so chosen, that it remains mostly within the government land. However, at some of the station locations private land is required for entry, exit and other facilities of station and running section. The details of land permanently required for the project are given in **Table 9.8**

Table 9.8
LAND RE UIREMENT

Agency	Purpose	Land Area Required in ha
Government	At stations & other locations	12.610
Private	At stations & other locations	0.032
Total		**12.641**

Detailed survey all along the proposed corridor was carried out. During the survey, it was observed that 3 Nos. of squatters at Lokhand bazaar near Andheri (east) and Ghatkopar area, PAFs along the alignment from Andheri east to DN nagar and near Varsova proposed station, Ghatkopar area as mentioned in **Table 9.9** need relocation. These squatters are used in Table 9.9

Table 9.9
VARSOVA TO GHATKOPAR
DETAILS OF PAFS ALONG THE PROJECT ALIGMENT

Sl. No.	Location	Type of family	Total no.s(Approx.)
1	Near Andheri (east) to DN Nagar Near Lokhand bazaar (shops)	PAFs Squatters	30 20
2	Near Jagruti Nagar & budh Vihar along the alignment in Ghtakopar area	Squatters	400
3	Along the alignment at various locations	PAFs	20
TOTAL NO. OF PAFs			**470**

9.2.2 Survey Design

In order to collect the primary data a structured interview schedule has been used in the field. The sample survey has been carried out for about 12% of the total affected families by using random sampling method evenly along the alignment. Only at two locations squatters have been identified i.e. near lokhand bazaar (hard ware shops) in Andheri (east) and in Ghatkopar area covering Jagruti nagar, Budh Vihar etc. Almost all the commercial shops along the alignment are pucca shops. These have been covered for the purpose of this study.

9.2.3 Socio - economic Profile of the PAF's

9.2.3.1 Socio-economic Conditions

Table 9.10 shows the details of socio-economic condition of project-affected people.

Majority of family members (59.0%) in Project Affected Families (PAFs) are male and remaining 41%are female. It is evident from the table that majority (45.0%) of family members of project affected areas falling in the age range of 16-40 years, 31.2 % belonged to the age of up to 15 years and only 18.7 % family members fall in the range of 40-60 years. Majority of respondents (67.0 %) are Hindus. Remaining 20.0 % are Bodh, 9.0 % are Muslim. Christian and Jain constitute only 4.0 % of total PAFs. About 33.3 %of the total respondents belong to scheduled castes, 29.6 % from other back ward classes, 22.2 %from general and remaining 14.8 per cent belong to scheduled tribe category**.** Main occupation of the people in project areas is business (48.2%) followed by labour (35.2%) and service (12.9%). Remaining 3.7 % people are unemployed. It is observed from the table that majority of them have studied up to primary level. Remaining 27.0 and 5.0 % had their education up to secondary and graduate level respectively. It is also important to be noted that 21.0 %out of total project affected people are illiterate. Around 40.74 %of the families have an income of Rs.5, 0001-10,000/- per annum. Majority of them (53.69%) have an income of less than Rs.50,000/- per annum. Only 5.55 % of them have an income of Rs. 10,000- 15,000/- per annum. However, average income of the people is Rs. 53,898.15/- per annum.

Table 9.10: Socio-economic Profile of Project Affected People

Sl. No.	Socio-economic condition	Frequency	Percentage (%)
1.	SEX (N=267)		
	Male	158	59.0
	Female	109	41.0
2.	AGE COMPOSITION (N=267)		
	0-5yrs	16	5.9
	6-15 yrs	68	25.3
	16-25yrs	61	22.7
	26-40yrs	60	22.3
	40-60	50	18.7
	>60	12	4.5
		X=26.6	
3.	RELIGION **(N 54)**		
	Hindu	36	67.0
	Muslim	05	9.0
	Christian	01	2.0
	Jain	01	2.0
	Bodh	11	20.0
4.	SOCIAL GROUP (N=54)		
	SC	18	33.3
	ST	08	14.8
	OBC/BC	16	29.6
	General	12	22.2
5.	OCCUPATION (N=54)		
	Labour	19	35.2
	Business	26	48.2
	Service	07	12.9
	Unemployed	02	3.7
6.	EDUCATION (N=54)		
	Illiterate	55	21.0
	Primary	125	47.0
	Secondary	73	27.0
	Graduate	14	5.0
7.	FAMILY INCOME(Annual Rs.) (N=54)		
	0- 25000	08	14.81
	25001-50000	21	38.88
	50001-100000	22	40.74
	100001-150000	03	5.55
	150001-200000	0	0.0
	> 200000	0	0.0
		X=Rs.53,898.15	

9.2.3.2 Family Particulars of PAPs

Table 9.11 interprets the family particulars of PAPs. Out of total Project Affected Families majority (78.0%) are nuclear and only 22.0 % are joint. Family size has been classified into four categories i.e., individual, small (2-4), medium (5-7) and large (7 & above). Majority of the families (48.15%) are Medium, 40.74%are small and remaining 9.26 % and 1.85 %of families are large and of one person respectively. Average family size is 5. So far as marital status of family members are concerned it is observed that out of 267 members, majority of them (64.0%) are unmarried and only 36.0 %are married.

Table 9.11: Family Particulars

Sl. No.	Family Particulars	Frequency	Percentage (%)
1.	TYPE OF FAMILY (N=54)		
	Joint	12	22.0
	Nuclear	42	78.0
2.	SIZE OF FAMILY (N=54)		
	Individual	01	1.85
	Small (2-4)	22	40.74
	Medium (5-7)	26	48.15
	Large (7 & above)	05 X=5	9.26
3.	MARITAL STATUS (N=267)		
	Married	95	36.0
	Unmarried	172	64.0

9.2.3.3 Details of Structure

The details of structures to be acquired of project-affected families are given in **Table 9.12.** About 67.0 %are houses, 28.0 %are shops and remaining 6.0 %are both house and shop. It is evident from the data that majority of houses are to be lost due to the development of project. 46.0 and 43.0 %construction of houses are pucca and semi-pucca respectively. Remaining 11.0 %are kutcha houses. It is also to be noted that about 74.0 per cent people are the squatters on the government land and only 26.0 %are having structure in their own land.

Table 9.12: Details of Structure

Sl. No.	Details of Structure	Frequency	Percentage (%)
1.	Type of Structure (N=54)		
	House	36	67.0
	House + Shop	03	6.0
	Shop	15	28.0

2.	Construction of Structure (N=54)		
	Kucha Semi-pucca Pucca Open Land	06 23 25 00	11.0 43.0 46.0 0.0
3.	Land Utilization (N=54)		
	Owned Leased Squatters	14 0 40	26.0 0.0 74.0

The socio-economic survey for the PAFs likely to be affected due to the proposed development was carried out and during the survey, resistance was shown by the occupants of the houses especially in the seven bunglows area, near buddh vihar in Ghatkopar area and near Andheri station area.

POSITIVE ENVIRONMENTAL IMPACTS

9.3.1 Based on project particulars and existing environmental conditions (**Section 9.1**), potential impacts have been identified that are likely to result from the proposed MRTS project and where possible these have been quantified. The positive environmental impacts are listed below:

- Traffic congestion reduction,
- Quick service and safety,
- Less fuel consumption,
- Reduction in Air Pollution,
- Better roads, and
- Employment opportunities,

9.4 NEGATIVE ENVIRONMENTAL IMPACTS

9.4.1 Based on project particulars and existing environmental conditions (**Section 9.1**), potential negative impacts likely to result from the proposed development have been quantified. Negative impacts have been listed under the following headings:

- Impacts due to project location,
- Impacts due to construction works, and
- Impacts due to project operation.

9.4.2 Impacts Due to Project Location

a) **Change of Land use:** The alignment is totally elevated such that both the land requirement and change of land use is minimum. The change in land use is estimated to be 12.641**ha** (includes both government and private land).

b) **Loss of Trees:** The details of 123 trees likely to be lost are given in **Table 9.5.** The total value of these trees lost is **Rs. 1.2 lakhs** as mentioned in **Table 9.13.**

Table 9.13
LOSS OF FOREST PRODUCTS

Total loss of Trees (Nos.)	123
Average cost of one tree (Rs.)	1000*
Total loss (Rs. lakhs)	**1.2 lakhs**

* - Based on market survey

There will be no encroachment into nature reserves, as the project area is in the urban centre.

c) **Loss of Historical and Cultural Monuments:** No historical/cultural monuments will be affected as a result of the proposed development. However, at two different locations, i.e. Saibaba temple adjacent to Shiv sena office at Jagruti nagar in Ghatkoar area and a Masjid in adjacent to the Andheri east Station located on the alignment of this project, which needs due consideration for relocation.

9.4.3 Impacts Due to Project Construction

a) **Soil Erosion and Health Risk at Construction Site:** Runoff from unprotected excavated areas can result in excessive soil erosion, especially when erodibility of soil is high. Mitigation measures include careful planning, timing of cut-and-fill operations and re-vegetation. Problems could arise from dumping of construction spoils (concrete, bricks), waste materials (from contractor's camp) etc. causing surface and ground water pollution. Under the management plan the excavated pillars sites are required to be restored and reclaimed in a satisfactory manner on completion of construction. Though the impact on productive soil is unavoidable, adequate measures need to be worked out for minimising the loss of soil, as by storing of topsoil to be laid back after the construction period etc. Emphasis should be laid on maximum use of the stripped topsoil in for redevelopment of areas and additional landscaping works in the project. The project shall take enforcement measures to prevent/minimise the use of topsoil from other locations. Health risks during construction activity include disease hazards to workers due to lack of sanitary facilities like safe disposal of human waste and garbage clearance and disposal facility. In order to avoid such a situation, proper mitigation measures should be incorporated, which should include proper water supply, sanitation, drainage, healthcare and human waste disposal facilities in labour camps. In addition reduced contaminated water spillage and adoption of disease control measures should be adopted to reduce the health risks.

b) Muck disposal during construction: Construction activity involves earthwork and construction material. The metro route is elevated. Hence piers/pillars will be constructed. The muck will be from excavated soil and construction material. The quantity of muck and disposal sites will be finalised during detail engineering.

c) Traffic Diversions and Risk to Existing Buildings: During construction, traffic diversions on roads will be essentially required. As most of the construction activities will be confined to centre of the road and most of the roads are double lane, it will be appropriate that the side lanes may also be utilised for traffic and also for smooth progress of construction activities. Advance information on communication systems will be an advantage to users of any particular road. As most of the proposed sections are elevated and located in the middle of the road with deck width being much less than the existing road width, hence risk to the existing buildings all along the route will be practically negligible.

d) Impact on Water uality: Construction activities may have impact on water bodies due to disposal of waste. The waste could be due to: the spillage of construction materials, dumping of used water from the stone crusher, oils and greases, and labour camp. But the quantities of such spills are very negligible. Care, however, needs to be taken to provide adequate sanitary facilities and drainage in the temporary colonies of the construction workers. Provision of adequate washing and toilet facilities with septic tanks and appropriate refuse collection and disposal system should be made obligatory. Contamination of ground water can take place, if the dump containing above substances gets leached and percolate into the ground water table. This is not the case with the present project, as the activity does not involve usage of any harmful ingredients. Moreover activities are of short duration. Hence, no impact on either ground or surface water quality is anticipated in the present project.

9.4.4 Impacts due to Project Operation

a) **Oil Pollution:** Oil spillage during change of lubricants, cleaning and repair processes, in the maintenance Depot cum workshop for maintenance of rolling stock, is very common. The spilled oil should be trapped in grit chamber for settling of suspended matter. The collected oil should either be auctioned or incinerated, so as to avoid any underground water contamination.

b) **Noise:** Noise and Vibration is of similar phenomenon. Noise is a random vibration. It can be broken down into a set of unrelated, elementary components. Vibration can cause the emission of audible noise. Noise is usually either airborne or propagated through the structure. The main sources of noise from the operation of trains include: engine noise, cooling fan noise, wheel-rail interaction, electric generator and miscellaneous noise like passenger's chatting. An attempt has been made to predict the rise in ambient noise at different distances. A hemi spherical sound wave propagation model through a homogeneous free medium is used. The mathematical representation of the model is as follows:
$L(P) = Lps - 20 \log (d) - 8$
where Lp = Sound pressure level at distance d,
d = distance in meters
Lps =Point noise source
The cumulative impact of different sources in a partcupat place is calculated by the logarithmic additional model as
$L(P)\ total = 10 \text{ Log } (10^{Lpq1/10} + 10^{Lpq2/10} + 10^{Lpq3/10} + \text{------})$

Roughnesses of the contact surfaces of rail and wheel and train speed are the factors, which influence the magnitude of rail - wheel noise. The vibration of concrete structures also radiates noise. The maximum noise level is estimated as 64DB(A). However, due to reduction of vehicular traffic, the road traffic noise as compared with existing levels may come down by about 7 to 9%.

c) **Accidental Ha ards:** In view of the hazards potential involved due to failure of system and accident the on-site and off- site emergency measures have been formulated and will be implemented.

d) **Water Supply:** CPHEEO has recommended 45-litres/day, water supply to persons working at railway stations. All the stations are in urban area. Water requirement at stations has various components, viz. Personal use of Staff, Fire demand, Make up water for air conditioning and ventilation, and Wastage. The water demand at each station would be about 100m^3 per day. Adequate provision of drinking water has to be made for passengers at the railway stations. Platform washing requirement has been worked out at the rate of 2-lit per sqm.

Fire fighting water requirement has been taken as per Calcutta Metro norms.

e) **Railway Station Refuse:** The refuse from railway station includes; Garbage, Rubbish, and Floor Sweepings. The total refuse generated at all the stations of the present section under consideration is estimated to be about 3-4 tonnes/day with the assumption that only about 25% of the passengers visiting various stations will be producing refuse. For the maintenance of adequate sanitary facilities, containers/collection bins not exceeding 120-litres and equipped with side handles will be appropriately designed and installed at stations and platforms.

f) **Visual Impacts:** The construction of Versova to Ghatkopar corridor will bring about a change in visual look of the streets through which it will operate. An architecturally well-designed structure, which could be aesthetically pleasing and able to reduce impact due to visual disfiguration have been incorporated in present corridor. Since a low profile would cause least intrusion, the basic elevated section should be optimised at the design stage itself.

9.5 CHECKLIST OF IMPACTS

9.5.1 A typical checklist identifying anticipated environmental impacts is shown in **Table 9.14.**

Table 9.14
CHECKLIST OF IMPACTS

Parameter		Negative Impact	Positive Impact	No Impact
A)	**Impacts Due To Project Location**			
i)	Change of Land Use and Ecology	✓		
ii)	Impact on Historical/Cultural Monument			Nil
B)	**Impact Due To Project Construction**			
i)	Soil Erosion, Pollution and Health Risk at Construction Site	✓		
ii)	Traffic Diversions and Risk to Existing Buildings	✓		Nil
iii)	Impact on Water Quality	✓		
C)	**Impact Due To Project Operation**			
i)	Oil Pollution	✓		
ii)	Noise and Vibration	✓		
iii)	Accidental Hazards	✓		
iv)	Water Supply	✓		
v)	Railway Station Refuse	✓		
vi)	Visual Impacts	✓		
D)	**Positive Impacts**			

Parameter		Negative Impact	Positive Impact	No Impact
i) ii) iii) iv) v) vi)	Traffic Congestion Reduction, Quick Service and Safety, Less Fuel Consumption, Reduction in Air Pollution, Better Roads, and Employment Opportunities		✓ ✓ ✓ ✓ ✓ ✓	

9.6 ENVIRONMENTAL MANAGEMENT PLAN

Based on environmental baseline conditions, planned project activities and its impacts assessed, the set of measures to be taken during implementation and operation to avoid or offset adverse environmental impacts or to reduce them to acceptable levels, together with the action which needs to be taken to implement them are enumerated in this section.

