DETAILED PROJECT REPORT

SWAMI SAMARTH NAGAR – JVLR – SEEPZ – KANJURMARG – VIKHROLI(EEH) METRO RAIL CORRIDOR

CLIENT : MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY (MMRDA)

Prepared By

DELHI METRO RAIL CORPORATION LTD.

December, 2016

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SALIENT FEATURES

1. GAUGE (NOMINAL): 1435 mm

2. ROUTE LENGTH: 14.477 km (Entirely Elevated)

3. NUMBER OF STATIONS: 13 (All Elevated)

4. TRAFFIC PROJECTION:

YEAR	TOTAL TRIP	AVERAGE LEAD (KM)	MAXIMUM PHPDT
2021	6,50,050	8.12	24716
2031	7,69,530	8.95	29658

5. TRAIN OPERATION:

Particulars	2021	2031
Cars/trains	6	6
Head way (Minutes)	4.25	3.50
Max. PHPDT Demand	24716	29658
PHPDT Capacity Available	24791* (31680**)	30103* (38469**)

* @ 6 persons per square meter of standee area

** @ 8 persons per square meter of standee area

Year	Headway (min)	No. of Rakes	No. of car per rake	No. of Coaches
2021	4.25	16	6	96
2031	3.5	18		108

6.
i. Design speed — 90 Kmph
ii. Maximum operating speed — 80 Kmph
iii. Schedule (Booked) Speed — 35 Kmph

7. Traction Power Supply:

a. Traction system voltage — 25 kV AC
b. Current Collection — Over Head Catenary
c. Receiving Sub Stations — One at JVLR second at Depot

Power Demand Estimation (MVA)

Load	Year	
	2021	2031
Traction	11.40	14.04
Auxiliary	8.52	10.87
Total	19.92	24.91

8. ROLLING STOCK:

a. 3.20 m wide rolling stock with stainless steel body
b. Axle load — 17 T
c. Seating arrangement — Longitudinal
d. Capacity of 3 coach unit With 6 standees / sqm. — 900
e. Class of accommodation — One (Air conditioned)

9. MAINTENANCE FACILITIES:

Maintenance Depot has been proposed near Kanjur Marg (West) (main depot). Total land area proposed for maintenance facilities is 15.02 Ha.

10. SIGNALLING, TELECOMMUNICATION AND TRAIN CONTROL:

a) Type of Signalling — 'CATC' (Continuous Automatic Train Control System) based on "CBTCS" (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

b) Telecommunication —
i. Integrated System with Optic Fibre cable, SCADA, Train Radio, PA system etc.
ii. Train information system, Control telephones and Centralized Clock System.

11. FARE COLLECTION:

Automatic Fare collection system with POM and Smart card etc.

12. STRUCTURE:

i. Viaduct: Precast twin 'U' girders on Single pier with pile / Open foundations upto radius 300m and flatter, for sharper curves and location of Points & Crossings I-Girder.
ii. Station structure on columns, independent of viaduct piers.

13. ESTIMATED COST:

i)	Estimated Cost with all Taxes& Duties (At October 2016 prices)	**Rs. 5567.00 Crore.**
ii)	Estimated Completion Cost with all Taxes & Duties (by April 2021 At 6% p.a escalation)	**Rs. 6691.00 Crore.**

14. INDICES:

i)	FIRR	**8.46%**
ii)	EIRR	**21.92%**

EXECUTIVE SUMMARY

0.1 INTRODUCTION

0.1.1 Background

Mumbai does have a very good transportation system but has not been able to keep pace with the increasing demand. The carrying capacity of the bus and rail system has increased considerably but has been always on lower side than what is needed. Though metro for Mumbai had been talked for last 50-60 years, but something concrete did not come up till MMRDA got prepared Master Plan of Mumbai Metro network in 2003. Master Plan was totaling to 146.5 km comprising the under-mentioned corridors:

Table 0.1

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 – KanjurMarg via Airport	19.50	11.00	8.50
7	Andheri (E) – Dahisar (E)	18.00	18.00	
8	HutatmaChowk – Ghatkopar	21.80	13.30	8.50
9	Sewri – Prabhadevi	3.50		3.50

DMRC prepared the DPRs for Line-1: Varsova – Andheri – Ghatkopar – 2005, Line-2: Colaba – Bandra – Charkop – 2008, Line – 3: Bandra – Kurla - Mankhurd – 2006. Subseqnently, the corridors 2 & 3 were rearranged and DMRC prepared another DPR for the corridor between Charkop – Bandra – Mankhurd

Inspite of above, the implementation of Mumbai metro remained very slow. So far only one line between Varsova – Andheri – Ghatkopar could be implemented. Another corridor presently under implementation is between Colaba and Aarey Colony via International Airport measuring to about 30 kms.

The status for other lines is as under:
In November/December, 2009, MMRDA awarded the work of preparing DPRs for the following corridors to the agencies as indicated herein:

Table 0.2

S. No.	Corridor	Length (Km)	Agency
1.	Charkop – Dahisar	7.5	M/s SPAN Consultants Pvt Ltd.(August, 2010)
2.	Andheri(E)-Dahisar(E)	18.00	M/s SPAN Consultants Pvt Ltd.(May, 2010)
3.	Mahim – BKC - Kanjurmarg	12.5	M/s RITES & LASA (Sept, 2011)
4.	Ghatkopar-Mulund	12.50	M/s Consulting Engineering Services
5.	Bhakti Park- Wadala – Ghatkopar -Kasarvadavali	32	M/s RITES (following LBS Road) (September, 2014
6.	Wadala – Ghatkopar – Kasarvadavali	30.00	M/s CES (following Eastern Expressway)(March, 2013)
7.	Wadala – Carnac Bandar	13.1	M/s RITES (December, 2012)

The Government of Maharashtra is keen to implement expeditiously the Master Plan Corridors recommended by DMRC on a fast track mode and to complete them in the next 3-4 years. To start with, it is decided to take up the task of updation of DPRs and also preparation of new DPRs for the following potential elevated metro corridors:

Table 0.3

Sr. No.	Alignment	Length in km
A*	**Updation of DPRs for Mumbai Metro Master Plan Corridors**	
	(a) D.N. Nagar – Dahisar	18.00
	(b) Dahisar (E) –Andheri (E) (Along WEH)	18.00
	(c) Bandra – Mankhurd (Via BKC)	13.00
	(d) Wadala – Ghatkopar – Thane	22.00
	(e) Thane - Kasarvadavali	10.00
	(f) Wadala – GPO along R.A. Kidwai Rd. – Barrister Nath Pai Rd. – P.D. Mello Rd	8.00
B	**Review of Metro alignment and updation /preparation of DPRs**	
	(a) D.N. Nagar - BKC	10.00
	(b) Jogeshwari Vikhroli Link Road – SEEPZ – Kanju rMarg	10.00
	(c) Andheri (E) – BKC (Via WEH)	9.00
	Total	**118.00**

0.1.2 Demographic Profile and Transport Scenario

Mumbai, the financial capital of India, has witnessed phenomenal growth in population and employment and the trend is expected to continue in the future. The job opportunities it offers have served as a major attraction for immigration from hinterland of Maharashtra as well as from all parts of the Country.

Mumbai Metropolitan Region (MMR) is one of the fast growing metropolitan regions in India. It comprises of 7 municipal corporations, 13 municipal councils and 996 villages and extends over an area of 4,355sq.km. MMR is projected to have population and employment (both formal and informal) as 34.0 million and 15.3 million respectively in the year 2031

The dominant feature of the passenger movements in Mumbai is overwhelming dependence of travel on public transport modes and walk. In MMR, public transport systems are overcrowded and the road network is congested as there is a large gap between the demand and supply.

Four fold growth of population since 1951 has been largely accommodated in the suburbs while the highest concentration of jobs has remained in the Island City. 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. Today's major challenge is to provide connectivity and promote growth by providing adequate inputs to the infrastructure which would improve the quality of life of the residents.

0.2 TRAFFIC FORECAST

0.2.1 The daily ridership, peak hour station loads and peak hour section loads for the proposed Metro Corridor are given in **Table 0.4** and **0.5**.

Table 0.4: Peak Hr. Ridership for Metro Line - 6 (Swami Samarth Nagar – Vikhroli (EEH)) for 2021

S. No	Station Name	Chainage(m)	Inter Distance Between Two Stations.
	DEAD END	-822.5	
1	Swami Samarth Nagar	0.0	822.5
2	Adarsh Nagar	728.8	728.8
3	Jogeshwari (W)	1717.9	989.1
4	JVLR	2877.7	1159.8
5	Shyam Nagar	3839.6	961.9
6	Maha Kali Caves	5387.4	1547.8
7	SEEPZ Village	6510.3	1122.9
8	Saki Vihar Road	7646.6	1136.3
9	Rambaug	8658.9	1012.3
10	Powai Lake	9508.2	849.3
11	IIT, Powai	10572.6	1064.4
12	Kanjur Marg(W)	12230.6	1658.0
13	Vikhroli (EEH)	13204.2	973.6
	DEAD END	13654.2	450.0

Table 0.4 A: Peak Hr. Ridership for Metro Line - 6 (Swami Samarth Nagar - Vikhroli (EEH)) for 2021

S. No.	Direction Vikhroli (EEH) to Swami Samarth Nagar	Sectional Loads	Boarding	Alighting
13	Vikhroli (EEH)		5307	0
12	Kanjur Marg (W)	5307	13950	2009
11	IIT, Powai	17248	558	153
10	Powai Lake	17653	86	232
9	Rambaug	17507	290	91
8	Saki Vihar Road	17706	905	1020
7	SEEPZ Village	17592	2462	1686
6	Maha Kali Caves	18368	855	242
5	Shyam Nagar	18981	2807	1455
4	JVLR	20333	970	10425
3	Jogeshwari (W)	10878	756	2491
2	Adarsh Nagar	9143	29	1144
1	Swami Samarth Nagar	8028		8028
	Peak Hour Ridership	**65005**		
	PHPDT	**24716**		

Table 0.5: Peak Hr. Ridership for Metro Line - 6 (Swami Samarth Nagar –Vikhroli (EEH)) for 2031

S. No.	Direction Swami Samarth Nagar to Vikhroli (EEH)	Sectional Loads	Boarding	Alighting
1	Swami Samarth Nagar		11493	0
2	Adarsh Nagar	11493	2802	72
3	Jogeshwari (W)	14223	1776	1614
4	JVLR	14385	12828	823
5	Shyam Nagar	26390	3193	1708
6	Maha Kali Caves	27875	939	330
7	SEEPZ Village	28484	2053	2852
8	Saki Vihar Road	27685	723	1556
9	Rambaug	26852	119	165
10	Powai Lake	26806	411	487
11	IIT, Powai	26724	156	5172
12	Kanjur Marg (W)	21708	1318	17824
13	Vikhroli (EEH)	5202	0	5202

Table 0.5 A: Peak Hr. Ridership for Metro Line - 6 (Vikhroli (EEH) – Swami Samarth Nagar) for 2031

S. No.	Direction Vikhroli (EEH) to Swami Samarth Nagar	Sectional Loads	Boarding	Alighting
13	Vikhroli (EEH)		3317	
12	Kanjur Marg (W)	3317	20324	1109
11	IIT, Powai	22532	5237	108
10	Powai Lake	27661	75	311
9	Rambaug	27425	363	109
8	Saki Vihar Road	27679	852	1078
7	SEEPZ Village	27453	2623	2037
6	Maha Kali Caves	28039	1007	357
5	Shyam Nagar	28689	3271	2302
4	JVLR	29658	1097	13356
3	Jogeshwari (W)	17399	940	3144
2	Adarsh Nagar	15195	36	1390
1	Swami Samarth Nagar	13841		13841
	Peak Hour Ridership	**76953**		
	PHPDT	**29658**		

0.3 SYSTEM DESIGN

0.3.1 Permanent Way

0.3.1.1 Choice of Gauge

The issue of Broad Gauge vs. Standard Gauge for Metro in India has been debated widely and the decision has been in favour of Standard Gauge. Even Delhi Metro which started with Broad Gauge has switched over to Standard Gauge It is advantageous for many reasons as indicated below:

- In general alignment has to follow the road alignment, which has sharp curves. Standard Gauge permits adoption of sharper curves.
- In Standard Gauge 1 in 7 and 1 in 9 turn-outs which occupy lesser length can be used while in Broad Gauge 1 in 8 ½ and 1 in 12 turnouts are required.
- For Standard Gauge, optimized state-of-the-art rolling stock designs are available ‘of-the-shelf’ which is not so in case of Broad Gauge.
- Standard gauge has been adopted for metros all over the world. Due to large market, constant up-gradation of technology takes place on a continued basis. This is not available Broad Gauge.
- For 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.
- Once technology for Standard Gauge coach gets absorbed and manufacturing base for this setup in India, there will be considerable export potential for the coaches.

0.3.1.2 Track Structure

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 as the regular cleaning and replacement of ballast at such location will not be possible. Only in case of the depot, normal ballasted track is proposed for adoption. 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.

0.3.2 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 main lines will have sharp curves and steep gradients, 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.

0.3.3 Signalling

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.

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 ‘CATC’ (Continuous Automatic Train Control System) based on “CBTC” (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

This will:

- Provide high level of safety with trains running at close headway ensuring continuous safe train separation and for bidirectional working.
- 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 / and other information 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.

Signalling & Train Control system on the line shall be designed to meet the required headway during peak hours. Radio for CBTC shall work in License free ISM band.

0.3.4 Telecommunication

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
- Telephone Exchange
- Integrated Passenger Announcement System and Passenger Information and Display 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&M SCADA is not envisaged as part of Telecomm System as such, hence catered to separately in DPR
- Integrated Network Control System

0.3.5 Automatic Fare Collection

0.3.5.1 Mass Rapid Transit System handles large number of passengers. Ticket issue 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 less manpower. In view of the 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 of 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.

Seamless ticketing is now being thought of for Mumbai. This system is recommended to be adopted as this will enable the commuters to travel hastle free by different modes of transport viz. Metro, suburban trains, buses, water transport (whenever introduced) and even taxies without purchasing multiple tickets for each mode separately.

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 it 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 leakages of revenue due to 100% ticket check by control gates.
3. Recycling of ticket fraudulently by staff avoided.
4. Efficient and easy to operate.
5. System is amenable for quick fare changes.
6. Management information reports generation is easy.
7. System has multi operator capabilities. Same Smart Card can be used for other applications also.
8. AFC systems are the world wide accepted systems for Metro environment.

0.3.5.2 The proposed ticketing system shall be of Contact less Smart Token / Card type. The equipments for the same shall be provided at each station counter / booking offices 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 prone to dusty environment.

0.3.5.3 Choice of Control Gates:

Retractable Flap type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally.

0.3.5.4 Ticket Vending Machine (TVM)

At all stations, Passenger Operated Ticket Vending Machines (Automatic Ticket Vending Machines) are proposed. The TVM's will provide convenience to passengers to avoid standing in queues at ticket booths and provide them international standard service.

0.3.5.5 Ticket Reader/Add Value Machines

These machines will be used to know the Card/Token balance and can also be used as Add value device in case payment for Card top up is made through alternate Internet based channel like net banking, Credit/Debit card (Payment gateway) etc.