9.6.1 Mitigation Measures: Based on project description, Environmental Baseline Data and Environmental Impacts, it is proposed to prepare the Environmental Management Plan for the following:

a) Compensation for Loss of Land,
b) Compensation for Loss of Trees,
c) Compensatory Afforestation and Fencing,
d) Compensation for Relocation/Resettlement,
e) Water Supply & Sanitation,
f) Oil Pollution Control
g) Noise Control
h) Vibration Control

a) Compensation for Loss of Land: The land likely to come under project is 14.26ha. The cost of land for compensation is taken under the project cost.

b) Compensation for Loss of Trees: There are 123 trees on the proposed alignment, which are required to be uprooted. The Compensation for Loss of Trees works out to **Rs. 1.2 lakhs.**

c) Compensatory Afforestation and Fencing: According to the survey, about 123 trees are likely to be lost due to the project. 10 times the number of trees are to be planted as per the general norms of Department of Forests, administration stipulations. Hence, about 1230 plants are required to be planted. The total area required for afforestation of these tress comes to about 0.975ha. It is presumed that government land will be provided for afforestation, hence no land cost will be involved. Compensatory afforestation cost (excluding fencing) for 0.975ha will be about Rs. 1,46,250/- @about Rs.1, 50,000 per ha. Fencing shall be provided in order to save the saplings from the animals. The cost towards fencing is estimated to be about Rs. 1,20,000/- Thus, the total cost works out to **Rs. 2.66 lakhs**. The recommended plant species for afforestation include: Papdi, Ghulmor, babool, Pipal, Ashok, Badaam, Dhdkher, Kodumar, Neem etc.,

d) **Compensation for Relocation/Resettlement**: The project involves relocation of shops, commercial cum residential buildings and hutments along the alignment. As per Resettlement & Rehablatation policy for Mumbai Urban Transport Project (MUTP) March 1997 and as amended in December 2000, the principles of resettlement are as follows:
(i) *Project affected structures* shall be categorized by referring to ownership, land use and type of construction:
Ownership:

- Land and building owned by the same person,
- Land owned by one person and building owned by the lessee,
- Land and building both leased to lessee,
- Land and building occupied by statutory tenants with owner occupant or where owner is a absentee,

(ii) *Land occupied by squatters* without any legal title. Category of squatters includes-non-resident structure owners, resident structure

(iii) *Selection of Resettlement Site :* The site for resettlement shall be selected out of the feasible options in consultation with the affected community as a part of the RAP preparation. The principal criteria for site selection shall include access to employment opportunities, infrastructure and social services. Environmental assessment of the resettlement site shall be carried out as part of the preparation of EMP.
Since, the Maharashtra R&R policy doest not specify the compensation cost, market survey data have been taken wherever found appropriate.
Following are the details of structures to be relocated due to this project. About **Rs**. **671.85lakhs** will be paid as compensation for relocation of shops, commercial cum residential buildings likely to be affected due to the project along the alignment. The details of replacement cost of resettlement are presented in **Table 9.15.** The R&R cost is presented n **Table 9.16.**

Table 9.15
REPLACEMENT COST

S. No.	Plot No	Location	Area in Sqm	Description	Cost for Land	Description of the area	Average construction Cost @ Rs 5,000 per sq mtrs
Eastern alignment							
1.	STE8P1	Ghatkopar	284	Pvt	Considered in project cost	Res. Built – up	1420000

2.	STE8P2	Ghatkopar	266	Pvt	Considered in project cost	Com. Built - up	1330000
Western alignment							
3	STW1P6	DO	395	Pvt	Considered in project cost	Commercial	1975000
4	STW2P3	DO	2495	Govt.	Considered in project cost	Partly Built – up	12475000
5	RSW3P1	Between Versova Station Area	600	Pvt	Considered in project cost	Commercial	3000000
6	RSW3P2	DO	52	Pvt	Considered in project cost	Commercial	260000
7	DPP2	DO	1335	Pvt	Considered in project cost	Open space in Res. Area & two Bldgs (G+7)	46725000
TOTAL							**67185000**

- Based on the market value of land (Rs. 20 to 30 Lakh per acre) in Mumbai city on both western and eastern side of the alignments, as enquired during the field visits

Table 9.16
R&R COST

A	**Compensation for Land Acquisition**			
1.	Land Acquisition			
	(A) Land acquisition along eastern side of the alignment	12.641ha. Considered in project cost.		
	(B) Land acquisition on Western side of the alignment			
B	**Compensation for Residential structures**			
2.	Acquisition of residential structures in PAPs in the built up area.	As per **Table 9.15**		Rs. 671.85
C	**Acquisition of squatters structure**			
3.	Acquisition of squatters structure near Lokhand bazar and near Ghatkopar area.	420	24000/unit*	Rs. 125. 1Lakhs
D	**Assistance to Vulnerable People**			
4.	BPL/ SC/ ST/ Old Age people	210^	5000	Rs. 10.08 Lakhs

E	**Shifting allowance**			
	PAFs	=5427 x 0.5 =2713sq.m^^	1000	Rs. 27.13 Lakhs
	GRAND TOTAL (A B C D)			**Rs. 834.16Lakhs. Say Rs. 834 Lakhs**

The budget is an indicative cost and the detailed R& R cst shall be carried out during the detailed study and survey which is likely to change the land requirement and the budget accordingly

* Average size of an encroachment (structure) is about 12sq.m and considering its cost @ Rs.2000/sq.m

^ Assuming that 50% of affected population falls in this category, based on the sample analysis.

^^ considering 50% is the floor area can be considered for shifting charges.

e) **Water Supply & Sanitation:** The public health facilities, such as water supply, sanitation and toilets are much needed at project location. Water should be treated before use upto WHO drinking water standards. In addition, water will be required for contractor's camps during construction, for which additional arrangements have to be made in consultation with the Mumbai Municipal Corporation & Mumbai Development Authority. The collection and safe disposal of human wastes are among the most important problems of environmental health. The water carried sewerage solves the excreta disposal problems. The sewerage disposal systems should be adopted for sewage disposal. The total of app. 120 bins of 50-120 litres capacity will be required which can be accommodated at different stations and platforms. The total cost for bins works out to be **Rs. 2.40 lakhs**.

f) **Oil Pollution Control:** Oil tends to form scum in sedimentation chambers, clog fine screens, interfere with filtration and reduce the efficiency of treatment plants. Hence oil and grease removal tank has to be installed at source. Such tanks usually employ compressed air to coagulate oil and grease and cause it to rise promptly to surface. Compressed air may be applied through porous plates located at the bottom of the tank. The tank may be designed for a detention period of 5 to 15 minutes. Adding Chlorine in an amount of 2.0-mg/l will increase the efficiency of removal.

g) **Noise:** There will be an increase in noise level in ambient air due to construction and operation of this corridor. However, noise levels in the core city will go down. The increase in levels is marginal; hence local population will not be adversely affected. However the exposure of workers to high noise levels especially, near the engine, vent shaft etc. need to be minimized. This can be achieved by job rotation, automation, protective devices, noise barriers, and soundproof compartments, control rooms etc.

The workers employed in high noise level area could be employed in low noise level areas and vice-versa from time to time. Automation of equipment and machineries, wherever possible, should be done to avoid continuous exposure of workers to noise. At work places, where automation of machineries is not possible or feasible, the workers exposed to noise should be provided with protective devices. Special acoustic enclosures should be provided for individual noise generating equipments, wherever possible.

Pile driving operation can produce noise levels upto 100 dB (A) at a distance of 25-m from site. This can reduce the noise levels to 70 dB (A) at a distance of 15m from the piles. Safety precautions as stipulated in IS: 5121 (1969) 'Safety Code for Piling and other Deep Foundation' need to be adopted.

Noise level from loading and unloading of construction materials can be reduced by usage of various types of cranes and placing materials on sand or sandy bag beds. Sound barriers are usually effective along route having fast traffic. The reduction in noise level increases with height of barrier. Ballast-less track is supported on two layers of rubber pads to reduce track noise and ground vibrations.

h) **Vibration Control:** Vibrations emanates from rail - wheel interaction and the same can be reduced by minimizing surface irregularities of wheel and rail, improving track geometry, providing elastic fastenings, and separation of rail seat assembly from the concrete plinth with insertion of resilient and shock absorbing pad.
While designing track structure for Mass Rapid Transit System, all the above points have been taken into consideration in the following ways:

- To prevent development of surface irregularities on the rail, a fairly heavy rail section of 60-kg/m, 90 UTS, supported at every 60-cm. has been proposed. Further, rail grinding at regular intervals by Rail grinding machine have been contemplated.
- Rail will be continuously welded and also will be laid to fine tolerances, so that any noise/vibration on account of irregular track geometry could be reduced.
- The vibration generated from rail-wheel interaction will be greatly absorbed by the elastic fastening system proposed to be used.

9.7 ENVIRONMENTAL MONITORING PLAN

9.7.1 **Environmental Monitoring:** The environmental monitoring will be required for the construction and operational phases. The parameters need to be monitored are: Water Quality, Air quality and Noise levels.

a) **Water uality:** Water quality parameters shall be monitored one year before the construction, during the construction phase and also for at least three years after the completion of the project (total 10years). Monitoring shall be carried out at least four times a year to cover seasonal variations. The parameters for monitoring would be: pH, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids, Chlorides, Nitrates, Sulphates, Total Nitrogen, Total Phosphates, oils and greases etc. The main monitoring stations could be at_near S. V. Road, Andheri (west), near bus depot, near Varsova station, starplus office, and near Ghatkopar station the cost for water quality analysis works out to be **Rs. 10.8 lakhs.**

b) **Air uality and Noise Levels:** Ambient air quality and Noise levels should be monitored one year before the construction, during the construction phase (6 years) and for at least three years after the completion of the project (total 10 years). The proposed monitoring programme for field monitoring and laboratory analysis of air and noise is given in **Table 9.16.** The cost for ambient air quality and Noise levels monitoring works out to be **Rs. 20.2 lakhs**.

Table 9.16
PROPOSED MONITORING PROGRAMME FOR AIR AND NOISE UALITY

Monitoring	Monitoring Parameters	Proposed Site	Sampling Duration	Frequency	Cost (Rs. lakhs)
Ambient Air Quality	SPM, SO_2, NO_x and CO and HC	1. Varsova Station 2. Near SV Road, 3. Near Star Plus 4. Near Ghatkopar Station	Twice week, 4 weeks in a season	Once in a season	2x4x5x10x5000=**20.00**
Noise Levels	dB (A)	*-Do-*	Once a week	Once in a year	1x4x10x500=**0.2**
				TOTAL COST	**20.20**

9.8 ENVIRONMENTAL MANAGEMENT SYSTEM

9.8.1 The Environmental Management System constitutes provision of an Environmental Division, which should be staffed by an Environmental Engineer/Officer, an Environmental Assistant and two other assistants (miscellaneous works). The task assigned should include supervision and co-ordination of studies, monitoring and implementation of environmental mitigation measures. An Environmental Advisor shall review progress of the division every year. Cost of such an establishment has been estimated as **Rs. 30.60 lakhs.** However, it may be mentioned that this division will be for the entire MRTS. Therefore, the cots are attributable to another system.

9.9 COST ESTIMATES

9.9.1 All costs involved in Environmental mitigation and management and monitoring to be put on the account of the proposed project are summarised in **Table 9.17**.

Table 9.17
ENVIRONMENTAL COSTS

S. No.	ITEM	Rs. (Lakhs)
1	Compensation for loss of trees	1.23
2	Compensatory Afforestation & fencing	2.66
3	Compensation for Resettlement	834
4	Monitoring of Water	10.8
5	Monitoring of air/noise during construction & operation	20.2
6	Establishment of Environment Division	30.6
7	Provision of bins for Railway Station Refuse	2.4
	Total	**901.89**
8	Miscellaneous items @10%	90.19
GRAND TOTAL		**992.08**

Say Rs. 9.92 Crores

9.9.2 The Environment Management Plan should be implemented in phases, so that optimum benefit could be achieved and it should be synchronised with the construction schedules.

Chapter 10
COST ESTIMATES

10.1 INTRODUCTION

10.1.1 Detailed cost estimates for Versova-Andheri-Ghatkopar corridor have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, environmental protection, rehabilitation, etc. considering 25kv AC Traction at June, 2004 price level.

10.1.2 While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) route km length of alignment, (ii) number of units of that item and (iii) item being an independent entity. All items related with alignment, whether in elevated or at-grade construction, permanent way, OHE, Signalling & telecommunication, whether in main lines or in maintenance depot, have been estimated at rate per route km/km basis. Cost of station structures, other electrical services at these stations and automatic fare collection (AFC) installations at all stations have been assessed in terms of each station as a unit. Similarly, for items like Rolling stock, Receiving Sub-station (RSS)/Traction Sub-station (TSS)/Auxiliary Sub-station (ASS), service connections, etc. costs have been estimated in terms of number of units required for each item. In remaining items, viz. land, utility diversions, rehabilitation, etc. the costs have been assessed on the basis of each item, taken as an independent entity.

10.1.3 In order to arrive at realistic cost of various items, costs have been assessed on the basis of accepted rates in various contracts recently awarded by DMRC for their ongoing works of Line No. 3 (East-West Corridor) & other works of Line No. 1. A suitable escalation factor has been applied to bring these costs to June, 2004 price level. For some of the items, tenders have been finalised recently and most of these tenders are with fixed price rates (i.e. no escalation is payable during contract period). Such rates have been adopted, as they are. In some of these tenders, there is an element of Customs Duty (CD) on the equipment/components to be imported for the work, Works Tax (WT), etc. built in the quoted rates. The element of customs duty and works tax has been excluded for working out the project cost. However the details of taxes and duties are worked out separately.

10.1.4 The capital cost has been worked out for base case, Versova – Andheri - Ghatkopar alignment with Depot at D N Nagar. Separate costing is done for the Airport Link (though not recommended) and for a depot at Godrej land with suitable connection.