0.3.5.6 Recharge Card Terminal Machine (RCTM)

RCTM will be used to recharge the Card using Credit Card /Debit card /Pre Paid card as well as bank Note

0.3.5.7 Integration of AFC with other Lines and Modes of Transport:

In Mumbai, different metro lines are being constructed and operated by different operators. In view of passenger convenience and operational efficiency, it is proposed that AFC for different metro lines should be integrated and smart card based fare products should be inter-operable. AFC system shall take into account revenue sharing mechanism among different operators based on journeys performed at each system. The single ride tickets (tokens) may not be inter-operable and may be limited to each operators system.

The proposed AFC system shall provide interfaces to other operators such as Suburban Rail, Bus, Parking, Toll etc so that these systems may also be integrated with common smart card based fare products. This will facilitate the passengers as they need not carry different cards for different applications.

0.3.6 Rolling Stock:

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. The forecasted Peak Hour Peak Direction Traffic calls for an Medium Rail Transit System (MRTS). Initially, trains are proposed to have 6 coaches but can be expanded to 8 coaches if need arises. All the platforms are proposed to be provided for 8 Coach Trains.

0.3.6.1 The following optimum size of the coach has been chosen for this corridor

Table 0.6 - Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC) /DTC	**21.84 m**	**3.2 m**	**3.9 m**
Trailer /Motor Car (TC/MC)	**21.74 m**	**3.2 m**	**3.9 m**

**Maximum length of coach over couplers/buffers = 22.6 m*

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted.

Following train composition is recommended:

6-car Train: DMC + TC + MC+MC+TC+DMC

Table 0.6A shows the carrying capacity of Medium Rail Vehicles.

Table 0.6A Carrying Capacity of Medium Rail Vehicles

	Driving Motor car/ Driving Trailer car		Trailer car/Motor car		6 Car Train	
	Normal	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**
Seated	42	42	50	50	284	284
Standing	120	240	124	248	736	1472
Total	162	282	174	298	1020	1756

NORMAL-3 Person/sqm of standee area
CRUSH -6 Person/sqm of standee area

The recommended performance parameters are:

Traction Power Supply: 25Kv ac
Motoring capacity: 67%
Maximum Design Speed: 90 kmph
Maximum Operating Speed: 80 kmph
Max. Acceleration $1.0\ m/s^2$ @ AW3
$1.2\ m/s^2$ @ AW2
Max. Deceleration $1.0\ m/s^2$ @ AW3
$1.1\ m/s^2$ @ AW2
$1.3m/s^2$(Emergency Brake)

0.3.6.2 Rolling Stock proposed will be most advanced and have sophisticated system with latest State of Art Technology. The important criteria for selection of rolling stock are:

- Proven equipment with high reliability
- Passenger safety features
- Energy efficiency
- Light weight equipment and coach body
- Optimized scheduled speed
- Aesthetically pleasing Interior and Exterior
- Low life cycle cost
- Flexibility to meet increase in traffic demand
- Anti-telescopic

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.

0.4 CIVIL ENGINEERING

0.4.1 Geometric Design Norms:

0.4.1.1 The geometrical design norms are based on international practices adopted for similar metro systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 80kmph. 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.

Desirable minimum horizontal curve radius specified is 200 m but in extreme cases it can be reduced to 120 m. Minimum curve radius at stations is specified as 1000 m.

Vertical curves are proposed at every change of grade. Radii of vertical curves are 2500 m desirable and 1500 m minimum.

The viaduct carrying the tracks will have a vertical clearance of minimum 5.5 m above road level.

0.4.1.2 Gradients

Normally stations should be on a level stretch. In limiting cases, stations may be on a grade of 0.1%. In this corridor all stations are on level gradient.

Between stations, normally grades may not be steeper than 3.0%. However, where existing road gradients are steeper than 2%, gradients up to 4% (compensated) can be provided in short stretches.

0.4.1.3 Design Speed

The maximum Design speed has been proposed as 90 kmph and maximum operating speed 80 kmph. The scheduled speed has been taken as 35kmph.

0.4.2 Alignment

0.4.2.1 First station on this corridor is named as Swami Samarth Nagar and last station is Vikhroli (EEH).

0.4.2.2 Chainage of Swami Samarth Nagar proposed station is taken as 0.0 for reference and dead end chainage of this station as (-) 822.5 m.

0.4.2.3 Total length of the corridor from dead end to dead end is 14.477 km. The entire corridor proposed is elevated.

0.4.2.4 Thirteen stations have been proposed on the corridor. Names of stations are Swami Samarth Nagar, Adarsh Nagar, Jogeshwari (W), JVLR, Shyam Nagar, Maha Kali Caves, SEEPZ Village, Saki Vihar Road, Rambaug, Powai Lake, IIT Powai, Kanjur Marg (W) and Vikhroli (EEH). Attempt has been made to locate stations at about a kilometer apart. However due to various considerations such as ridership, accessibility, availability of land, design considerations etc; a few stations could not be located at one km distance apart. The maximum and minimum inter station distances are 1658 m and 728.8 m respectively. Depot for this corridor has been planned at Vikhroli.

0.4.2.5 This corridor runs in West to East direction. It connects eastern suburbs, market places, Kanjur Marg Railway Station, etc.

0.4.3 Station Locations

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport such as Railway Stations, Bus Terminals, etc. 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 close to one km.

0.4.3.1 All stations except Jogeshwari (W) and Shyam Nagar, will be two level stations. Jogeshwari (W) station is partly projected over the flyover and Shyam Nagar station is on proposed above flyover. Concourse of these two stations will be on ground level. For all other stations, the concourse comprising of passenger facilities and station facilities will be at lower level and the platforms on the higher level. Stations on the road has been planned cantilever leaving 10.5m road width either side of the median.

0.4.4 Terminals

- **Swami Samarth Nagar Terminal**
  This Station is proposed on the road. Since the road alignment on both sides of the station is kinky, hence there is no space on front end of the station to provide crossover. On rear end of the station, alignment has been extended about 0.8 km to provisde scissors crossover.

- **Vikhroli (EEH) Terminal**
  This Station is proposed on median of the road just before depot location. Scissors cross overs are proposed at the rear end of station and depot entry also has been planned at rear end of the station.

0.4.5 Maintenance Depot

It is proposed to provide depot at Vikhroli, in the Government land identified by MMRDA. The total land for depot will be 15 Ha.

0.4.6 Viaduct–Elevated Structure

The proposed Viaduct Structure is fully elevated. Generally four types of Superstructure are used for construction of elevated section of Metro Corridor, i.e. (i) Segmental Box Girder, (ii) Segmental U Girder, (iii) I Girder and (iv) Double U Girder, depending upon characteristic of the corridor such as traffic congestion on roads, available working space, etc.

In case of this corridor of Mumbai Metro, it is suggested to use Double U-Girder in the superstructure upto radius 300m and for Radius less than 300 m and at locations where point and crossing are to be provided, it is suggested to use I-Girder.

0.4.7 Geo Technical Investigations

No fresh Geotechnical Investigation has been carried out by DMRC. The data available in the DPR prepared by M/s RITES for Mahim to Kanjur Marg corridor has been used for SEEPZ to Kanjur Marg section of the corridor, as the alignment beyond SEEPZ village is more or less same as it was proposed by RITES and ground profile does not changes for smaller deviation in this section of corridor. MCGM is constructing the flyover along JVLR, geotechnical data of the same may be referred for that section.

0.4.7.1 Summary and Recommendations

Type of Foundation -Considering the insitu conditions (sample disturbance), confinement aspect do play a major role in transfer of loads to the bearing stratum. In the light of recovery pattern, the visual inspection of samples covering the texture, fracture and weathering aspect we recommend that the foundations may be laid based on chiseling criteria. IS: 2911 (Part-I/Sec2)-1999 provide design approach in weathered rock stratum for bored cast in-situ piles.

Type of Piles -In the present case bored cast in situ Concrete or precast piles can be adopted. From quality control considerations prebored and precast piles, may be preferred. If one considers bored cast insitu and precast piles, the technical parameters connected with both the methods are almost similar. Pile soil interaction, Pile chipping head, loose materials at tip etc. are governing in a similar pattern.