10.1.5 The overall capital cost for Versova-Andheri-Ghatkopar Corridor, at June, 2004 price level, works out to Rs. 1488 crores, excluding taxes and duties, but including general charges @ 3% on all items except land and 3% contingencies on all items. The abstract capital cost estimates are shown at **Table 10.1.**

TABLE 10.1 : CAPITAL COST ESTIMATE (BASE CASE)
Versova-Andheri-Ghatkopar Corridor

Total Length	**11.07 km**
Western Segment	3.21 km
Eastern Segment	7.86 km
Elevated Stations	12
DEPOT at D N Nagar	

June 2004 price level

S. No.	Description	Unit	Rate	ty.	Amount
1	**Land**				
1.1	Eastern Segment				
	Private Land				
a	Andheri Vacant	Hact.	31.320	0.095	2.96
b	Marol Naka Vacant	Hact.	13.560	0.065	0.88
c	Subhash Nagar Vacant	Hact.	9.500	0.027	0.25
d	Asalpha Road	Hact.	10.590	0.040	0.42
e	Ghatkopar Residential	Hact.	46.400	0.028	1.32
f	Ghatkoper RS	Hact.	94.980	0.027	2.53
	Total (Eastern Segment)			0.281	**8.36**
1.2	Western Segment				
1.2.1	Govt. Land	Hact.	18.000	0.031	0.56
1.2.2	Private Land				
a	Azad Nagar Commercial	Hact.	87.730	0.017	1.47
b	Azad Nagar Vacant	Hact.	38.720	0.065	2.52
c	Azad Nagar Residential	Hact.	64.530	0.002	0.10
d	D N Nagar Depot (Vacant)	Hact.	21.750	12.250	266.44
	Total (Western Segment)			12.365	**271.10**
1.3	Temporary land required for construction Depot	Hact.	3.600	6.330	22.79
1.4	Misc. Boundary wall etc. for both Eastern and Western Segment	Km.	0.500	4.800	2.40
	Total of item 1				**304.65**
2	**Alignment & formation**				
2.1	Elevated section	R. Km.	22	11.07	243.54
	Total				**243.54**
3	**Station Buildings (Elevated)**				
3.1	Type A (Normal Stations)	Each	10	8	80.00
3.2	Type B (Junction Station)	Each	11	1	11.00
3.3	Type C (major stations)	Each	12	3	36.00
	Total				**127.00**
4	**P. Way**				
4.1	Ballastless track for Elevated section	R. Km.	4.95	11.07	54.80
	Total				**54.80**
5	**Traction & Power, Lifts & Escalators**				
5.1	Traction & Power incl. OHE, ASS etc.	R. Km.	As per Table		68.58
5.2	Lifts	Each	0.2	39	7.80
5.3	Escalators	Each	0.8	50	40.00
	Total				**116.38**

6	**Signalling, Telecom & AFC**				
6.1	Sig. & Tellecom	Stn.	11.5	11.07	127.31
6.2	Automatic fare collection	Stn.	2.5	12	30.00
	Total				**157.31**
7	**Depot**				
	Elevated structures, Equipment, Track, Boundary etc.				130.00
8	**Rolling Stock**	**Each**	**4.25**	**56**	**238.00**
9	**Resettelment and Rehabilitation**	**LS**			**7.00**
10	**Misc. Utilities, road works misc. other civil works such as median, stn. signages, Environmental protection etc.**	**R. Km.**	**3**	**11.07**	**33.21**
10	Total of all items except land				**1107.23**
11	General charges 3 % on all items except land				**33.22**
12	Total of all items 1 to 11				**1445.10**
13	Contingencies 3% on all items.				**43.35**
	Gross Total				**1488.45**

Say Rs. 1488.00 Crores

10.2 CIVIL ENGINEERING WORKS

10.2.1 Land

i) Land requirements have been kept to the barest minimum & worked out on area basis. For elevated alignment, no land is proposed to be acquired permanently, except small areas for locating entry/exit structures, traffic integration, etc. at stations.

ii) Cost of land for the depot (12.25 hact.) has been taken @ 21.75 crores per hact. These are based on prevailing rates of land in this area as per Ready Reckaner & these have been increased to provide for 30 % solatium & 12 % interest.

iii) 0.36-hac private land is proposed to be acquired. Rates for private land both commercial & residential have been based on rates in Ready Reckoner published by Architects publishing Corp. of India, Mumbai (2004 edition). Over & above these rates, provision for 30 % solatium & 12 % interest has been made.

iv) Cost of the land to be acquired permanently, has been considered in the project construction cost.

v) In addition to the lands required permanently, 6.33 hact. of private land is temporarily required for construction depots. Ground rent charges for 3 years @6% per year of the cost of land (i.e. @ 3.60 Crore/Hact.) have been provided for, in the project cost estimates.

vi) Cost of boundary wall required at stations has been added to the cost of land.

10.2.2 Formation & Alignment

i) **Elevated Section-**Rates are based on accepted rates of Barakhamba Road-Dwarka section, duly updated to June 2004 price level.

10.2.3 Station Buildings

i) **Elevated Stations-**Estimated rate is based on accepted rates for stations on Dwarka - Barakhamba Road Corridor and modified for 6 coach length platforms. The cost includes the general services at the stations but excludes the cost of viaduct, lifts & escalators, which have been considered separately under, respective items.

10.2.4 Permanent Way-For elevated sections, ballastless track and for at-grade alignment and in depot area ballasted track has been planned. Rates adopted are based on accepted rates for Shahdara-Rithala Section, which covers both ballastless & ballasted tracks.

10.3 DEPOT

10.3.1 For this section of about 11.07 km., depot at D N Nagar has been proposed. The depot is planned at an elevated level due to land constraints. Costs have been worked out for various items of building, elevated structures, tracks, boundary wall & plants machinery etc. This depot can also be used for the North - South line of the Metro Network.

10.3.2 A depot at Godrej land is also proposed which can be constructed at ground level. For this purpose 20 Ha land is proposed to be acquired. The cost for this depot is not included in the main estimate but indicated seperately. The cost also includes the cost of approach track for this depot.

10.4 UTILITY DIVERSIONS

10.4.1 Costs per running meter of various utilities like trunk and main sewers, water mains, storm water drains etc. requiring diversion have been worked out. The costs of utility diversions involved in elevated stretches have been considered under head utility diversions. In addition to sewer/drainage/water pipelines other important utilities works considered are road diversions, road restoration etc.

10.5 ENVIRONMENTAL IMPACT ASSESSMENT

10.5.1 Provision for environmental impacts of this MRTS corridor has been made to cover various protection works, additional compensatory measures, compensation for loss of trees, compensatory afforestation and fencing, monitoring of water quality, air/noise pollution during construction, establishment of Environmental Division.

10.6 REHABILITATION & RESETTLEMENT

10.6.1 Private Structures-Provision towards compensation/rehabilitation of these on private land, likely to be affected has been assessed after site inspection. The provision is kept in the estimate though it is stated that the most of the rehabilitation shall be done under road widening and D P Road construction schemes.

10.7 TRACTION & POWER SUPPLY

10.7.1 Provisions have been made to cover following subheads:

- OHE (Flexible).
- Receiving-cum-Traction Sub-stations including cables.
- ASS for elevated and at-grade stations.
- Service connection charges for Receiving Sub-stations.
- Scada augmentation.
- Catenary maintenance vehicle.
- Miscellaneous items e.g. illumination, lifting T&P, etc.

10.7.2 The rates adopted for various items are based on the accepted contract rates for similar works for NS & rail corridors. These rates include escalation during contract period but exclude CD & WT & are provided in consultation with DMRC. The details of the cost for traction and power supply is given in **Table 10.2.**

Table 10.2

Figures in Rs. Crores

S. No.	item	ty,	Unit	Unit rate	Total cost (W/o taxes & duties)	Taxes & duties				
						Custom duty @44.7%	Excise duty@ 16%	Salex Tax@4%	Works contract tax @4 %	Total of Taxes & duties
1	Service connection charges (33kV bays)									
	Versova RSS	2	No.	0.25	0.50	0.00	0.00	0.00	0.00	0.00
	Arrey RSS	2	No.	0.25	0.50	0.00	0.00	0.00	0.00	0.00
2	33kV cables (3 phase single circuit)									
	From Versova RSS to Depot RSS	2	Km.	0.60	1.20	0.00	0.12	0.04	0.05	0.21

	From Arrey RSS to Marol Naka RSS	6	Km.	0.60	3.60	0.00	0.37	0.11	0.14	0.62
3	Depot RSS	1	No.	6.06	6.06	0.00	0.52	0.15	0.24	0.91
4	Maro Naka RSS	1	No.	5.60	5.60	0.00	0.47	0.14	0.22	0.83
5	ASS for elevated stations	12	No.	1.32	15.90	0.34	1.50	0.43	0.64	2.91
6	33kV cables (Ring main, feeder & interconnection cables	35	Km.	0.25	8.75	0.00	0.89	0.26	0.35	1.50
7	25kV OHE	22	TKM	0.60	13.20	0.00	1.35	1.35	1.35	4.04
8	SSP, SP & motorised isolators	1	LS	2.50	2.50	0.00	0.26	0.07	0.10	0.43
9	SCADA System	1	LS	3.52	3.52	0.50	0.18	0.05	0.14	0.87
10	Catenary Maint Vehicle	1	LS	2.50	2.50	0.36	0.05	0.01	0.00	0.42
11	DOT charges for clearance	1	LS	1.00	1.00	0.00	0.00	0.00	0.00	0.00
12	Necessary spares, tools , fault diagnosis equip, Earthing, Bonding etc.	15	Rkm	0.25	3.75	0.53	0.19	0.06	0.15	0.93
	Grand Total				68.58	1.73	5.89	2.66	3.38	13.66

10.8 ELECTRICAL SERVICES AT STATIONS

10.8.1 These are included in estimated costs of stations on elevated alignment section. Cost of escalators, lifts for all stations have not been included in station costs, are therefore provided under electrical estimates & shown separately.

10.9 SIGNALLING & TELECOMMUNICATION WORKS

10.9.1 The rates adopted are based on accepted rates of N. S. & rail corridors of line no.3. These rates include escalation during manufacture & supply of equipment and their installation at site, but exclude CD and WT. The same rates have been adopted.

10.10 AUTOMATIC FARE COLLECTION

10.10.1 Adopted rates are based on accepted contract rates of Rail and N-S Corridors of line no.3. These rates exclude CD & WT, but include escalation during the period of equipment manufacture and their supply, including installation.

10.11 ROLLING STOCK

10.11.1Adopted rates are in consultation with DMRC & do not include CD and WT. These cover escalation during period of supply.

10.12 GENERAL CHARGES & CONTINGENCIES

10.12.1 Provision @ 3% has been made towards general charges on all items except cost of land, based on assessment by DMRC. Design charges of 2% are not included in the cost estimates as the project is being planned on BOT as design and construct basis. Provision for contingencies has been made @ 3% on all items including general charges.

10.13 TAXES AND DUTIES

Estimate for taxes and duties is given in **Table10.3**. It is estimated that the taxes and duties will amount to Rs. 182 crore and the total cost inclusive of taxes and duties is Rs. 1670 crores

TABLE 10.3
Details of Taxes and Duties

		East-West (Elevated)						
			Taxes and duties					
		Total cost without Taxes & duties	**custom duty**	**works tax**	**excise duty**	**sale tax**	**total**	**Total cost with tax & Duties**
1	**Land**	304.65						304.65
2	**Civil Engg. Works**							
	Elevated section	243.54	0.00	9.74	0.00	0.00	9.74	253.28
	Station bldg ele.	127.00	0.00	5.08	0.00	0.00	5.08	132.08
	Misc.like Utilities etc.	40.21	0.00	0.00	0.00	0.00	0.00	40.21
	Permanent way	54.80	22.73	2.27	0.00	0.00	25.00	79.80
3	**Electrical works**							
	Traction and power supply	68.58	1.73	5.89	2.66	3.38	13.66	82.24
	Lifts & Esclators	47.80	5.57	0.11	5.02	0.44	11.14	58.94
4	**S and T Works**							
	S & T	127.31	28.64	5.09	1.02	0.25	35.01	162.32
	AFC	30.00	6.75	1.20	0.24	0.06	8.24	38.24

5	**Depot****	130.00	14.78	2.35	1.77	1.95	20.85	150.85
6	**Rolling stock**	238.00	0.00	-	38.08	14.85	52.93	290.93
7	**General charges & Contigencies**	76.57						76.57
	Total	**1488.46**	**80.20**	**31.74**	**48.78**	**20.93**	**181.66**	**1670.12**
						SAY	**1670**	**Crores**

10.14 Cost with Alternative Proposals

Two alternatives have been proposed along with the main corridor. These are:

(i) Link to International Airport

(ii) Link to Godrej Depot

The estimated project cost for these links are shown in annexure 10.1 and 10.2 respectively.

(a) Project Cost with Airport Link

Estimated cost of the airport link	Rs.	90 Crores
Total cost including Airport Link	Rs.	**1578 Crores**.

(b) Project cost with Godrej Depot (excluding D N Nagar Depot)

Estimated cost of Godrej Depot including Link Line	Rs.	469 Crores
Total cost with two Depots	**Rs.**	**1957 Crores**
Cost with Goderej Depot only	**Rs.**	**1545 Crores**

It is observed that the cost for depot at D N Nagar (Rs. 412 crores) is less than the cost for Godrej depot due to 1.625 km link line.

The taxes and duties for the two alternatives is given in Annexure 10.3 a and 10.3 b respectively. The taxes and duties on Air port link amunts to Rs. 12.84 crores while on the Godrej Depot (inclusive of link line) is Rs. 26 crores.

Annexure 10.1

Project Cost-Estimates of Airport Link
Length 1.3 Km. (Elevated)
Station 1 Elevated

S. No.	Item	Unit	ty.	Rate without Taxes (In Crores)	Amount (In Crores)
1.1	Land	L.S.			4.00
	Sub Total (1)				**4.00**
2.0	Alignment and Formation				
2.1	Elevated Section	R. Km.	1.3	22.00	28.60
	Sub Total (2)				**28.60**
3.0	Station Buildings elevated	Each	1	12.00	**12.00**
4.0	Depot Augmentation		LS		**0.00**
5.0	P Way				
5.1	Ballstless track for elevated section	R.Km.	1.3	4.95	**6.44**
6.0					
6.1	Traction & power supply	R. Km.	1.3	5.00	6.50
6.2	Lifts & Escalators	Each	1	4.00	4.00
	Sub total (6)				**10.50**
7.0	Signalling and Telecom.				
7.1	Sig. & Telecom.	R. Km.	1.3	11.50	14.95
7.2	Automatic fare collection	Stn.	1	2.50	2.50
	Sub Total (7)				**17.45**
8.0	Utilities (0.2+1.5+2.00+0.5 Elect)	R. Km.	1.3	3.00	**3.90**
9.0	R & R		LS		**1.00**
10.0	Rolling Stock	Each	Nil	4.25	**0.00**
10.0	Total of all items except Land				**79.89**
11.0	General Charges @ 3 % on all items except land				**2.40**
12.0	Total of all items including G. Charges@ 3%				**86.28**
15.0	Continegencies @ 3 %				**2.59**
16.0	**Gross Total**				**88.87**
	Say				**90 Cr.**

Annexure 10.2

Project Cost-Estimates of Godrej Depot Link
Length 1.625 Km. (Double Line)
Elevated incl. Ramp 1.125 Km. At-grade 500 mtr.