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 8 m to 10 m 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 1000 mm, 1200 mm or 1500 mm diameter are proposed to be adopted. Actual socket length in completely weathered rock will be 3 times the pile diameter. However for design purpose only 0.5 times diameter length is considered. Piles transmit foundation loads through soil strata of low bearing capacity to deeper rock stratum having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance. The minimum diameter of pile should be 1000 mm.

0.4.8 Utility Diversions

A number of utilities like sewer lines, water pipelines, gas pipelines, power and communication cables etc. are there along and across the alignment. Some of these will have to be diverted or bridged. Details are given in chapter 5 on Civil Engineering.

0.4.9 Land

In order to minimise land acquisitions and to provide good accessibility from either directions, the metro alignments are located mostly along the road, which lie on the corridor. But, at some locations the geometrics of the roads especially at road turnings may not match with geometric parameters required for metro rail systems. In such cases, either the alignment will be off the road or some properties abutting the road would get affected. Further, some land is required for various purposes as detailed below.

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.
- Staff quarters, office complex and operation control centre (OCC)

.

0.4.9.1 Summary of Land Requirements

Abstract of land requirements for different components of this corridor is given in **Table 0.7 and Table 0.8**.

Table 0.7 Summary of Permanent Land Requirement (All figures in Sq. m)

S. No.	Description	Govt.	Pvt.
1	Stations	11332	6417
2	Running Section	5362	32024
3	Depot	150000	0
4	Staff Quarter	5000	0
5	OCC	5000	0
6	RSS	11200	0
	Total (Area in sq m)	**187894**	**38441**

Total Permanent Land = 22.6335ha
Permanent Land (Govt.) = 18.7894 ha
Permanent Land (Pvt.) = 3.8441 ha

Table 0.8 - Summary of Temporary Land Requirement

S. No.	Description	AREA (m^2)	OWNER-SHIP
1	Temporary Office/ Site Office	6000	Government
2	Segment Casting Yard	60000	Government
	Total	**66000**	

Total land required for temporary acquisition is **6.6 ha,** which is assumed that it will be government land.

0.4.10 Safety & Security Systems

This chapter lays down the standards and requirements for safety & security, arising out of fire and unauthorized entry into premises. The system will be designed and installed for safe transportation of passengers & premises safety in Metro Railway System.

0.4.10.1 Requirements

i. The System shall protect the passengers against the fire in train services and at the premises of Metro Railway.
ii. The system shall protect vulnerable premises from fire.
iii. The system shall be able to detect the unauthorized entry and exit at nominated places.
iv. The system shall include
- Fire alarm system.
- Fire Hydrant and Sprinkler System.
- Fire Extinguishers.
- Closed circuit television with video analytics.
- Security Gates – Metal Detector.
- Baggage Scanner.

0.5 STATION PLANNING

The Proposed corridor for Mumbai Corridor runs from Swami Samarth Nagar to Vikhroli (EEH).

The length of the proposed corridor from Swami Samarth Nagar to Vikhroli (EEH) is approximately 14.477 km. Along this section of the proposed corridor, 13 stations have been planned and all are elevated. The locations of the stations have been identified taking into consideration the constraints in land acquisition and congestion issue. Stations are proposed in such a way so as to attract the maximum demand from the traffic nodal points.

0.5.1 Salient features

Salient features of a Metro Rail station are as follows:

i) Most of the stations have two unpaid area.
ii) The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.
iii) The plat form level at elevated stations is determined by a critical clearance of 5.50m above the road level, and 3.30m for the concourse height, about 1m for concourse floor and 2 m for structure of tracks above the concourse. Further, the platforms are 1.100m above the rail level. This would make the platforms in an elevated situation at least 13.5m aboveground.
iv) 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.

v) The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements.

vi) Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.

vii) Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right-of-way.

viii) The DG set, bore well, pump house, underground water tank and refuge collection would be located at street level.

ix) Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The requirements of such areas are given in below.

Table 0.9 Station Accommodation Requirements

Room No.	Description	Minimum Area(m^2)	Remarks
1	Station Control Room	50	
2	Station Manager	15	
3	Ticket Counter (2 nos.)		**2.5m deep x 1.7m per counter**
5	Security Room	9	
6	First Aid Room	10	
7	Female Toilet in paid area	25	**As per National Building Code**
8	Male Toilet in paid area	25	**As per National Building Code**
9	Handicap Toilet	9	**As per National Building Code**
10	Signaling Equipment Room	60	
11	Communication Room	40	
12	UPS Room (SIG/TEL)	60	
13	Mess room	25	
14	Staff Lockers (Gents)	9	
15	Staff Lockers (Ladies)	9	
16	Tank / Pump Room		**At Street level as/requirement**
17	Excess Fare Collection (2 nos.)	6.25	**2.5mx2.5m**
18	Diesel Generator Room	29	**At Street level as/requirement**
19	ASS (Auxiliary Substation)	160	
20	Electrical Switch Room	40	
21	Electrical UPS room	25	
22	F.H.C		**As/requirement**
23	Cleaner Room	10	
24	Refuse Collection Room	5	**Street level**
25	Commercial Area		**As per space available at concourse**

x) The stations have been designed with following criteria in view:

- Minimum distance of travel to and from the platforms.
- Adequate capacity for passenger movements.
- Convenience, including good signages relating to circulation and orientation.
- Safety and security.
- To help visually impaired citizens, tactile tiles are laid in platform, concourse and road level to access metro rail.

xi) The number and sizes of staircases / escalators are determined by checking the capacity against morning and evening peak flow rates for both normal and emergency conditions.

xii) 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 minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers.

xiii) Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to handle the peak traffic from street to platform and vice-versa (These facilities will also enable evacuation of the station under emergency conditions, within the specified time limit).

0.5.2 Station Types

All thirteen stations planned in this section are elevated and have side platforms. Average inter-station distance is approximately 1.1 km varying from 728.8m to 1658m depending upon the site, Operational and traffic constrains. The sequence of stations with their respective chainages, Inter station distance and platform characteristics is presented in Table 0.10

Table 0.10 List of Stations

S. No.	Station Name	Chainage (m)	Inter Distance Between Two Stations.	Station Type
1	SWAMI SAMARTH NAGAR	0.0		Elevated
2	ADARSH NAGAR	728.8	728.8	Elevated
3	JOGESHWARI (W)	1717.9	989.1	Elevated
4	JVLR	2877.7	1159.8	Elevated
5	SHYAM NAGAR	3839.6	961.9	Elevated
6	MAHA KALI CAVES	5387.4	1547.8	Elevated
7	SEEPZ VILLAGE	6510.3	1122.9	Elevated
8	SAKI VIHAR ROAD	7646.6	1136.3	Elevated
9	RAMBAUG	8658.9	1012.3	Elevated
10	POWAI LAKE	9508.2	849.3	Elevated
11	IIT, POWAI	10572.6	1064.4	Elevated
12	KANJUR MARG(W)	12230.6	1658.0	Elevated
13	VIKHROLI (EEH)	13204.2	973.6	Elevated

0.6 TRAIN OPERATION PLAN

The underlying operation philosophy is to make the Metro 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, but also during off-peak period.
- Multi-tasking of train operation and maintenance staff.