S. No.	Item	Unit	ty.	Rate without Taxes (In Crores)	Amount (In Crores)
1.1	Land for alignment	L.S.			3.00
	Land for Depot	Hact	20.00	14.57	291.40
	Sub Total (1)				**294.40**
2.0	Alignment and Formation				
2.1	Elevated Section	R. Km.	22.00	1.125	24.75
2.2	At-grade Section	R. Km.	6.05	0.5	3.03
	Sub Total (2)				**27.78**
3.0	Station Buildings elevated	Each	Nil	1	
4.0	P Way				
4.1	Ballstless/Ballassted track for elevated section	R.Km.	1.625	4.95	8.04
	Sub Total (4)				**8.04**
5.0					
5.1	Traction & power supply	R. Km.	1.625	5.00	8.13
5.2	Lifts & Escalators	Each	Nil		
	Sub total (5)				**8.13**
6.0	Signalling and Telecom.				
6.1	Sig. & Telecom.	R. Km.	1.625	5.00	8.13
6.2	Automatic fare collection	Stn.	Nil		
	Sub Total (6)				**8.13**
7.0	**Depot**	LS			**100.00**
8.0	Utilities	R. Km.	1.625	2.00	**3.25**
9.0	R & R		LS		**1.00**
10.0	Rolling Stock	Each	Nil	4.25	**0.00**
11.0	Total of all items except Land				**156.32**
10.0	General Charges @ 3 % on all items except land				**4.69**
12.0	Total of all items including G. Charges				**455.41**
13.0	Continegencies @ 3 %				**13.66**
14.0	**Gross Total**				**469.07**
	Say				**469 Cr.**

	Annexure 10.3 a							
		Airport link (Elevated)						
			Taxes and duties					
S No	Item	Total cost without Taxes & duties	custom duty	works tax	excise duty	sale tax	total	Total cost with tax & Duties
1	**Land**	**4**						**4**
2	**Civil Engg. Works**							
	Elevated section	28.60	0.00	0.05	1.14	0.07	1.26	29.86
	Station bldg ele.	12.00	0.00	0.02	0.48	0.03	0.53	12.53
	Misc.like Utilities etc.	4.90	0.00	0.01	0.00	0.01	0.02	4.92
	Permanent way	6.44	2.67	0.01	0.27	0.02	2.96	9.40
3	**Electrical works**							
	Traction and power supply	6.50	0.16	0.32	0.56	1.29	2.34	8.84
	Lifts & Esclators	4.00	0.47	0.01	0.42	0.04	0.93	4.93
4	**S and T Works**							
	S & T	14.95	3.36	0.60	0.12	0.03	4.11	19.06
	AFC	2.50	0.56	0.10	0.02	0.00	0.69	3.19
5	General Charges and Contigencies	4.99						4.99
	Total	**88.88**	**7.23**	**1.11**	**3.01**	**1.49**	**12.84**	**101.72**
	Total Taxes & Duties					**SAY**	**102**	**Crores**

	Annexure 10.3 b							
		Godrej Depot						
			Taxes and duties					**Total cost with tax & Duties**
		Total cost without Taxes & duties	**custom duty**	**works tax**	**excise duty**	**sale tax**	**total**	
1	**Land**	**294.4**						**294.4**
2	**Civil Engg. Works**							
	Elevated section	27.78	0.00	0.00	1.11	0.00	1.11	28.89
	Station bldg ele.		0.00	0.00	0.00	0.00	0.00	0.00
	Misc.like Utilities etc.	4.25	0.00	0.00	0.00	0.00	0.00	4.25
	Permanent way	8.04	3.33	0.00	0.33	0.00	3.67	11.71
3	**Electrical works**							
	Traction and power supply	8.13	0.20	0.40	0.70	1.62	2.92	11.05
4	**S and T Works**							
	S & T	8.13	1.83	0.33	0.06	0.02	2.24	10.37
5	Depot	100.00	11.37	1.81	1.36	1.50	16.04	116.04
5	General Charges and Contigencies	18.35						18.35
	Total	**469.08**	**16.74**	**2.54**	**3.57**	**3.13**	**25.98**	**495.06**
	Total with Taxes & Duties					**SAY**	**495**	**Crores**

CHAPTER 11

FINANCIAL VIABILITY, FARE STRUCTURE AND FINANCING OPTIONS

11.1 INTRODUCTION

The Ghatkopar – Andheri – Versova Line of Mumbai Metro is proposed to be constructed from 2006-2009. The fixed cost of the project at June 2004 prices is estimated to be Rs. 1488 crore, excluding taxes and duties but including the cost of land (Rs. 305 crore). With an estimated escalation factor of 5% p.a. the project would cost Rs. 1720 crore on completion. This cost does not include the element of interest during construction (IDC). Land cost is not escalated since land acquisition would have to be completed in the initial two years of the construction period and, hence, should not invite any escalation.

11.2 Costs

11.2.1 Investment Cost

11.2.1.1 For the purpose of calculating the Financial Internal Rate of Return (FIRR), the completion cost of Rs. 1720 crore has been taken as the initial investment. The cash flow of this investment is in **Table –11.1** below.

Table 11.1 Year –wise Investment

Figs in Rs. Cr.

Year	Construction Cost (Fixed)	Land Cost	Completion Cost
2006-07	59	152.50	217
2007-08	414	152.50	628
2008-09	473		571
2009-10	177		225
2010-11	59		79
Total	1183	305	1720

11.2.1.2 Although the construction is expected to get over by 31st March 2009 the cash flow spills up to March 2011 on account of payment normally required to be made to the various contractors up to that period necessitated by contractual clauses.

11.2.1.3 The land cost is divided into two initial years during which it is expected that the land acquisition work would be over and related payments would have to be released.

11.2.1.4 The escalation factor used is 5% p.a.

11.2.1.5 These costs do not take into account taxes and duties. In case taxes and duties are taken into account the fixed cost at June 2004 prices is estimated at Rs. 1670 crore and the completion cost at Rs. 1936 crore.

11.2.2 Additional Investment

Total additional investment cost of Rs.108 crore (at June 2004 price level) has been provided in the years 2024 and 2034. These costs have been provided to take care of increased requirement of Rolling Stock and related equipment on account of the increased traffic since the existing rolling stock would be insufficient to carry the traffic estimated in these years. These costs have been brought to the current price level by using an escalation factor of 5% p.a.

11.2.3 Operation & Maintenance Costs

11.2.3.1 The Operation & Maintenance costs can be divided into three major parts:

- (i) Staff costs
- (ii) Maintenance cost which include expenditure towards upkeep and maintenance of the system and consumables
- (iii) Energy costs

11.2.3.2 The staff is assumed to be provided @ 45 persons per kilometer and the annual cost on this account in the year 2009 is estimated at Rs. 20.19 crore. The escalation factor used for staff costs is 9% per annum to provide for both escalation and growth in salaries.

11.2.3.3 The cost of other expenses is based on the O & M unit cost expected for the Delhi Metro Phase-1 project. The rate of electricity assumed in the Delhi Metro study is about Rs. 2.30 per unit whereas at present in Mumbai the applicable rate is Rs. 4.50 per unit. The latter has been used for all calculations. The O&M cost for Mumbai metro (excluding staff cost) has been obtained by providing an escalation of 5% per annum.

11.2.3.4 The total O&M cost in the year 2009 is expected to be Rs. 75.39 crore. The year-wise O&M costs are as indicated in **Table 11.2** below:

Table 11.2 Operation and Maintenance Costs
Figs in Rs. Cr.

Year	Staff	Maintenance Expenses	Energy	Total
2009	20.19	36.25	18.95	75.39
2010	22.00	38.06	19.90	79.97
2011	23.98	39.97	20.90	84.85
2012	26.14	41.97	21.94	90.05
2013	28.49	44.06	23.04	95.60
2014	31.06	46.27	24.19	101.52
2015	33.85	48.58	25.40	107.83
2016	36.90	51.01	26.67	114.58
2017	40.22	53.56	28.00	121.79
2018	43.84	56.24	29.40	129.48
2019	47.79	60.23	30.87	138.89
2020	52.09	64.51	32.42	149.01
2021	56.78	75.86	37.28	169.92
2022	61.89	81.25	39.14	182.28
2023	67.46	87.02	41.10	195.57
2024	73.53	93.20	43.15	209.88
2025	80.14	99.81	45.31	225.27

2026	87.36	106.90	47.58	241.83
2027	95.22	114.49	49.96	259.66
2028	103.79	122.62	52.45	278.86
2029	113.13	131.32	55.08	299.53
2030	123.31	140.65	57.83	321.79
2031	134.41	165.40	66.51	366.32
2032	146.51	177.14	69.83	393.48
2033	159.69	189.72	73.32	422.74
2034	174.07	203.19	76.99	454.25
2035	189.73	217.62	80.84	488.19
2036	206.81	233.07	84.88	524.76
2037	225.42	249.62	89.12	564.16
2038	245.71	267.34	93.58	606.63
2039	267.82	286.32	98.26	652.40
2040	291.93	306.65	103.17	701.75
2041	318.20	328.42	108.33	754.95
2042	346.84	351.74	113.75	812.32
2043	378.05	376.71	119.43	874.20

11.2.4 Depreciation

Although depreciation does not enter the FIRR calculation (not being a cash outflow) unless a specific depreciation reserve fund has been provided, in the present calculation, depreciation calculations are placed for purpose of record. These are taken @ 3% of the total completion cost adjusted for land cost.

11.2.5 Replacement Cost

The replacement costs are provided for meeting the cost on account of replacement of equipment due to wear and tear. With the nature of equipment proposed to be provided for Mumbai Metro, it is expected that only 10% of the equipment comprising signalling and electrical works would require replacement after 20 years. These roughly add up to 10% of the project cost. Further, 25% of the project cost comprising Rolling Stock and traction is expected to have a life of 30 years after which it shall be required to be replaced. These costs have been provided duly escalated @ of 5% per annum.

11.2.6 The interest charge on the loan is assumed to be 11%. The IDC element forms part of the principal amount of the loan to be repaid as part of the loan.

11.3 Revenues

11.3.1 Fare box

11.3.1.1 Traffic

11.3.1.1 a. In the year 2009 traffic has been estimated at 3.91 lakh trips per day. This is 50% of the traffic projected for full phase 1 operations. Traffic has been taken as 60% of the projected traffic in the years 2021 & 2031.These percentages have been applied to full phase1 traffic since with a single sectional functioning traffic is likely to be restricted to about 60%. Further, for the year 2011 this has been taken as 50% since traffic develops with a lagged effect. The traffic figure for 2009 has been derived from the growth factor for the traffic from 2011-2021.

Year	Trips per day @ 60% of full network traffic
2009	3.91
2011	4.28 (50%)
2021	6.65
2031	8.83

11.3.1.1 b.The growth rate for traffic from 2011 to 2021 is assumed at 4.51% per annum and after 2021 @ 2.88% per annum.

11.3.1.2 Trip Distribution

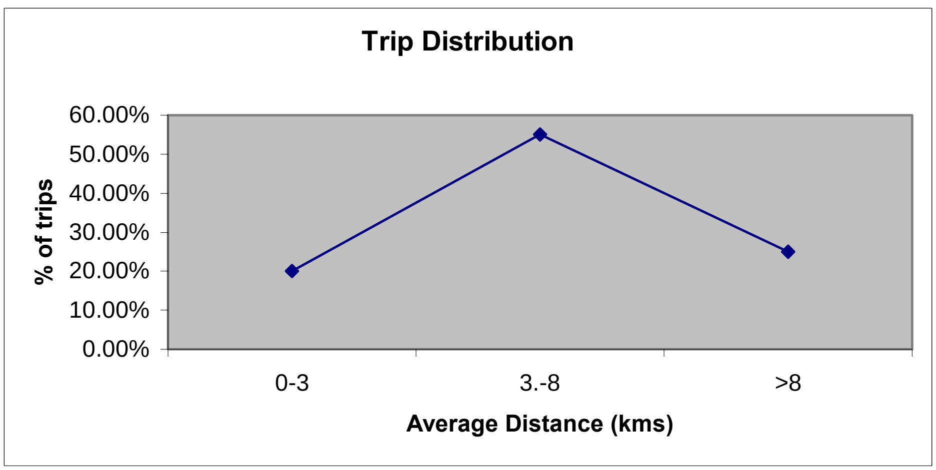
The distribution has been assumed as in **Table 11.3** below: -

Table 11.3 Trip Distribution

Distance in kms.	Percent distribution
0-3	20%
3-8	55%
>8	25%

The graphic presentation of the same is placed below in **Figure-11.1**.

Figure 11.1 –Trip Distribution



11.3.1.3 Fare Structure

The fare structure has been estimated @ 1.5 times of the ordinary bus fare prevalent in the year 2009. The present bus fares have been merged into three slabs and the bus fare for the year 2009 have been obtained by escalating the existing BEST fares by an overall factor of 10%. The metro fare obtained by multiplying the bus fare by 1.5 times has been rounded off to the closest rupee. These fares have been escalated once every two years @ 5% per annum since it is not possible to carry out changes in fare every year. The fare table used is as depicted in **Table 11.4**.

Table 11.4 Fare Structure in 2009

Distance in kms	Bus Fare - 2004	Bus Fare - 2009	1.5 times bus fare	Metro fare - 2009
0-3	3	3.3	4.95	5
3.-8	5	5.5	8.25	8
>8	7.5	8.25	12.38	12

11.3.2 Other sources of revenues

Other revenues from Property Development and advertisement have been estimated at 5% of the fare box revenues. Apart from development of property on metro stations and depot it is possible to raise resources through leasing of parking rights at stations, advertisement on trains and tickets, advertisements within stations and parking lots, advertisements on viaducts, columns and other metro structures, co-branding rights to corporates, film shootings and special events on metro premises.

11.4 Financial Internal Rate of Return (FIRR) and Return on Equity

11.4.1 The Financial Internal Rate of Return (FIRR) obtained with the above revenues and costs is 7.56 % over a horizon period of 30 years of operation (2009-2039). This is produced in **Table 11.5**.

Table 11.5 –FIRR
Figs in cr. (Rs.)

Year	Completion Cost and Additional Capital	Running Expenses	Replacement Costs	Total Costs	Fare Box Revenue	PD & ADVT	Total Revenue	Net Cash Flow For IRR
2006	217			217			0	-217
2007	628			628			0	-628
2008	571			571			0	-571
2009	225	75.39		300	114.73	5.7	120.46	-180
2010	79	79.97		159	119.90	6.0	125.89	-33
2011	0	84.85		85	138.15	6.9	145.06	60
2012	0	90.05		90	144.38	7.2	151.60	62
2013	0	95.60		96	166.36	8.3	174.68	79
2014	0	101.52		102	173.87	8.7	182.56	81
2015	0	107.83		108	200.33	10.0	210.35	103
2016	0	114.58		115	209.37	10.5	219.84	105
2017	0	121.79		122	241.24	12.1	253.30	132
2018	0	129.48		129	252.12	12.6	264.72	135
2019	0	138.89		139	290.50	14.5	305.02	166
2020	0	149.01		149	303.60	15.2	318.78	170
2021	82	169.92		252	349.81	17.5	367.30	116
2022	0	182.28		182	359.89	18.0	377.88	196
2023	0	195.57		196	408.20	20.4	428.61	233
2024	0	209.88		210	419.96	21.0	440.96	231
2025	0	225.27		225	476.34	23.8	500.16	275

2026	0	241.83		242	490.06	24.5	514.56	273
2027	0	259.66		260	555.85	27.8	583.64	324
2028	0	278.86		279	571.86	28.6	600.45	322
2029	0	299.53	289	588	648.63	32.4	681.06	93
2030	0	321.79	303	625	667.31	33.4	700.68	76
2031	267	366.32		633	756.90	37.8	794.74	162
2032	0	393.48		393	787.17	39.4	826.53	433
2033	0	422.74		423	902.57	45.1	947.70	525
2034	0	454.25		454	938.68	46.9	985.61	531
2035	0	488.19		488	1076.29	53.8	1130.10	642
2036	0	524.76		525	1119.34	56.0	1175.31	651
2037	0	564.16		564	1283.43	64.2	1347.61	783
2038	0	606.63		607	1334.77	66.7	1401.51	795
2039	0	652.40	2351	3004	1530.45	76.5	1606.97	-1397
	2067	**8146**	**2943**	**13157**	**17032**	**852**	**17884**	**7.56%**

The FIRR, in case taxes and duties are included in the project cost, is placed as Annexure 1. The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in **Table 11.6** below: -

Table 11.6 –FIRR Sensitivity

	CAPITAL COSTS			
	20% Increase	10% Increase	10% decrease	5% Decrease
FIRR	6.02%	6.77%	8.43%	7.99%
	REVENUES			
	5% Increase	10% Increase	10% Decrease	20% decrease
FIRR	8.33%	9.04%	5.73%	3.12%
	O&M COSTS			
	10% Increase	10% Decrease		
FIRR	6.75%	8.31%		

These sensitivities have been carried out independently for each factor.