Details of stations for Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH)) are given below:

Table 0.11 - Details of Stations

S. No.	Station Name	Chainage (m)	Inter Distance Between Two Stations.	Station Type
	DEAD END	-822.5		
1	SWAMI SAMARTH NAGAR	0.0	822.5	Elevated
2	ADARSH NAGAR	728.8	728.8	Elevated
3	JOGESHWARI (W)	1717.9	989.1	Elevated
4	JVLR	2877.7	1159.8	Elevated
5	SHYAM NAGAR	3839.6	961.9	Elevated
6	MAHA KALI CAVES	5387.4	1547.8	Elevated
7	SEEPZ VILLAGE	6510.3	1122.9	Elevated
8	SAKI VIHAR ROAD	7646.6	1136.3	Elevated
9	RAMBAUG	8658.9	1012.3	Elevated
10	POWAI LAKE	9508.2	849.3	Elevated
11	IIT, POWAI	10572.6	1064.4	Elevated
12	KANJUR MARG(W)	12230.6	1658.0	Elevated
13	VIKHROLI (EEH)	13204.2	973.6	Elevated
	DEAD END	13654.2	450.0	

0.6.1 Salient Features

- 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 for this corridor has been taken as 35 Kmph.

0.6.2 Train Formation

To meet the above projected traffic demand, the possibility of running trains with composition of 6 Car trains with different headways have been examined.

Composition

DMC : Driving Motor Car
MC : Motor Car
TC : Trailer Car
6-car train composition: DMC+TC+MC+ MC+TC+DMC(67% Powering)
Or DTC+MC+MC+MC+MC+DTC(67% Powering)

Capacity@ 6 passengers per square meter of standee area

DMC : 282 passengers (Sitting-42, Standing-240)
MC : 298 passengers (Sitting-50, Standing-248)
TC : 298 passengers (Sitting-50, Standing-248)
6 Car Train : 1756 Passengers (Sitting-284, Standing-1472)

The PHPDT capacity provided on this corridor in different years of operation is given in Table 0.12:

Table 0.12 PHPDT Capacity Provided

Particulars	2021	2031
Cars/trains	6	6
Head way (Minutes)	4.25	3.50
Max. PHPDT Demand	24714	29657
PHPDT Capacity Available	24791* (31680**)	30103* (38469**)

* @ 6 persons per square meter of standee area

** @ 8 persons per square meter of standee area

0.6.3 Year-Wise Rake Requirement

Based on Train formation and headway as given above to meet Peak Hour Peak Direction Traffic Demand, Rake requirement has been calculated and has been tabulated below in Table 0.13:

Table 0.13: Year wise Rake requirement

Corridor	Year	Headway (min)	No. of Rakes	No. of car per rake	No. of Coaches
Swami Samarth Nagar to Vikhroli (EEH)	2021	4.25	16	6	96
	2031	3.50	18		108

0.6.4 Recommendation

TOP chapter has been prepared considering 6-car train with 67% motoring.

Trains with 6 car train consist (with 67% powering cars) operating @ 90 seconds headway can achieve PHPDT of approximately 72,000 with loading of 6 Passengers per sq m. The traffic projections do not suggest such requirements. However, for higher PHPDT requirements in future (upto approximately 96,000 @ average train capacity of 2400 passengers with 62% motoring), the train consist of 8 cars (addition of one 'T+M' Unit) can be adopted in future. In case such scenario is envisaged, platform lengths shall be planned for 8 car trains.

Also, it is recommended that 3.2 m wide stock, suitable for SG may be adopted.

0.7 MAINTENANCE DEPOT

Depot for this corridor is proposed at Vikhroli (EEH).

0.7.1 Depot- Cum- Workshop

It is proposed to establish one depot- cum- workshop with following functions:

(i) Major overhauls of all the trains.
(ii) All minor schedules and repairs.
(iii) Lifting for replacement of heavy equipment and testing thereafter.
(iv) Repair of heavy equipments.

The Depot planning is based on following assumptions:

(i) Enough space should be available for establishment of a Depot- Cum- workshop.
(ii) All inspection lines, workshop lines, stabling lines are designed to accommodate one train set of 8- Car each and space earmarked for future provision.
(iii) All Stabling lines are designed to accommodate one trains of 8- Car each.
(iv) All stabling lines are planned in the proposed depot-cum-workshop assuming adequate space availability. In case of space constraints, if any, stabling facilities may need to be created at terminal stations or elsewhere.

In broad terms, based on the planned Rolling Stock requirements, this chapter covers conceptual design on following aspects and will work as a guide for detailed design later:

- Layout of Stabling-shed, Inspection-shed, minor repairs and heavy repair overhauling workshop 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.

0.7.2 Maintenance Philosophy

- ➢ 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 daily check, “A” checks, “B” type checks, “IOH” and “POH”.
- ➢ Labour intensive procedures are kept to the minimum. 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 is given due attention.

0.8 POWER SUPPLY

0.8.1 Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc.) and workshops, depots & 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 – 80 KWh/1000 GTKM
(ii) Regeneration by rolling stock – 30%
(iii) Elevated/at –grade station load – initially 350 kW, which will increase to 450 kW in the year 2031
(iv) Depot auxiliary load - initially 2000 kW, which will increase to 2500 kW in the year 2031.

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirements projected for the year 2021 and 2031 are summarized in table 0.14 below:

Table 0.14 Power Demand Estimation (MVA)

Load	Year	
	2021	2031
Traction	11.40	14.04
Auxiliary	8.52	10.87
Total	**19.92**	**24.91**

0.8.2 Sources of Power Supply

The high voltage power supply network of Mumbai city was studied in brief. The city has 220, 110 and 100 kV network to cater to various types of demand in vicinity of the proposed corridors.

Keeping in view the reliability requirements, two Receiving Sub-stations are proposed to be set up for the line. This is an economical solution without compromising reliability. It is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations of M/s Reliance Infrastructure Ltd (RIL) at 220, 110 & 100 kV voltage through cable feeders:

Table 0.15 Sources of Power Supply

	Corridor	Grid sub-station (GSS) (Input voltage)	Location of RSS of Metro Authority	Approx. length cables from GSS to RSS
1	**Swami Samarth Nagar To Vikhroli (EEH)** 13 Stations (14.477 km)	220 kV Goregaon GSS	Near JVLR station	3 km
2		220 kV Aarey GSS	Near Depot	8 km

DMRC has done a joint survey/ meeting with M/s MMRDA, M/s Reliance Infrastructure Ltd and M/s TATA Power Company Ltd on 22.08.2016 & 23.08.2016 for this corridor for feasibility of Power Supply (Annexure-8.2). Accordingly, availability of power supply has been planned and tabulated above. Projected Power demand is calculated on each RSS and furnished below: -

Table 0.16– Power Demand projections for various sources

Input Source	Peak demand – Normal (MVA)		Peak demand** – Emergency (MVA)	
	Year (2021)	Year (2031)	Year (2021)	Year (2031)
RSS Near JVLR Station				
Traction	4.87	5.91	11.40	14.04
Auxiliary	3.03	3.89	8.52	10.87

Input Source	Peak demand – Normal (MVA)		Peak demand** – Emergency (MVA)	
	Year (2021)	Year (2031)	Year (2021)	Year (2031)
Sub-total (A)	**7.90**	**9.80**	**19.92**	**24.91**
RSS Near Depot				
Traction	6.53	8.12	11.40	14.04
Auxiliary	5.50	6.98	8.52	10.87
Sub-total (B)	**12.03**	**15.10**	**19.92**	**24.91**

****** Incase of failure of other source of power

0.8.3 Various options of Traction system

There are three options available for power supply system for MRTS:-

- 25 kV & 2X25 kV AC Overhead Catenary system
- 750 V DC third rail system
- 1500 V DC Overhead Catenary system.

In view of above techno-economic consideration 25 kV ac Traction System is suggested for this corridor.

0.8.4 Standby Diesel Generator Set

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 180 kVA capacity at the elevated 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.

0.8.5 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. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fiber provided for telecommunications will be used as communication carrier for SCADA system.

0.8.6 Energy Saving System

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.