11.4.2 The post tax return on equity is 6.73% (Annexure 2). In case taxes and duties are also included in the cost the return on equity falls to 5%. In such a scenario it would be difficult to sustain the project on its own and government support would be required. The level of support required (assuming inclusion of taxes and duties in the project cost) in the scenario of debt equity ratio of 1.5:1 is as shown in **Table 11.7**.

Table 11.7

Government Support (Rs. Cr.)	Return on Equity (post tax)
50	5.37%
100	5.76%
150	6.11%

200	6.46%
250	6.85%
300	7.23%
350	7.61%
400	8.01%
450	8.42%
500	8.86%
550	9.29%
600	9.70%
650	10.17%
700	10.61%
750	11.06%

Annexures 3 & 4 depict the cashflows with a grant of Rs. 500 crore and Rs. 750 crore respectively in the scenario of D/E ratio of 1.5:1. Annexures 5 & 6 show the cashflows with a grant of Rs. 500 crore and Rs. 750 crore in the D/E ratio of 2:1.

11.5 Financing Options

11.5.1 Background

11.5.1.1 Rail-based systems are heavily capital intensive with long gestation periods. They are viewed more as investments with a view to increasing the economic benefits to the society at large rather than yielding high financial rates of return. Very few metros all over the world are able to cover their operating costs and therefore grants and subsidies for operations as well as additional investments are the order of the day. However, history is full of examples where volume of traffic is not very high except in areas like Japan and Hong Kong. Since costs of operation are more or less fixed in nature, any increase in passenger volumes would improve the viability of the system. There are other issues peculiar to this nature of travel. The setting up of such systems generates externalities which normally do not get monetised and flow back to the system to sustain its development. In other words, the economic benefits flowing to the society and other benefits generated by the setting up of metro systems do not get translated to monetary benefits for the system itself. Very few countries have been able to channelise these as sources of revenue back to the system.

11.5.1.2 Since the governing objective of setting up these systems is social the fares are set at levels which are publicly and politically acceptable thus setting in the vicious cycle of deficits leading to a fallback on subsidies/government support.

11.5.2 Alternative Models of Financing

11.5.2.1 A wide variety of models can be theoretically considered for financing of metros ranging from completely government owned to totally privatised. There are certain benefits and drawbacks of both. Whereas completely government owned lack transparency and are shackled by bureaucracy the completely privately owned ones would not serve the social sector but be lured by the objective of profit maximisation. The social purpose of such projects can never be ignored, however, at the same time it is of utmost importance to run these systems with efficiency comparable to the private sector. These purposes can be served by creating an SPV independent of the bureaucratic controls and vested with sufficient powers to run the system independently or be evolving some form of Public –Private partnership which would bring together the strengths of both the public and private sectors. The Delhi metro model is the SPV model which has been able to construct and run the system efficiently without compromising the social objective.

11.5.2.2 SPV Approach: The Corporate model involves the formation of a special purpose vehicle (SPV) to own/implement and also to operate the project. There is a possibility/potential of involving some private sector entity as equity holder. The financial structure of the project can then be determined in such a way that a part of the capital cost is contributed as equity and the remaining is borrowed as senior or subordinate debt from the government, financial institutions, banks or bilateral / multilateral funding agencies. Another source of funding which has been extensively used in Hong Kong is funds from real estate development for financing capital expenditure. In this case upfront contribution required from the equity holders is much less than the project cost. The debt and the interest there on are repaid by the SPV from its net revenue streams. Long time debt is normally possible only when government guarantees are made available for repayment of loan as well as for the interest charges there on. Because of the need for high volume of debts, the project viability depends to a large extent on the rate of interest and the tenure of the debt. The SPV, being a corporate body, has flexibility in implementation and operation of the project. It can be responsive to customer requirement and can attempt various ways of revenue augmentation. SPV being a corporate body is liable to pay corporate tax and other taxes if applicable. The above model can be further improved upon if after construction the SPV hands over the operations and maintenance of the same to a private body.

11.5.2.3 Public-Private Partnerships

11.5.2.3.1The various forms Public-private partnerships can take are *Supply and service contracts, Management contracts, Leases*, *Concessions, Joint ventures and Divestiture.* Supply and service contracts and management contracts are in the nature of contracts awarded to a private party as out sourced jobs or management of the operations. Concessions not only give the private operator the responsibility of O&M of utility asset but also for investment. The ownership remains with the government but full use rights vest with the operator. Concessions are a form of lease in which the contractor agrees to make certain fixed investments and retains the use of the assets for a longer contract period. In this approach, the state (or municipality or other public entity) delegates the right to provide a service to the private sector and yet retains some control over the sector by incorporating a concession contract or license defining the terms and conditions (including the rights and obligations of the service provider) that will govern the infrastructure project or company. This type of arrangement is most suited to sectors with monopolistic characteristics. This may take the form of lease and operate (or affermage) contract, under which the private contractor is responsible at his own risk for providing the service, including operation and maintenance of the infrastructure against payment of a lease fee. The other forms of concession could be BOOT/BOT/BOO. These are used generally for Greenfield projects. The concessionare in such projects is also responsible for building and financing new investments. At the end of the concession term the sector assets are returned to the state. BOO (build own operate) is a similar scheme but it does not involve transfer of assets. All these forms of concession stipulate transferring of the right and the obligation to provide an infrastructure service to a private company. This company takes over responsibility for the operations and at least for a part of the commercial risk of service provision. The concessionaire is, by and large, held responsible for achieving specified results in service delivery and is given some freedom to choose the means for meeting those targets.

11.5.2.3.2 The success of this type of contracts depends on their duration which reflects the number of years the investors need to recoup their investment. In the French style concessions (affermage) the assets return to the state at the end of the period free of charge or for a nominal amount. The public authority remains responsible for financing most investments; hence, affermage are shorter (10-15 years) than Greenfield BOTs or concessions requiring major upfront capital expenditures. In the latter cases these can exceed 30 years.

11.5.2.3.3 The concessionaire approach has not been adopted in the rail based urban transit system in India because the project construction costs are very high. This naturally involves requirement of huge amount of debt to be raised from the market sources to undertake such a project. The highway sector has been quite successful in the country in developing Highway projects through the BOT .Power sector has a very limited experience of project development under BOO route.

11.5.2.3.4 It is important to understand that project beyond the size of Rs 300 cr have not been successful in attracting debt in the Indian market. Recent experience of road sector suggests that projects in the size of Rs 50 to Rs 200 cr could only be developed under BOT mechanism, with majority of projects in the lower end category. The success of these projects was solely dependent on the assurance of traffic or revenue. These projects were based on a clearly defined risk mitigation mechanism.

11.5.2.3.5 There is no available history to justify the development of mega transport projects under BOT route in India except in the case of Konkan Railway Corporation. KRCL was the first effort by the Indian Railways in the form of a corporate enterprise for the construction of a railway track. The finances for KRCL came from the promoters – the Ministry of Railways and the State governments of Goa, Maharashtra, Karnataka and Kerala- and the issue of tax-free bonds. The funds could be secured at an average cost of 11%. . This emerges from the inability of the major debt market players to provide resources for large projects. The other, and the most important factor responsible for the inability of raise resources from the market is the inability of project developer to come out with a risk mitigation mechanism acceptable to the lenders.

11.5.3 Options for Financing of Mumbai Metro

11.5.3.1 The consultant is of the view that two possibilities regarding funding of Mumbai metro can be examined. The first is the SPV model based on the Delhi Metro approach. In this model the element of equity contribution by the government is suggested at 40% against 28% in Delhi Metro since in the case of the latter the exchange rate fluctuation risk is being borne by the government. Apart from this the land cost should be made available by the State government. The balance amount of funds (41% of project cost) should be raised by external/ domestic debt. The external debt is characterised by exchange rate fluctuation whereas the domestic debt rates are much higher as compared to external funding. Government guarantees would be required in both the cases.

11.5.3.2 The second possibility of funding Mumbai metro is through the PPP route. The land would be made available to the concessionaire free of cost and of the balance project cost 40% would be funded out of equity. The share of the government in the equity would be 26% and the balance would have to be brought in by the concessionaire. It is also presumed that the additional capital required in the years 2024 and 2034 would be shared in the same proportion as the original investment. The residual value of the investment at the end of the concession would be nil. The cashflows showing the concessionaire's expected position are shown in Annexures 7 & 8.

11.5.3.3 In this option Mumbai Metro Rail Corporation's (MMRC) role would be limited to that of a regulatory authority. Thus MMRC would monitor the implementation of the project and on its commissioning perform the tasks such as laying down passenger fares, targets for the minimum number of services to be run by the Concessionaire, their frequency, punctuality, reliability and safety, etc. MMRC, in this option, will have to enter into an agreement with the Concessionaire clearly listing out obligations and rights of the Concessionaire and the client. Following are the important terms, which are usually included in the agreement.

- Land required for the project and equity for the project shall be made available to the Concessionaire. The balance project cost is to be mobilised by the Concessionaire himself.
- Implementation of the project and its subsequent operation and maintenance is to be the responsibility of the Concessionaire. The concession is for a period of 30 years of construction plus the period of construction.
- A guarantee for the minimum level of ridership would be required to be given to the concessionaire. If this level of ridership does not materialize for any reason, the Concessionaire will have to be compensated for the shortfall.
- Operation and maintenance expenditure for the project shall be borne by the Concessionaire. All revenues generated shall go to the Concessionaire including revenues from property development, advertisements, etc.
- Standards to which the assets of the project are required to be maintained and the quality of the assets at the time of transfer of these assets to the Client at the end of the concession period should be clearly spelt out.

- Normally a metro system will require addition of assets like rolling stock, etc. over a period of time due to increase in traffic. The source of funding of the same is explicitly spelt out in the agreement — the Concessionaire or the Client. Similarly, the responsibility of replacement of assets on completion of their life, if due during the period of Concession, is clearly spelt out — whether by the client or the Concessionaire.
- A mechanism for quick resolution of disputes between the Concessionaire and the Client is provided for.
- Insurance liability of the Concessionaire is indicated.
- The Concessionaire transfers all the assets to the Client at the end of the concession period at a nominal residual value.

11.6 IMPLEMENTATION THROUGH PPP

Generally a MRTS project is high cost infrastructure project and normally implemented through governmental support. There are very few examples of undertaking an urban transport project through Public - Private Partnership (PPP). However at present Government of India is encouraging private participation in the infrastructure projects. It is felt that the MRTS on Versova - Andheri - Ghatkopar corridor can be implemented through PPP due to following reasons:

i) The corridor is very busy and congested.
ii) This will provide link between Central and Western Railway suburban system connecting suburbs on the east and west side
iii) Considerable reduction in Journey time (more than 50%)
iv) Metro is more reliable, efficient and provides more comfort at very reasonable price.
v) Commuters in Mumbai are habitual of public transport as modal share in favour of public transport is 88%.
vi) The length of the corridor is about 12 km and doesn't cost very high for private participation
vii) Likelihood of connecting with North - South Corridor which shall help in increases in ridership.

However, the response for the same will be known only after testing the market. The only risk involved is loss of time in case of insufficient response. This would lead to cost overruns.

11.7 RISK ANALYSIS

Normally certain risks are involved with the implementation of such large infrastructure projects. These risks are enhanced with implementation through PPP. The major risks involved are:-

- Construction risk
- Revenue risk
- Operations risk
- Financial risk
- Legal risk
- Commercial risk
- Exchange rate risk
- Policy risk

- Guarantees
- Exclusivity
- Speed of process

Table 11.8 identifies some of the main risks in the project and suggested mitigation measures. However, as mentioned earlier, the work of selection of suitable concessionaire should be done through specialised consultant as success of implementation of Metro project on PPP shall depend on suitable concessionaire.

Table 11.8
Risk Mitigation Measures

Main Risks	**Risk Mitigation measures**	**Relevant Document(s)/ contract(s) to cover the risk**
Commuter Volume Risk	No competitive mode of public transport Due diligence by concessionaire on traffic risk Traffic risk guarantee not a solution as the same encourages inefficiencies	NIL
Passenger Fare Increase Risk	The fares of rail as well as well as competing bus system should be set by an independent regulator to ensure that bus fares are not subsidized Better if independent regulator is in place before grant of license or concession	Safety clause in concession on setting up of regulator.
Increase in Capital Cost and implementation period	Lump sum fixed time construction contract with considerable penalty and bonus provision	EPC Contract
Poor Maintenance of Infrastructure	Penalty for poor upkeep. Agreement should provide for detailed specification and standards.	Technical audit by regulator to be provided for in concession/ license agreement.
Risk of bankruptcy in case of poor financial returns	Competent financial advisor to help avoid over-zealous bids.	Proper conditions in the agreement for take over of assets and smooth O&M in case of bankruptcy
Non Performance by Concessionaire	Selection of competent consultant for bid process management Proper pre-qualification and selection process Reasonable equity stake in project vehicle	Relevant clauses in the Bid document and Agreement

	compulsory for main operator Adequate Performance Guarantees from the Concessionaire	
Poor maintenance of rolling stock	Penalty for poor upkeep.	Agreement should provide for detailed specification and standards.
Insufficient investment in trains sets	To be covered under minimum frequency clause for which train sets for peak and non-peak periods has to maintained	Specific provisions in agreement for frequency during peak and non-peak period. Some flexibility to concessionaire necessary for the sake of financial viability
Safety Risk	Mandatory filing of safety plan with Regulator and implementation of the same Continuous monitoring of safety plan, with stiff penalty for non compliance Proper Disaster Management Plan to be in place in coordination with other civic authorities	Concession/ License Agreement
Law and order risk in trains, as well as, at stations	Government to assist concessionaire on stations. Concessionaire to hire security staff for security during operations. The concessionaire security staff to work under overall supervision of state police	Agreement Conditions
Risks associated with any public utility serving people at large.	Protection against fire, rioting, general stampede Insurances and better management through trained security personnel in trains as well as at stations.	Concession Agreement to provide for insurances, as well as, for level of training required for the staff
Natural and force majeure risks	Insurances, Insurance costs to be part of cash flows	Concession Agreement and Contract Agreements to ensure proper coverage

Direct and Indirect Political Risk	GOM to ensure payment of Debt Due and equity investments on line of NHAI policy in case of Direct and In-Direct political risk events Political risk insurances may prove costly and counter productive for the project Lower equity and investment and more management commitment may reduce overall political risk on investment.	Concession Agreement to provide for payments in case of such events
Third party Liability risk	Insurances, Insurance costs to be part of cash flows	Concession Agreement to specify amount and type of Insurances to be maintained and assignments
Financing Risk	Concessionaire to bear the risk. Pre-qualification process and specific guarantee to ensure financial strength of the Concessionaire Financial closure condition must before start of condition.	Concession/ License agreement
Regulatory risk	Concessionaire to bear the risk Competent, independent Regulator. Clear and unambiguous scope of regulation Appeal process should be available	Concession Agreement
Legal Risk	GOM and Concessionaire Enact and notify the required laws	Concession Agreement to mention enactment of laws (if required) as conditions precedent

11.8 RECOMMENDATIONS

It is felt that the response to an attempt at PPP may not be encouraging unless the government agrees to give an upfront subsidy of Rs. 500-750 crore (depending on the exemptions and relaxations made available) to the project apart from the equity contribution. Hence, it is recommended that the SPV model may be followed for Mumbai Metro. The component of debt, not being very high in absolute terms, could be arranged through the domestic market or by tapping external sources of debt. This effort would be strengthened by the fact that the Project FIRR is 7.56%.

Annexure 1

PROJECT FIRR

Year	Completion Cost	Running Expenses	Depreciation	Replacement Costs	Total Costs	Fare Box Revenue	Pd & Advt	Total Revenue	Net Cash Flow For IRR
2006	227				227			0	-227
2007	701				701			0	-701
2008	658				658			0	-658
2009	259	75.39	49.41		335	114.73	5.7	120.46	-214
2010	91	79.97	49.41		171	119.90	6.0	125.89	-45
2011	0	84.85	49.41		85	138.15	6.9	145.06	60
2012	0	90.05	49.41		90	144.38	7.2	151.60	62
2013	0	95.60	49.41		96	166.36	8.3	174.68	79
2014	0	101.52	49.41		102	173.87	8.7	182.56	81
2015	0	107.83	49.41		108	200.33	10.0	210.35	103
2016	0	114.58	49.41		115	209.37	10.5	219.84	105
2017	0	121.79	49.41		122	241.24	12.1	253.30	132
2018	0	129.48	49.41		129	252.12	12.6	264.72	135
2019	0	138.89	49.41		139	290.50	14.5	305.02	166
2020	0	149.01	49.41		149	303.60	15.2	318.78	170
2021	82	169.92	51.86		252	349.81	17.5	367.30	116
2022	0	182.28	51.86		182	359.89	18.0	377.88	196
2023	0	195.57	51.86		196	408.20	20.4	428.61	233
2024	0	209.88	51.86		210	419.96	21.0	440.96	231
2025	0	225.27	51.86		225	476.34	23.8	500.16	275
2026	0	241.83	51.86		242	490.06	24.5	514.56	273
2027	0	259.66	51.86		260	555.85	27.8	583.64	324
2028	0	278.86	51.86		279	571.86	28.6	600.45	322
2029	0	299.53	58.71	325	625	648.63	32.4	681.06	56
2030	0	321.79	66.05	341	663	667.31	33.4	700.68	37
2031	267	366.32	74.05		633	756.90	37.8	794.74	162
2032	0	393.48	74.05		393	787.17	39.4	826.53	433
2033	0	422.74	74.05		423	902.57	45.1	947.70	525
2034	0	454.25	74.05		454	938.68	46.9	985.61	531
2035	0	488.19	74.05		488	1076.29	53.8	1130.10	642
2036	0	524.76	74.05		525	1119.34	56.0	1175.31	651
2037	0	564.16	74.05		564	1283.43	64.2	1347.61	783
2038	0	606.63	74.05		607	1334.77	66.7	1401.51	795
2039	0	652.40	138.99	2649	3301	1530.45	76.5	1606.97	-1694
	2285	**8146**	**1864**	**3316**	**13747**	**17032**	**852**	**17884**	**6.60%**

RETURN ON TOTAL EQUITY (PROJECT COST WITHOUT TAX)								D/E RATIO	1.5 :1				ANNEXURE 2					
Year	Completion Cost	Running Expenses	Depreciation	Replacement Costs	Total Costs	Fare Box Revenue	PD & Advt	Total Revenue	Net Cash Flow For IRR	Equity	Loan	Repayment Of Loan	IDC + Financing Charges	Interest	PBT	Cumulative cash	Return on Equity - PRE TAX	Return on Equity - POST TAX
2004																		0
2005																		0
2006	217				217			0	-217	189	0						-189	-189
2007	628				628			0	-628	189	177		13.86				-189	-189
2008	571				571			0	-571	189	424		42.20		0		-189	-189
2009	225	75.39	44.37		300	114.73	5.7	120.46	-180	0	231		6.74	66	-65	-21	-21	-21
2010	79	79.97	44.37		159	119.90	6.0	125.90	-33	0	16		2.36	92	-90	-67	-46	-46
2011	0	84.85	44.37		85	138.15	6.9	145.06	60	0				93	-77	-100	-33	-33
2012	0	90.05	44.37		90	144.38	7.2	151.60	62	0				100	-83	-138	-39	-39
2013	0	95.60	44.37		96	166.36	8.3	174.68	79	0		91		100	-66	-251	-112	-112
2014	0	101.52	44.37		102	173.87	8.7	182.56	81	0		91		100	-64	-361	-110	-110
2015	0	107.83	44.37		108	200.33	10.0	210.35	103	0		91		90	-32	-440	-79	-79

2016	0	114.58	44.37		115	209.37	10.5	219.84	105	0		91		80	-19	-506	-66	-66
2017	0	121.79	44.37		122	241.24	12.1	253.30	132	0		91		70	17	-536	-30	-30
2018	0	129.48	44.37		129	252.12	12.6	264.72	135	0		91		60	31	-552	-16	-16
2019	0	138.89	44.37		139	290.50	14.5	305.02	166	0		91		50	72	-527	25	25
2020	0	149.01	44.37		149	303.60	15.2	318.78	170	0		91		40	85	-488	39	39
2021	82	169.92	46.83		252	349.81	17.5	367.30	116	33	49	91		30	120	-412	43	13
2022	0	182.28	46.83		182	359.89	18.0	377.88	196	0		101		25	123	-343	69	69
2023	0	195.57	46.83		196	408.20	20.4	428.61	233	0		10		15	171	-135	208	208
2024	0	209.88	46.83		210	419.96	21.0	440.96	231	0		10		4	180	82	217	217
2025	0	225.27	46.83		225	476.34	23.8	500.16	275	0		10		3	225	344	262	262
2026	0	241.83	46.83		242	490.06	24.5	514.56	273	0		10		2	224	605	261	261
2027	0	259.66	46.83		260	555.85	27.8	583.64	324	0		0		1	276	927	323	323
2028	0	278.86	46.83		279	571.86	28.6	600.45	322	0		0		0	275	1249	322	322
2029	0	299.53	52.91	289	588	648.63	32.4	681.06	93	0		0		0	329	1342	93	93
2030	0	321.79	59.42	303	625	667.3	33.4	700.6	76	0				0	319	1418	76	76

						1		8										
2031	267	366.32	67.42		633	756.90	37.8	794.74	162	107	160	32		0	361	1814	290	290
2032	0	393.48	65.47		393	787.17	39.4	826.53	433	0		32		18	350	2198	383	245
2033	0	422.74	65.47		423	902.57	45.1	947.70	525	0		32		14	445	2676	479	305
2034	0	454.25	65.47		454	938.68	46.9	985.61	531	0		32		11	455	3165	489	311
2035	0	488.19	65.47		488	1076.29	53.8	1130.10	642	0		32		7	569	3800	635	415
2036	0	524.76	65.47		525	1119.34	56.0	1175.31	651	0		0		4	582	4447	647	422
2037	0	564.16	65.47		564	1283.43	64.2	1347.61	783	0		0		0	718	5231	783	509
2038	0	606.63	65.47		607	1334.77	66.7	1401.51	795	0		0		0	729	6025	795	515
2039	0	652.40	65.47	2351	3004	1530.45	76.5	1606.97	-1397	0		0		0	889	4629	-1397	-1058
	2067	**8146**	**1611**	**2943**	**13157**	**17032**	**852**	**17884**	**7.56%**		**1057**	**1120**	**65**	**1077**	**7050**		**7.81%**	**6.73%**

Chapter 12
NOMIC ANALYSIS

12.0 INTRODUCTION

The purpose of the undertaking an economic evaluation is to provide a overall picture of the contributions of the MRT system to broadly defined social goals thereby justifying its implementation. The economic viability is commonly expressed in terms of Economic Internal Rate of Return (EIRR).

12.1 ECONOMIC ANALYSIS APPROACH

12.1.1 The economic appraisal of MRT Corridor from Varsova- Andheri to Ghatkopar in Mumbai has been carried out within the broad framework of Social Cost ï Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the ñwithò and ñwithoutò project scenario. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices. This has been done to iron out distortions due to externalities and anomalies arising in real world pricing systems. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost/ benefit and to calculate the economic viability of the project in terms of EIRR.

12.1.2 The Economic Internal Rate of Return (EIRR) for the project has then been arrived using Discounted Cash Flow technique to the net benefit stream at economic prices.

12.2 EVALUATION ASSUMPTIONS

The key evaluation assumptions used in the economic evaluation are listed in **Table 12.1**

Table 12.1 KEY EVALUATION ASSUMPTIONS

PARAMETER	ASSUMPTION
Price Level	Juneó2004
First year of operation	2009
Last year of operation	2039
Construction period	3 years (2006-2009)
Daily to annual factor	340

12.3 ESTIMATION OF COSTS

12.3.1 The project cost comprises capital cost, operation and maintenance cost . Cost components considered for the purpose of this exercise include:

- Capital cost of infrastructure (civil engineering, land, track, power supply, traction system, signalling and telecommunications, etc.) and rolling stock.
- Operating cost of MRTS

e estimated cost (Rs. in Crores) to economy for par Corridor of Mumbai MRTS. The completion cost is estimated at Rs. 1720 Cr. assuming escalation factor of 5%.

TABLE 11.2
ESTIMATED COST TO ECONOMY FOR VARSOVA - ANDHERI-GHATKOPAR CORRIDOR OF MUMBAI MRTS IN 2010

SYSTEM	COST	Rs. In Crores
MRTS	Capital cost (AT JUNE 2004 PRICES)	1488
	Completion Cost	1720
	Operating Cost	79.97

12.4 ESTIMATION OF BENEFITS

12.4.1 The Varsova - Andheri- Ghatkopar corridor of Mumbai MRTS will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain socio-economic benefits. Introduction of MRT will result in reduction in number of buses, usage of private vehicles, air pollution and increase the speed of road-based vehicles. This, in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general.

12.4.2. The benefit stream that has been evaluated and quantified includes:

- Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing bus system and private vehicles in case MRTS project is not taken up.
- Savings in operating costs of all buses and other vehicles due to de-congestion including those that would continue to use the existing transport network even after the MRTS is introduced.
- Savings in time of commuters using the MRTS over the existing transport modes because of faster speed of MRTS.
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of MRTS.

rastructure and development costs that would be ncrease in traffic, in case MRTS is not introduced.

- Savings in fuel consumption on account of less number of vehicles on road and decongestion effect with introduction of MRTS are included in those of vehicle operating cost.

The values used for various parameters used for the analysis are given in Appendix ï 1.

12.4.3 Quantification of some of the social benefits has not been attempted because universally acceptable norms do not exist to facilitate such an exercise. However, it has been considered appropriate to highlight the same, as given below:

- Reduced road stress
- Better accessibility to facilities in the influence area
- Economic stimulation in the micro region of the infrastructure
- Increased business opportunities
- Overall increased mobility
- Facilitating better planning and up-gradation of influence area.
- Improving the image of the city.

12.5 TRANSPORT DEMAND ON MRT CORRIDOR

12.5.1 At present the transport demand on Varsova - Andheri- Ghatkopar is being met mostly by buses operated by BEST and by suburban trains with interchange at Dadar station. Part of the demand is also met by IPT modes and private modes. As explained in Chapter 11, the transport demand for various years is given in **Table 12.3.** The growth of traffic between 2011 ï 2021 is assumed at 4.51% per annum and after 2021 @ 2.88%.

TABLE 12.3
TRANSPORT DEMAND FORECAST ON VARSOVA - ANDHERI-GHATKOPAR CORRIDOR OF MUMBAI MRTS

ITEM	2011	2021	2031
Total Trips (Lakh)	8.56	11,08	14.72
Trips on MRTS (Lakh)	4.28	6.65	8.83
Trips by other modes (Lakh)	4.28	4.43	5.89

12.5.2 The traffic on MRTS will come from shifting from traffic from buses, train, IPT and private modes. The major shifting of traffic would be from buses. It has been estimated that 210 buses are likely to decrease with the introduction of this MRT corridor. This will save Rs. 65.37 Crores in the year 2011 towards capital and operating cost of bus system. The saving in respect of private vehicles will be approx**.** Rs. 70.52Crores.

CONGESTION

ds reducing the congestion and journey time on roads because of diversion of some traffic to MRTS. Reduction in traffic congestion will save the necessary capital investment and vehicle operating cost as well as increase in time saved per vehicle. With the implementation this MRTS corridor, the savings from operating costs due to decongestion effect of MRTS has been estimated to be Rs 55.60 Crore in the year 2011.

12.7 REDUCTION IN FUEL CONSUMPTION

12.7.1 Savings in fuel consumption with the introduction of Mumbai MRTS have already been included in savings of vehicle operating cost. The effect of MRTS on fuel savings alone has been calculated separately as follows. The main fuels used in vehicles are CNG and petrol. The saving because of fuel alone from the savings in vehicle operating costs and savings due to decongestion effect for the year 2011 works out to Rs 47.22 Crore as shown in **Table 12.3**.

TABLE 12.3
SAVINGS IN FUEL ALONE WITH THE PROJECT SCENARIO IN YEAR 2011
(Rs. in Crores)

PARAMETERS	SAVINGS
Savings in CNG/Diesel due to - Less number of vehicles - Decongestion effect	 11.92 1.69
Savings in Petrol due to - Less number of vehicles - Decongestion effect	 15.64 17.96
TOTAL	**47.22**

12.8 PASSENGER TIME SAVING

12.8.1 With the introduction of Mumbai MRTS, there will be reduction in traffic congestion on the roads and correspondingly, there will be saving in time of commuters travelling by various modes of road transport. Similarly, MRTS System itself being faster than conventional road transport modes, will also lead to considerable saving in time of commuters travelling on MRTS. The passenger timesavings per passenger would be maximum for train passengers who are taking change over at Dadar. With the implementation of the project the passenger timesavings are estimated at Rs.133.57 Crore for the year 2011.

12.9 SAFETY

12.9.1 The reduction in traffic volumes on roads brought about by modal transfer to Varsova - Andheri- Ghatkopar MRTS is expected to reduce number of accidents. Any reduction in number of accidents will involve savings from damage to vehicles and savings towards medical and insurance expenses to persons involved in accidents. The benefits because of accidents prevented

MRTS corridor works out to Rs.1.39 Crores in the

12.10 REDUCED AIR POLLUTION

12.10.1The benefits because of saving in cost of prevention of vehicular pollution, with the implementation of Varsova - Andheri- Ghatkopar Corridor of Mumbai MRTS in the year 2011 is expected to be Rs 10.13Crores.

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12.11 SAVINGS IN ROAD INFRASTRUCTURE

12.11.1The MRT corridor may bring savings in investment in road infrastructure because shifting of passengers to MRT and withdrawal of vehicles in the project area. Since no local data is available concerning the road infrastructure investment on this account, this saving has not been incorporated into economic evaluation.