0.8.7 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 58.29 million units in initial years 2021, which will be about 72.54 million Units in the 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 110/220 kV voltage level) plus nominal administrative Charges i.e. on a no profit no loss basis. The power tariff of Maharashtra Electricity Regulatory Commission for M/s TATA power Company and M/s Reliance Infrastructure Ltd for FY 2015 – 16 demand charges Rs 200/ kVA per month and energy charges Rs 7.63/ kWh. Therefore, it will be in the range of **Rs 7.91 to Rs 8.00 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. Similar approach has been adopted for Delhi Metro.

0.9 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

0.9.1 Objective and Scope of the Study

The objective of the Environment and Social Impact Assessment study is to facilitate the Mumbai Metropolitan Region Development Authority (MMRDA) evaluate the environmental impacts of its proposed activity. MMRDA proposes to apply for loan to seek financial support from Multilateral Funding Agencies. Thus, the objective of the study is to conduct Environmental Impact Assessment as per requirement of Multilateral Funding Agencies. The scope of EIA includes the impacts resulting from pre-construction, during construction and operation phases of Swami Samarth Nagar – Vikhroli (EEH) Metro corridor at Mumbai. In addition, it is proposed to establish environmental baseline and safeguard measures for protection of environment for sustainable development during project cycles.

0.9.2 Approach and Methodology

The MMRDA has considered different alternative corridors. The underlying principles for evaluation for each corridor, without affecting the overall usefulness of the corridor, are minimum private land acquisition, least disturbance to properties, minimal disturbance to ecology/biodiversity. In the analysis of alternatives, a comparison of scenario with and without the project has also been made. The final alternative was fixed based on Technical Feasibility, Socio-economic acceptability, and Environmental sustainability for Metro Corridors. The environmental study is carried out for the alignment proposed by MMRDA. The approach is to follow the sequence of steps adopted in an EIA study. The basic concept is to ascertain the existing baseline conditions and assess the impacts as a result of construction and operation of the project. The changes likely to occur in different components of the environment viz. physical, biological / ecological, environmental and socio-economic etc. have been studied, analyzed and quantified, wherever possible. The identification of parameters for data generation and impact assessment are important. The analysis of assessment depends upon the reliable data generated/ available on environmental attributed. This study has documented the baseline data for various parameters of physical, ecological and environmental pollution (air, water and noise). The impacts are assessed for various phases of project cycle namely:

- Impacts due to project location,
- Impacts due to project design,
- Impacts due to project construction, and
- Impacts due to project operation.

0.9.3 Environmental Scoping

Baseline environmental status in and around the proposed project depicts the existing environmental conditions of the location. Baseline data was collected for various/environmental attributes so as to compute the impacts that are likely to arise due to proposed project.

The scope of the present study includes detailed characterization of following environmental components, which are most likely to be influenced by the proposed project:

- ❖ Land Environment
- ❖ Water Quality (Surface + Ground water)
- ❖ Meteorological conditions
- ❖ Ambient Air Quality
- ❖ Noise Levels
- ❖ Biodiversity
- ❖ Socio Economic studies.

0.9.4 Environmental Impacts

This section identifies and appraises the negative impacts on various aspects of the environment likely to result from the proposed development. It is pertinent to mention that the negative environmental impacts listed below are based on the assumption that no negative impact mitigation measure or benefit enhancements are adopted.

- Land Environment
- Water Environment
- Air Environment
- Noise Environment
- Biological Environment
- Socio-Economic Environment

The impacts on the above environmental components have been further assessed during various phases of project cycle namely project location, project design, construction and operation.

0.9.5 Environmental Management Plan

The Mumbai Metro Project will provide employment opportunity, quick mobility service and safety, traffic congestion reduction, less fuel consumption and air pollution on one hand and problems of muck disposal, traffic diversion, utility dislocation etc. on the other hand.

Protection, preservation and conservation of environment have always been a primary consideration in Indian ethos, culture and traditions. Management of Environment by provision of necessary safeguards in planning of the project itself can lead to reduction of adverse impacts due to a project. This chapter, therefore, spells out the set of measures to be taken during project construction and operation to mitigate or bring down the adverse environmental impacts to acceptable levels based on the proposed Environmental Management Plan (EMP).

0.9.6 Environmental Monitoring Plan

Environmental monitoring plan has been developed for construction as well as operation phase so as to maintain and regulate the project activities keeping environment safe.

0.10 MULTI MODAL TRAFFIC INTEGRATION

The Swami Samarth Nagar to Vikhroli (EEH) Metro Rail Corridor will cover 14.477 km length in Mumbai city. It will be augmented through enhanced flexibility of criss-cross interchanges to other modes and reduce the travel time of commuters. While Metro is a high capacity mode of transport, the need for integration with other secondary/intermediate transport mode is getting highlighted more than ever to ensure a seamless journey. This concept is to provide first mile and last mile connectivity to the commuters with their places of stay. With top priority to this issue, MoUD has laid down policy guidelines to include the need and provisioning of all public, IPT and private modes in the DPRs for the Metro Rail Systems.

0.10.1 Way Forward

There is a need for providing a transportation system which is seamlessly integrated across all modes and provides first mile as well as last mile connectivity. It is also necessary that various public transportation modes including Inter-mediate Public Transport (IPT) and feeder buses etc. work together in order to facilitate increase in ridership to the Metro/Metro system and provide ease of using Metro system by the public at large.

Therefore, there is a need for doing more scientific study exclusively for this. To achieve this goal, Metro Stations influenced zone need to be defined which can be taken as approximately 5 kms for the motorized traffic and 1.5 km. for pedestrian/cyclists. Detailed Study is required to be done in this influenced zone of a Metro station for following aspects mainly:

i) Availability and review of existing public and IPT facilities, in terms of motorized and non-motorised mode with main consideration of the streets/roads adjoining to the stations and also to examine adequacy of availability of pedestrians/cycle paths in the influenced zone.

ii) Analysis and identification of gaps between supply and demand in terms of feeder facilities and other requirements for better first and last mile connectivity.

iii) Proposal for introduction/enhancement of feeder buses and cycle/pedestrians tracks, bike sharing arrangement for each Metro station to be finalised.

iv) Proposal for better integration of Metro station with other mode of transport, such as relocation of existing bus stop, introduction of new bus stop, bus base etc.

v) Cost of the requirements namely road widening including roads for pedestrian/cycle paths, feeder buses based on the outcome of the study.

The detailed study and requirement for providing first mile as well as last mile connectivity to the Metro users will be carried out separately and the same should be in place before the commercial operation of the Metro services for the benefit of the users as well as for better ridership and the financial viability of the project.

0.11 FRIENDLY FEATURES FOR DIFFERENTLY ABLED

The objective of making this chapter is to create a user-friendly mass transport system in India which can ensure accessibility to persons with disabilities, people travelling with small children or are carrying luggage, as well as people with temporary mobility problems (e.g. a leg in plaster) and the elderly persons.

The design standards for universal access to Public Transport Infrastructure including related facilities and services, information, etc. would benefit people using public transport.

The access standards given in Chapter-11 are extracted from Indian Roads Congress Code, IRC 103: 2012, Guidelines for Pedestrian Facilities; Model Building Bye-Laws, 2011 and National Building Code, 2005. Central Public Works Department's (CPWD) "Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons", 1998 and 2013 edition (under revision by MoUD), and international best practices / standards.

Further, it has also been attempted to provide guidelines/ standards for alighting and boarding area, approach to station, car parking area, drop-off and pick-up areas, taxi/auto rickshaw stand, bus stand/stop, footpath (sidewalk), kerb ramp, road intersection, median/pedestrian refuge, traffic signals, subway and foot over bridge etc. to achieve a seamless development around Metro stations.