12.12 SHADOW PRICING

The value of Project cost and benefits have been expressed in terms of market prices. These prices, however, do not reflect the real resource cost and value of benefits derived from the project to the economy. The market prices are distorted due to variety of factors. These factors could be controlled/administered prices of inputs, monopolistic market of inputs, tax structure etc. The factors used for converting project inputs and output to economic costs are given in following **Table 12.4**

S.NO	ITEM	FACTOR
1	CAPITAL COST	0.85
2	OPERATIONS & MAINTENANCE COST	0.80
3	SAVINGS IN CAPITAL & OPERATING COST OF BUSES	0.89
4	SAVINGS IN CAPITAL & OPERATING COST OF PRIVATE VEHICLES	0.8
5	SAVINGS IN PASSENGER TIME	1.0
6	SAVINGS IN VOC	1.1
7	SAVINGS IN ACCIDENT COSTS	1.0
8	SAVINGS IN POLLUTION COSTS	1.0

12.13 RESULT OF ECONOMIC ANALYSIS

12.13.1 The cost and benefit streams for 38-year period in the economic prices have been worked out and presented in **Tables 12.5** for Varsova - Andheri-Ghatkopar corridor of Mumbai MRTS. The residual value of MRTS facilities (e.g. Metro and Rail corridors, equipment for power supply and tele-communication, rolling stock, etc.) in last year has not been taken into account as benefit in these tables. The total cost worked out on the above basis is then subtracted from the total benefits to estimate the net benefit of the project. This flow is then subjected to the process of discounting to work out the internal rate of return on the project, to examine the viability of the Project in Economic terms. Thereafter, the Project EIRR in economic terms has been arrived by using shadow prices.

erms works out to 21.53% for Varsova - Andheri-
bai MRTS.

12.14 SENSITIVITY ANALYSIS

12.14.1 A sensitivity analysis of the EIRR with 10% cost overrun and 10% reduction in traffic materialisation (separately) has been carried out. The EIRRs under these scenarios are given in **Table 12.6.**

TABLE 12.6

EIRRs - SENSITIVITY ANALYSIS

SENSITIVITY	EIRR (%)
Basic EIRR	21.53
With increase in cost by 10%	20.00
With reduction in traffic materialization by 10%	21.04
With 10% reduction in traffic and increase in cost by 10%	19.55

12.14.2 It can be seen from the above table that 10% increase in cost affect economic viability more than it does in case of reduction in traffic the project. Accordingly, it is recommended that controls should be exercised required for to keep the cost of construction under control.

CHAPTER 13

IMPLEMENTATION PLAN

13.1 WAY FORWARD FOR IMPLEMENTING THE PROJECT

On receipt of the Detailed Project Report, following action will require to be taken for implementing the Versova - Andheri - Ghatkopar section of Mumbai Metro project:

- Approval of the Detailed Project Report by Maharashtra State Government and the Central Government, both the Governments committing to an investment decision.

- Signing of an MOU between Maharashtra State Government and the Central Government for firming up arrangements for equity and other related items pertaining to this project.

- Setting up of a special purpose vehicle for implementing the project. *As per current status MMRDA has been nominated for implementing this corridor through Public – Private Partnership (PPP).*

- Providing legal cover for construction as well as operation and maintenance stages of the project.

- In case the project cann't be implemented through PPP, the two Governments to agree to financing of the debt portion of the project and also to the time frame for completing the project.

Normally above actions will require about 6 to 8 months. However selection of concessionaire may take one year. During this period the implementing agency can go ahead with the following preliminary work.

- Preliminary action for diversion of utility and preparation of estimates thereof.

- Reservation of land along the corridors, identification and survey for acquisition.

13.2 INSTITUTIONAL ARRANGEMENTS

To enable the Mumbai Metro rail project to be implemented without any loss of time and cost over-run, effective institutional arrangements would need to be set up. Details of these arrangements are explained below:

Two options are available to implement Mumbai Metro project. It may either be implemented through PPP, as decided by the Government of Maharashtra or as per DMRC model through SPV.

13.2.1 Special Purpose Vehicle

Experience of implementing Delhi Metro project has shown that a Special Purpose Vehicle (SPV), vested with adequate powers, is an effective organisational arrangement to implement and subsequently operate and maintain a metro rail project. An SPV should, therefore, be set up for Mumbai Metro and registered under the Companies Act, 1956. This SPV should be on the same lines as Delhi Metro Rail Corporation Ltd. (DMRC) and may be named as ôMumbai Metro Rail Corporation Ltd.ô (MMRC). Since equity will be contributed in equal proportion by the State and the Central Governments, it will have equal number of Directors on its Board from these two Governments. While the Managing Director of MMRC should be the nominee of the State Government, its Chairman should be the Secretary, Ministry of Urban Development & Poverty Alleviation, being the nominee of the Central Government. In order to avoid delays usually associated with bureaucratic process of decision-making, the Board of Directors (BOD) of MMRC should be vested with full powers needed to implement the project. The BOD, in turn, should delegate adequate powers to the Managing Director to take all decisions in day-to-day matters. The Managing Director should be a technocrat of proven record and impeccable integrity. A railway background would be an added advantage. A metro background would be most desirable.

13.3 Implementation Schedule (PPP)

The suggested implementation schedule for implementing the project on PPP basis is given in **Table 13.1.** As stated earlier, MMRDA is the implementing agency for Versova ï Andheri ï Ghatkopar corridor on PPP model.

Table 13.1
Suggested Implementation Schedule on BOT

S. No.	Item of Work	Completion Date
1	Approval of DPR	31.10.2004
2	Obtain Government Clearances	28.02.2005
3	Arranging Consultant for selection of concessionaire	Completed
4	Calling for Tender on BOT (Based on Feasibility Report)	In progress
5	Finalising Suitable Concessionaire	30.05.2005
6	Financial closer	30.11.2005
7	Execution of work and Procurement of equipments, coaches and installations	01.12.2008 ï 31.12.2008
8	Testing and Commissioning	01.12.2008 ï 3.12.2008
9	Revenue Operation	31.03.2009

The land acquisition process can start immediately after approval of DPR so that land is available before construction works take off.
It is also recommended to appoint an independent engineering consultant to monitor and advise MMRDA during the execution phase.

13.4 IMPLEMENTATION THROUGH SPV

In case the PPP approach is not successful, the project can be implemented through public sector as in case of Delhi. In such a case a SPV is to be formed on the pattern of Delhi Metro Rail Corporation (DMRC) and can be named as MMRC (Mumbai Metro Rail Corporation). Once the SPV formed, it has to take action for appointment of General Consultants for project management including preparation of tender documents. Till the General Consultants are in position, MMRC should appoint an interim Consultant for all preliminary and enabling jobs such as land acquisition, detailed design of civil structures, utility diversions, etc.

A suggested project implementation schedule is given below. The proposed date of commissioning of the section with suggested dates of important milestones is given in **Table 13.2**.

Table 13.2
Implementation Schedule through SPV

S. No.	Item of Work	Completion Date
1	Approval of DPR	31.01.2005
2	Obtain Government Clearances	28.02.2005
3	Attempt to fix Concessionaire	30.05.2005
4	Fix interim Consultant for preliminary works	30.06.2005
5	Fix General Consultant	31.12.2005
6	Tender Finalisation for Civil Works for Viaduct	30.06.2006
7	Execution of works and Procurement of equipments, coaches and installations	01.07.2006 - 31.06.2009
8	Testing and Commissioning	01.07.2009 - 30.09.2009
9	Revenue Operation	01.10.2009

13.4.1 Civil Works

All civil contracts will be on ñConstructò basis. Therefore all designs are to be finalised and progress in advance.

- Detailed design contracts for elevated structures/stations.
- Construction contracts for elevated structures/stations.

The number of contracts can be decided when the detailed design work is in progress. Architectural finishes, fire fighting arrangements and general electrification, will form part of civil contracts.

13.4.2 System Contracts

- Design, construct and installation for Traction and Power Supply.
- Design, construct and installation of Signal and Telecommunication works.
- Design, construct and installation of lifts.
- Design, construct and installation of escalators.
- Design, construct and commissioning of Automatic Fare Collection System.
- Design and supply of rolling stock.
- Installation of track in Depot and on main line.
- Design and installation of Signages.

13.4.3 Depot Contracts

Following contracts are proposed for Depot works:

- Design of Depot layout and buildings.
- Construction of Depot including general electrification.

Supply of Depot Equipment, the number of contracts may be decided as and when the work is in progress.

13. 5 ORGANIZATIONAL SET UP of MMRC

Implementing a metro project in a congested metropolis is indeed a challenge. In sheer size, magnitude and technical complexity there are no parallels to metro projects. Further, these projects are to be carried out in difficult urban environment without dislocating city life, while at the same time preserving the environment. The project involves integration of a number of complex technical systems – some of these technologies used in these systems are totally new to the country – each one of which is a major project by itself. Interfacing various system contracts is a difficult and highly skilled exercise. Side by side, timely and adequate funds have to be assured for implementation and lands, without encumbrances, have to be taken possession of in time. Clearances from the local authorities have to be taken permission to cut trees, diversion of utilities, management of road traffic, etc., all of which will call for an efficient and competent project implementing agency.

Metro projects cannot be executed the way Government agencies execute projects in this country. Timely completion is very important to safeguard the financial viability. Competent and skilled technical personal to man such an organisation are difficult to mobilize. In fact such experienced persons are not readily available in the country. Being a rail based project, for most of the systems such as rolling stock, signaling, telecommunication, traction power supply, etc., persons with railway background would be necessary. It is therefore, impossible to have a single organisational set up which can be responsible for all aspects of metro implementation, namely investigation, planning, designs, drawing up of specifications, preparation of tender documents, fixing of contractors, supervising the contractor's works, ensuring interface fusion between different contractors, ensuring quality and safety during constructions, planning and supervising integration system trials and getting the project commissioned on time.

It is, therefore, suggested that a two-tier organisation with well-defined responsibilities for getting this project executed be set up. At the apex will be the MMRC itself. It should be a lean but effective organisation with full mandate and total power – with accountability- free from political and bureaucratic control. The second level will be a project management team called "General

Consultantsò who will be engaged by the MMRC on contract basis and who will be fully responsible for planning, design and full project management. In fact they will be the ñEngineerò for the MMRC, who is the ñclient ñThe General Consultants should be fixed on the basis of competitive bidding, the way General Consultants were fixed for the Delhi Metro Project. If any further detailed design consultants are needed, the same should be engaged by the General Consultants as their sub-consultants within their own contract responsibilities.

Learning from the Delhi Metro experience, we would recommend that all major contracts are awarded on ñconstruct basisò based on designs and specifications finalised by the General Consultants. In certain system contracts such as signaling, tele-communication, automatic fare collection, etc. it may be desired to go for ñdesign and constructò contracts based on broad technical specifications and performance requirements drawn up by the General Consultants. International Consultants are very expensive and should be engaged only in area where Indian experts cannot manage and they should invariably be part of the General Consultantsô team.

Since MMRC will not have the required expertise and experienced manpower to check and monitor the General Consultants it may be necessary to engage proof Consultants from the very start who will do this job on behalf of MMRC. Delhi Metro Rail Corporation can be considered for being appointed as Proof Consultant to MMRC.

Generally the General Consultants will cost about 2.5% of the project and cost the Proof Consultants about 0.5%.

The MMRC Organisation, as stated earlier, should be very lean but effective. It will consist of a non-executive Chairman, a Managing Director with full Executive Powers (in Schedule óAô) and three Functional Directors (in Schedule óBô) including Director (Finance). All the three Functional Directors will be full members of the Management Board. The Directors will be assisted by Heads of Departments in each of the major disciplines and they in turn will have Deputy Heads of Departments. The organisation should be basically officer-oriented with only Personal Assistants and Technical Assistants attached to senior officers by eliminating unproductive layers of staff such as Peons, Clerks, etc. We strongly recommend that the total organisational strength is limited to 45 to 50 eliminating too many tiers to enable faster decision-making. An organizational chart for MMRC is enclosed.

It is necessary for the MMRC officers to get exposed to the Metro technology and Metro culture through study tours of some of the selected foreign Metros and Delhi/Calcutta Metros.

13.5.1 High Power Committee

During the implementation of the project several problems with regard to acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. are likely to arise. For expeditious resolution of these problems, an institutional mechanism needs to be set up at the State Government level. Towards this end, it is recommended that a High Power Committee under the chairmanship of Chief Secretary, Maharashtra should be set up. Other members of this Committee should be Secretaries of the concerned Departments of the State Government and Heads of civic bodies who will be connected in one way or the other with the implementation of the project. This Committee should meet once a month and sort out all problems brought before it by MMRC. For Delhi Metro also such a High Power Committee was set up and it proved very useful in smooth implementation of the Delhi Metro rail project.

13.5.2 Empowered Committee

At the Central Government level an Empowered Committee, under the chairmanship of Cabinet Secretary, is presently functioning for Delhi Metro project. Other members of this Committee are Secretaries of Planning Commission, Ministry of Home Affairs, Ministry of Urban Development, Ministry of Surface Transport, Ministry of Environment and Forests, Department of Expenditure, Chief Secretary of Delhi Government and a representative from the PMO. The Empowered Committee meets regularly and takes decisions on matters connected with inter-departmental coordination and overall planning, financing and implementation of the Delhi Metro project. It is suggested that the role of this Empowered Committee should be enlarged to include Mumbai Metro project also and the Chief Secretary, Maharashtra should be inducted as a member of this Committee.

13.5.3 Group of Ministers

Union Cabinet had set up a Group of Ministers (GOM) to take decisions on behalf of the Cabinet on policy matters concerning Delhi Metro project. The Group of Ministers is chaired by the Home Minister. Other members of the GOM are Minister of Urban Development and Poverty Alleviation, Minister of Railways, Minister of Finance and Company Affairs and Deputy Chairman Planning Commission. Chief Minister, Delhi and Lt. Governor, Delhi, are permanent invitees to all meetings of the GOM. The GOM meets whenever any problem requiring decision on behalf of the Union Cabinet is to be taken. It is suggested that the role of this GOM should be enlarged to include Mumbai Metro. The Chief Minister, Maharashtra should be inducted as a member and should attend the meetings of GOM whenever any issue concerning Mumbai Metro is to be deliberated upon.

13.6 LEGAL FRAMEWORK

Metro rail projects are undertaken in congested urban environment. Metro lines have, therefore, to pass through heavily built-up areas. As vacant land for laying these lines is seldom available, they have to be constructed either as elevated or underground. When elevated, the metro lines are generally located along the medians of the existing roads to obviate the need for acquiring land. Even in such cases, land is to be acquired for sitting station buildings, traffic integration areas, etc. Whenever underground, metro lines may have to pass under privately owned buildings, involving use of underground space below such buildings. After construction of a metro line is complete, it has to be certified as ósafeô by a statutory authority before it can be opened for public carriage of passengers. For operation and maintenance of a metro line, which has been commissioned for traffic, several crucial issues having legal implications need to be taken care of. These include continued monitoring of safety of train operations, security of metro properties, maintaining law and order within metro premises, enquiries into accidents involving metro trains whenever they happen, deciding the extent of compensation payable for damages/injuries/casualties arising out of such accidents, laying down passenger fares and their subsequent revision etc. There has, therefore, to be a proper legal frame-work to take care of such problems encountered during construction as well as operation of metro rail lines. Hence the need for a comprehensive legislation on Metro Railways.

13.6.1 Existing legislations

The subject of óRailwaysô as per the Seventh Schedule of the Constitution falls in the Central List. Metro Rail projects come under the category of Railways and are, therefore, today a central subject. Despite this position the Central Government has not so far enacted a comprehensive legislation to regulate construction, operation and maintenance of Metro Railways in various cities of the country.