0.11.1 Contents

1. Metro Rail Station
    - Way finding

- Signage
- Automated Kiosks
- Public Dealing Counters
- Audio-visual Displays
- Public Telephones
- Rest Areas/Seating
- Tactile Paving - Guiding & Warning
- Doors
- Steps & Stairs
- Handrails
- Ramps
- Lifts/Elevators
- Platform/Stair Lift
- General and Accessible toilets
- Drinking Water Units
- Visual Contrasts
- Emergency Egress/Evacuation

2. Street Design
    - Footpath (Sidewalk)
    - Kerb Ramp
    - Road Intersection
    - Median/Pedestrian Refuge
    - Traffic Signals
    - Subway and Foot Over Bridge

3. Alighting and Boarding Area
    - Approach
    - Car Park
    - Drop-off and Pick-up Areas
    - Taxi/Auto Rickshaw Stand
    - Bus Stand/Stop

0.12 SECURITY MEASURES FOR A METRO RAIL SYSTEM

Metro Rail System is emerging as the most favoured mode of urban transportation system. The inherent characteristics of Metro Rail System make it an ideal target for terrorists and miscreants. Metro Rail System is typically open and dynamic systems which carry thousands of commuters. Moreover the high cost of infrastructure, its economic importance, being the life line of city high news value, fear & panic and human casualties poses greater threat to its security. Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally. Security differs from safety which addresses problems caused accidentally. Security problems or threats are caused by people whose actions aim to undermine or disturb the public transport system and/or to harm passengers or staff.

These threats range from daily operational security problems such as disorder, vandalism and assault to the terrorist threat.

0.12.1 Three Pillars of Security

Security means protection of physical, human and intellectual assets either from criminal interference, removal of destruction by terrorists or criminals or incidental to technological failures or natural hazardous events. There are three important pillars of security as mentioned under:

(i) The human factor
(ii) Procedures
(iii) Technology

0.12.2 Phases of Security

There are three phases of security as under:

(i) Prevention
(ii) Preparedness
(iii) Recovery

0.13 DISASTER MANAGEMENT MEASURE

0.13.1 Introduction

“Disaster is a crisis that results in massive damage to life and property, uproots the physical and psychological fabric of the affected communities and outstrips the capacity of the local community to cope with the situation.” Disasters are those situations which cause acute distress to passengers, employees and outsiders and may even be caused by external factors. As per the disaster management act, 2005 "disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area”. As per World Health Organization (WHO):

“Any occurrence that causes damage, economic disruption, loss of human life and deterioration of health and services on a scale sufficient to warrant an extra ordinary response from outside the affected community or area.”

A disaster is a tragic event, be it natural or manmade, which brings sudden and immense agony to humanity and disrupts normal life. It causes large scale human suffering due to loss of life, loss of livelihood, damages to property and persons and also brings untold hardships. It may also cause destruction to infrastructure, buildings, communication channels essential services, etc.

0.13.2 Need for Disaster Management Measures

The effect of any disaster spread over in operational area of Metro Rail System is likely to be substantial as Mumbai Metro will be dealing with thousands of passengers daily. Disaster brings about sudden and immense misery to humanity and disrupts normal human life in its established social and economic patterns. It has the potential to cause large scale human suffering due to loss of life, loss of livelihood, damage to property, injury and hardship. It may also cause destruction or damage to infrastructure, buildings and communication channels of Metro Rail System. Therefore there is an urgent need to provide for an efficient disaster management plan.

0.13.3 Objectives

The main objectives of this Disaster Management Measures are as follows:

- Save life and alleviate suffering.
- Provide help to stranded passengers and arrange their prompt evacuation.
- Instill a sense of security amongst all concerned by providing accurate information.
- Protect Metro Rail property.
- Expedite restoration of train operation.
- Lay down the actions required to be taken by staff in the event of a disaster in VMRT in order to ensure handling of crisis situation in coordinated manner.
- To ensure that all officials who are responsible to deal with the situation are thoroughly conversant with their duties and responsibilities in advance. It is important that these officials and workers are adequately trained in anticipation to avoid any kind of confusion and chaos at the time of the actual situation and to enable them to discharge their responsibilities with alertness and promptness.

0.13.4 Provisions at Metro Stations/Other Installations

To prevent emergency situations and to handle effectively in case 'one arises' there needs to be following provisions for an effective system which can timely detect the threats and help suppress the same.

(A) Fire Detection and Suppression System
(B) Smoke Management
(C) Environmental Control System (ECS)
(D) Track-Way Exhaust System (TES)
(E) Station Power Supply System
(F) DG Sets & UPS
(G) Lighting System
(H) Station Area Lights
(I) Seepage System
(J) Water Supply and Drainage System
(K) Sewage System
(L) Any Other System Deemed Necessary

The above list is suggestive not exhaustive actual provisioning has to be done based on site conditions and other external and internal factors.

0.14 COST ESTIMATE

Project Cost estimates for the Mumbai Metro Corridor No. 06: Swami Samarth Nagar to Vikhroli (EEH) has been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction etc. at October 2016 price level.

The overall Capital Cost for Swami Samarth Nagar to Vikhroli (EEH) Metro Corridor of Mumbai at October 2016 price level works out to **Rs. 4631 Crores** excluding applicable Taxes & Duties of **Rs. 936 crores** as tabulated hereunder.

Table 0.17 – Summary of Cost Estimate

Sr. No.	Name of the corridor	Capital Cost (Rs. Crore)	Taxes & Duties (Rs. Crore)	Total (Rs. Crore)
1.	Swami Samarth Nagar to Vikhroli (EEH)	4631	936	5567

Table 0.18 - Capital Cost Estimate

Total Length: 14.477 km (Elevated) Stations: 13 Nos. October 2016 level

S. No.	Item	Amount (Rs. in Cr.) Without taxes
1.0	Land and R & R	843.98
2.0	Alignment and Formation	696.95
3.0	Station Buildings	670.91
4.0	Depot	220.00
5.0	P-Way	163.69
6.0	Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators	164.25
7.0	Signalling and Telecom.	326.06
8.0	Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection	134.18
9.0	Rolling Stock (3.2 m wide Coaches)	960.00
10.0	Capital expenditure on security	5.77
11.0	Staff quarter for O & M	35.22
12.0	Capital expenditure on Multimodal Traffic Integration	32.11
13.0	Total of all items except Land	3466.92
14.0	General Charges incl. Design charges @ 7 % on all items except land	242.68
15.0	Total of all items including G. Charges except land	3709.61
16.0	Contingencies @ 3 %	111.29
17.0	Gross Total	3820.89
	Cost without land	3821
	Cost with land including contingencies on land	4631

Table 0.19 - Details of Taxes and Duties

Customs duty = 23.4155%

Excise duty = 12.50 %

VAT = **12.5%**

Octroi = **4%**

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties				Octroi	Total taxes & duties (Cr.)
			custom duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	Service Tax (Cr.)		
1	**Alignment & Formation**							
	Elevated, at grade & entry to Depot	696.95		60.98	68.61	26.14	15.16	**170.88**
2	**Station Buildings**							
	Elevated station - civil works	433.97		37.97	42.72	16.27	9.44	**106.40**
	Elevated station-EM works	119.08	5.58	10.12	11.39	4.47	3.77	**35.32**
	OCC bldg-civil works	35.00		3.06	3.45	1.31	0.76	**8.58**
	OCC bldg-EM works	15.00	0.70	1.28	1.43	0.56	0.48	**4.45**
3	**Depot**							
	Civil works	88.00	6.18	5.39	6.06	3.30	1.99	**22.93**
	EM works	132.00	6.18	11.22	12.62	4.95	4.18	**39.16**
4	**P-Way**	163.69	30.66	3.48	3.91	6.14	5.54	**49.73**
5	**Traction & power supply**							
	Traction and power supply	164.25	15.38	10.47	11.78	3.70	5.32	**46.65**
6	**S and T Works**							
	S & T	250.01	46.83	6.25	7.03	5.63	8.49	**74.23**
	AFC	76.05	13.36	2.38	2.67	1.71	2.57	**22.69**
	PSD	67.86	12.71	1.70	1.43	1.53	2.30	**19.67**
7	**R & R hutments**	57.78			3.61		1.16	**4.77**
8	**Misc.**							
	Civil works	153.86		13.46	15.15	5.77	3.35	**37.73**
	EM works	53.41		5.68	6.38	2.00	1.65	**15.72**
9	**Rolling stock**	960.00	197.81	9.36	10.53	21.60	37.35	**276.65**
	Total	**3466.92**	**335.41**	**182.80**	**208.78**	**105.07**	**103.51**	**935.56**
	Total taxes & Duties							**936**