Calcutta (now Kolkata) Metro Railway was the first metro system undertaken in our country. To facilitate construction of Calcutta Metro Railway, a legislation under the title óMetro Railways (Construction of Works) Act, 1978 was enacted. This Act was initially applicable to Calcutta but there is a provision in this Act that, by a notification in the Official Gazette, the Central Government may also extend it to the metropolitan cities of Mumbai, Chennai and Delhi. In fact, in the year 2000, the Central Government did extend this Act to the city of Delhi. This Act, however, suffers from several deficiencies. Firstly, there is no provision in this Act to extend it to cities, having population of a million or more other than the four metro cities mentioned above. Secondly, this Act covers only the construction stage of Metro Railways and does not provide legal cover to their operation and maintenance stage. When the first section of Calcutta Metro had to be opened for public carriage of passengers, the Central Government had to hastily get an Ordinance titled ôCalcutta Metro (Operation and Maintenance) Temporary Provisions Ordinance, 1984ö promulgated. This Ordinance was converted next year into Calcutta Metro Railway (Operation and Maintenance) Temporary Provisions Act, 1985. This latter Act also suffers from several deficiencies. As its very title indicates it is applicable to Calcutta Metro only, there is no provision in it to enable the Central Government to extend it to other cities of the country. Besides, it contains only bare minimum provisions, which were essential to enable commissioning of Calcutta Metro Railway for public carriage of passengers. The Central Governmentÿs intention probably was that after sufficient experience in operating and maintaining Calcutta Metro has been gained, many more provisions would be included in this Act to make it self-contained and the word ôTemporary Provisionsö would be dropped there from. This has, however, not happened even after expiry of 18 years since the passing of this legislation by the Parliament.

Construction of Delhi Metro is being done under the Metro Railways (Construction of Works) Act, 1978, after the same was extended to the city of Delhi. The Central Government had, however, to enact another legislation titled ôDelhi Metro Railway (Operation and Maintenance) Act, 2002 before its first section from Shahdara to Tis Hazari could be opened for public carriage of passengers. This Act, though comprehensive in nature, is applicable to Delhi Metro only and cannot be extended to cover a metro railway in any other city of the country.

13.6.2 Legal Cover for Mumbai Metro

Construction of Mumbai Metro phase I is expected to commence soon. Out of its three corridors in phase I, the first corridor may be ready for commissioning in about three years and other corridors may be ready for commissioning after a further period of two years. Thus there is immediate need to have a legislation to provide legal cover to the construction stage of Mumbai Metro. Enactment of any new legislation is a time-consuming exercise. Experience has shown that it takes a minimum of two to three years from conceptualisation stage for a new legislation to be enacted. To enable construction of Mumbai Metro to commence in the year 2005-06, it has, therefore, become necessary to extend the Metro Railways (Construction of Works) Act, 1978 to Mumbai.

As for the legal cover to the operation and maintenance stage of Mumbai Metro, it is high time to go in for a comprehensive legislation which will cater to both construction as well as operation and maintenance stages of Metro Railways in all million plus cities. After that Act is enacted, the existing Acts, namely, Metro Railways (Construction of Works) Act, 1978 and Delhi Metro (Operation and Maintenance) Act, 2002 and the Calcutta Metro Railway (Operation and Maintenance) Temporary Provisions Act, 1985 can be repealed. The comprehensive legislation should, inter-alia, contain provisions for the following:

- Functions and powers of the organisation to be entrusted with the tasks of implementing a metro system and its subsequent operation and maintenance. This organisation should be conferred adequate powers to enable it to expeditiously implement the metro system and later to operate and maintain it without any problem.
- Acquisition of land for construction of a metro railway, including acquisition of rights to use underground space below privately owned buildings for laying a metro line.
- Safety organization for certifying safety of a metro line before it is opened for public carriage of passengers. This organization should also be entrusted with the role of enquiring into the causes of accidents involving metro trains and suggesting remedial measures for avoiding recurrence of such accidents.
- Statutory authority for deciding the compensation payable for losses, injuries, casualties, etc. arising out of accidents involving metro trains.
- Penalty for offences committed in metro trains or metro premises.

13.6.3 Applicability of Tramway Act

It is observed that Government of Maharashtra is considering taking up the implementation of Rail-based Mass Rapid Transit System (MRTS) along Versova-Andheri-Ghatkopar corridor under Indian Tramways Act, 1886 amended from time to time vide Government Resolution NO. MUT-1004/1671/Case No. 158/2004/UD-10 Dt. 19.08.04

Versova-Andheri-Ghatkopar line in all respects is an elevated Metro line, even though it is wholly located within a municipal area. To categories this line of communication as a ñTramwayò by merely relying on the fact that it lies wholly within a municipal area may not stand the test of judicial scrutiny. Versova-Andheri-Ghatkopar line has all the trappings of a Metro line, such as dedicated right-of-way, maximum permissible speed as high as 80km/hr, six coach trains, train frequency 3 minutes during peak hours, signaling system with ATP etc. This line, therefore, does not qualify for being designated as a ñTramwayò since ñTramwaysò do not have dedicated right-of-way, their coaches operate either singly or in consists of twos, they have low maximum speeds (as they have to operate along with road vehicles on the same right-of-way), they do not have signaling system, etc. Versova-Andheri-Ghatkopar line can be called ñTramwayò in terms of section 3 (5) of the Indian Tramways Act, 1886 only if it is declared by an Act of Parliament not to be a Railway, in terms of Clause 30 of Article 366 of the constitution of India. If despite this position the State

Government goes ahead with this project under the ñTramwaysò Act, it is likely to lead to legal complications at a later stage.

13.7 CONCESSIONS FROM GOVERNMENT

Metro rail projects need very heavy investment. Loans have invariably to be taken to fund a part of the capital cost of the projects. These projects yield low financial internal rate of return though their economic internal rate of return is very high. With reasonable fair level, servicing of these loans often pose problems. To make the project financially viable, therefore, the fares need to be substantially increased to socially un-acceptable levels. This results in the ridership coming down significantly, as it is sensitive to increases in the fare level. Thus the very objective of constructing the metro rail system to provide an affordable mode of mass travel for public is defeated. It, therefore, becomes necessary to keep the initial capital cost of a metro project as low as possible so that the fare level of the metro system can be kept at reasonable level.

13.7.1 Experience of Delhi Metro project has shown that the taxes and duties constitute about 16 ï 18% of the project cost. Following are the taxes and duties, which have to be borne by a metro project:

- Custom Duty on all imported rolling stock and other equipment needed for the project.
- Excise Duty on all indigenously manufactured rolling stock and other indigenously finished goods required for the project.
- Sales Tax on all purchases made for implementation of the project whether directly by the project implementation authority or by the contractors executing the project.
- Sales Tax on works contracts to be executed for the implementation of the -project.
- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

13.7.2 In the case of Delhi Metro project, the Union Government has granted exemption from payment of Custom Duty and Excise Duty while the Delhi Government has agreed to give exemption from payment of Sales Tax and Sales Tax on works contracts. Delhi Metro Rail Corporation is also pursuing with the Government for exemption from tax on electricity being consumed by Delhi Metro for its operation and maintenance.

13.7.3 It is recommended that for Mumbai Metro similar exemptions from taxes and duties be granted by the Central Government/Maharashtra Government for

Mumbai Metro. In this connection it may be mentioned that the Central Government has been encouraging infrastructure projects in the country through fiscal and non-fiscal concessions Cities have emerged as the engines of growth and mass transport systems today are one of the most important pre-requisites for the balanced growth of the city. The Government can demonstrate the importance it attaches to this sector by granting the above concessions which would not only help reduce the initial cost of the project so that Mumbai Metro remains commercially viable during its operation phase but also send strong signals to the effect that it is committed to a safer and pollution free city. Moreover, public transport is employment-friendly and favours social balance in a sustainable way since it allows access to jobs and services to all.

13.8 NEED FOR DEDICATED FUND FOR METRO PROJECTS

Metro Rail projects, being capital intensive projects, have to be funded jointly by the Central Government and the State Government. In order to facilitate funding of these projects, the Central Government should set up a non-lapsable ôNational Metro Transport Fundö for financing its share of metro rail projects. The 10th Plan document has also recommended creation of such a Fund with an initial seed money contribution of Rs.3,000 crores by the Central Government, with another contribution of Rs.3,000 crores to be raised during the 10th Plan period through dedicated taxes. This Fund should be utilized to meet the Central Governmentÿs share towards equity contribution in the Special Purpose Vehicles to be set up to implement the metro rail projects for various cities. The Central Government may consider imposing of surcharge on petrol, diesel and CNG to raise resources for this Fund.

To enable the State Governments to provide their share of equity in the Special Purpose Vehicles set up for such projects, it would be necessary to constitute a Special Metro Fund at the State Government level also. The State Governments should resort to imposition of dedicated levies for raising resources for these Funds. Following dedicated levies may be considered by the State Governments for this purpose:

- A 50% cess on the tax levies for registration of road vehicles.

- A Surcharge on fuel (petrol, diesel and CNG).

The above two levies would also assist to discourage the use of personalised vehicles and encourage the use of public transport, which would not only reduce the pollution level in the city but also reduce traffic congestion on the road.

- Metro Tax @ 2% on pay rolls of all establishments having more than 100 employees. Such cess is in existence in a number of Western countries for raising resources for metro rail. The employerôs benefit a good deal by good Metro System.

- Surcharge @ 10% on luxury tax on the earning of all Star Hotels. At present level, the luxury tax is 10%. The surcharge will raise the level to only 11%. Chinese cities have adopted this scheme.

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CHAPTER 14

CONCLUSIONS

14.1 As discussed in previous chapters, Mumbai is the Commercial Capital of India and itôs fast growth especially in the suburbs is causing heavy stress on all infrastructure, especially the Transport. Being a linear city, the existing sub-urban rail services are very effective and the modal split in favour of public transport is about 88%, which is very high. Since the existing transport infrastructure has been heavily loaded, it has been observed that the population of private vehicle is increasing and it was also predicted that, the modal split in favour of public transport may also recede. Hence, it is proposed by MMRDA to introduce a rail based Mass Transportation System in Greater Mumbai and a master plan has been prepared for the same.

14.2 The master plan has recommended a total network of 146.5 Kms along 10 corridors for implementation three phases with horizon year as 2031.

14.3 The present corridor` Versova- Andheri ï Ghatkoparô is one of the phaseï I corridors, with route length of 11.07 Kms.

14.4 Metro rail systems are superior to buses because they provide much higher carrying capacity, require only 1/5th of the energy per passenger km compared to road-based systems, cause no air pollution, occupy no road space if underground and only about 2 meter width of the road if elevated. A metro system can carry the same amount of traffic as 7 lanes of bus traffic or 25 lanes of private motor cars, are more reliable, comfortable and safer than road-based systems and reduce journey time by anything between 50% and 75% depending on the road conditions. In view of this position, Mumbai Metro should not be delayed. Any further delay in taking up the project would escalate its cost and impose avoidable heavy price for delaying a decision.

14.5 Experience of implementing Delhi Metro project has shown that a Special Purpose Vehicle (SPV), vested with adequate powers, is an effective organisational arrangement to implement and subsequently operate and maintain a metro rail project. An SPV should, therefore, be set up for Mumbai Metro and registered under the Companies Act, 1956. This SPV should be patterned on the lines of Delhi Metro Rail Corporation Ltd. (DMRC), with equal Equity participation by the State and the Central Governments and may be named as ôMumbai Metro Rail Corporation Ltd.ô (MMRC). It will have equal number of Directors on its Board from these two Governments. While the Managing Director of MMRC should be the nominee of the State Government, its Chairman should be the Secretary, Ministry of Urban Development & Poverty Alleviation, as the nominee of to ensure full involvement and support of the the project. In order to avoid delays usually associated with bureaucratic process of decision making, the Board of Directors (BOD) of MMRC should be vested with full powers needed to implement the project. The BOD, in turn, should delegate adequate powers to the Managing Director to enable him to take all decisions in day to day matters.

Concessionaire model for implementing and later operating Mumbai Metro has also being examined. Financial implications of the concessionaire model vis-à-vis directly by MMRC have been spelt out. If concessionaire model is adopted, the role of MMRC will be that of an regulatory body.

14.6 For the successful implementation of Mumbai Metro project, it is essential that the Managing Director of MMRC should be very carefully chosen. The Managing Director should be a technocrat of proven track record and impeccable integrity. He should be preferably with a railway background since metro projects are with rail-based complex technology. A metro rail background with experience in underground and elevated construction would be most desirable. If the project is to be completed as scheduled and without any time or cost over-run, it would be necessary to allow the Managing Director to function without any bureaucratic or political interference. For ensuring accountability the tenure of the MD should be at least 5 years.

14.7 On receipt of the Detailed Project Report, following advance action would need to be taken urgently for implementing the Mumbai Metro project:

- Approval and acceptance of the Detailed Project Report by the State Government of Maharashtra and the Central Government and both Governments committing to the investment decision.

- Signing of an MOU between State Government Maharasthra and the Central Government for firming up arrangements for equity, interest free subordinate debt and other related items pertaining to this project.

- Setting up of a Special Purpose Vehicle (MMRC) for implementing the project and posting of its Managing Director.

- Providing legal cover for construction as well as operation and maintenance stages of the project.

- The two Governments to jointly decide on the financing of the debt portion of the project and also to the time frame for completing the project.

or Mumbai Metro project has been discussed in Chapter 13 of this Report. If the actions listed as above are taken promptly by the two Governments, it should be possible to start physical work on this project in the financial year 2004-05 itself.

14.9 Procurement of rolling stock is generally the most critical activity in metro commissioning. Energy efficient, light-weight and reliable rolling stock are required to be made available in time for starting integrated trials before commercial opening. Imported rolling stock is generally very expensive. M/s BEML, Bangalore have the required facilities and capability for indigenous manufacture of rolling stock on account of the transfer of technology that would take place during the manufacture of metro coaches for Delhi. However, BOT operator is free to bring Rolling Stock from any where as long as the specifications are met.

14.10 Mumbai Metro will be a State-of-the-art Metro. It will have 25 kV ac traction system & Automatic train protection (ATP). Ticketing will be through Automatic Fare Collection system.

14.11 For successful implementation of any metro project, which by its very nature is highly technical and complex, huge in size and to be executed in difficult urban environments, there should be a political will and commitment. The decision making process has to be fast and the implementing agency must have the required work culture, commitment to targets, commitments to safety, quality and cost consciousness. Any time overrun will have disastrous consequences by way of serious cost overruns.

14.12 Metro projects are highly capital intensive. On account of the high costs involved and the need to maintain a fare structure within the affordable reach of ordinary citizens, metro projects are not ordinarily financially viable. But considering the overwhelming economic gains to the society and the fact that cities with a population of more than ten million cannot just survive without an efficient metro system, we strongly recommend the Mumbai Metro system to be taken up for implementation in the financial year 2004-2005 itself.

14.13 Capital cost of Mumbai Metro project at June, 2004 prices has been estimated at Rs. 1475 crores. It is also proposed to provide a link to Sahar International airport with cost of Rs.90 crores. Further if the maintenance depot is provide at Godrej area (towards Eastern end) in stead of at DN Nagar, itøs cost will be Rs.315 Crores .The FIRR & EIRR have been calculated taking project construction cost as Rs. 1475 crores and they are 7.56% and 21.53%respectively.

...dor of first phase only. Mumbai being one of the ...gglomerations of the country will need a bigger metro network. The other corridors proposed in phase I will require to be extended.