0.15 FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

The Mumbai Metro Rail Corridor from Swami Samarth Nagar to Vikhroli (EEH) is proposed to be constructed at an estimated cost of Rs. 5254.00 Crore with central taxes and land cost. The route length of the proposed metro rail system and estimated cost at October-2016 price level without central taxes, with central taxes and with all taxes are placed in table 0.20 as under:

Table 0.20 Cost Details

Sr. No.	Name of Corridor	Distance (km)	Estimated cost without taxes (Rs/Crore)	Estimated cost with Central taxes & land cost (Rs/Crore)	Estimated cost with all taxes, Octroi & land cost (Rs/Crore)
1	Swami Samarth Nagar to Vikhroli (EEH)	14.477	4927.00	5254.00	5567.00

The estimated cost at October-2016 price level includes an amount of Rs. 5.77 Crore as one-time charges of security personal towards cost of weapons, barricades, and hand held and door detector machine. However, the recurring cost towards salary and allowances of security personal have not taken in to account in the FIRR calculation since providing required security at metro stations shall be the responsibility of state police.

It is assumed that the construction work will start on 01.04.2017 and is expected to be completed on 31.03.2021 with Revenue Opening Date (ROD) as 01.04.2021 for the corridor. The total completion costs duly escalated and shown in the table 0.21 have been taken as the initial investment. The cash flow of investments separately is placed in Table –0.21 as below.

Table 0.21 Year –wise Investment (Completion Cost including cost of land)

Figures in Rs. Crore

Financial Year	Estimated Cost including cost of land and all taxes & duties at Oct -2016 Price Level	Completion Cost including cost of land and all taxes & duties
2017-18	525.00	545.00
2018-19	995.00	1098.00
2019-20	1229.00	1434.00
2020-21	1410.00	1742.00
2021-22	940.00	1226.00
2022-23	468.00	646.00
Total	**5567.00**	**6691.00**

The cost of Land of Rs. 945 crore included in the above completion cost will be provided free of cost by the Maharashtra Government.

Fare Structure

The fare structure for the FY 2021-22 has been assumed based on the details provided by MMRDA. Considering the increase in the Consumer Price Index (CPI) and input costs of operation since then, the fare structure has been escalated by using @12.00% once in every two years. The fare structure for the FY 2021-22 as per the proposed fare slabs is shown in the table 0.22 below:

Table 0.22 Fare Structure in 2021-22

Sr. No.	Distance	Proposed Fare
1	0-2	11
2	2-4	13
3	4-6	16
4	6-9	20
5	9-12	22
6	>12	24

The above fare structure has been taken as furnished by MMRDA with the approval GOM. DMRC proposed that the under mentioned fare structure in a multiple of Rs. 10 be adopted at the time of commissioning of this Line to have convenience in making use of ticket vending machine and eliminate the problems of non-availability of changes for tendering changes to the passengers.

Year 2021-22	
SLAB	**FARE (Rs)**
0-3 km	10.00
3-12 km	20.00
12-18 Kms	30.00
18 Kms and More	40.00

The **Financial Internal Rate of Return (FIRR)** obtained costs for 30 years business model including construction period is **8.46%.**

Alternative Models of Financing:

The financing option shall depend upon selection of the dedicated agency created to implement the project. The prominent models are: -

(i) Special Purpose Vehicle under the State Government Control (Delhi Metro Rail Corporation (DMRC) /Bangalore Metro Rail Corporation (BMRC)

(ii) Built, Operate & Transfer (BOT)

SPV Model: - The funding pattern under this model (SPV) is placed in table 0.23 as under:

Table 0.23 Funding pattern under SPV model (with central taxes and land)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% of contribution
Equity By GOI	677.50	12.80%
Equity By GOM	677.50	12.80%
SD for CT by GOM	381.50	7.21%
SD for CT by GOI	381.50	7.21%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	3175.00	59.98%
Total	5293.00	100.00%
SD for Land by GOM	945.00	
SD for State Taxed by GOM	453.00	

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% of contribution
Total	6691.00	
PTA for Interest During Construction @1.40% (*)	25.00	
Grand Total	6716.00	

(*) In the case of loan @12% from domestic borrowings, the IDC works out to Rs. 163 crore.

BOT Model: - In this model, the private firm will be responsible for financing, designing, building, operating and maintaining of the entire project. The contribution of Government of Maharashtra will be limited to cost of land only. Such a project become eligible for Viability Gap Funding (VGF) upto 20% from the Central Government provided the state government also contribute same or more amount towards the project. The metro being a social sector project not much private parties are available to bid for such a project. Besides quite expectedly the private operator may demand assured rate of return in the range of 16% to 18% or a comfort of guaranteed ridership.

The funding pattern assumed under this model excluding the cost of land is placed in table 0.24 as under: -

Table 0.24 Funding pattern under BOT –Combined (16% EIRR) (With central taxes and without land cost)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% Of contribution
VGF by GOI	1059.00	20.01%
VGF by GOM	1139.00	20.57%
Equity by Concessionaire	1032.00	19.80%
Concessionaire's debt @12% PA	2063.00	39.63%
Total	5293.00	100.01%
Land Free by GOM	945.00	
State Taxes Free by GOM	453.00	
Total	6691.00	
IDC	319.00	
Total	7010.00	

0.15.1 Recommendations

The FIRR of the corridor with all taxes and land is 8.46%. The pre-tax Equity FIRR to the BOT operator worked out to 16% with total VGF of Rs.3143.00 crore. In addition to the above, the state government may have to exempt or reimburse state states amounting to Rs.453 crore.

The total fund contribution of GOI & GOM under various alternatives is tabulated in table 0.25 excluding state taxes.

Table 0.25

Particulars	SPV Model	BOT Model
GOI	1059.00	1059.00
GOM	2004.00	2084.00
Total	**3063.00**	**3143.00**

In addition to the above, the state government may either have to exempt or reimburse or interest free subordinate debt of state taxes amounting to Rs. 453 crore.

Considering the difference in the contribution of funds under SPV owned by GOI & GOM vis-a-vis BOT model, it is recommended to implement the project under SPV model (completely Government Funded) as per the funding pattern given in Table 0.23.

0.16 ECONOMIC ANALYSIS

Economic benefits are social and environmental benefits which are quantified and then converted into money cost and discounted against the cost of construction and maintenance for deriving Economic Internal Rate of Return (EIRR). When actual revenue earned from fare collection, advertisement and property development are discounted against construction and maintenance cost, interest (to be paid) and depreciation cost, Financial Internal rate of Return (FIRR) is obtained. Therefore, EIRR is viewed from socio-economic angle while FIRR is an indicator of pure financial profitability and viability of any project.

0.16.1 Economic appraisal of a project starts from quantification of measurable economic benefits in economic money values, which are basically the savings of resource cost due to introduction of the metro line. Economic savings are derived from the difference of the cost of the same benefit components under 'with' and 'without' metro line.

0.16.2 Economic Performance Indicators

After generating the cost and benefit stream table, values of economic indicators are derived and are given in table 0.26. Project period is 2017-2047, On the basis of COMPLETION cost, EIRR is found to be 21.92% and B/C ratio as 6.46 and with 12 % discount, EIRR is 8.86% and B/C ratio is 2.19. NPV without discount is Rs 94677 Cr. and with 12% discount rate, NPV is Rs. 7665 Cr. On the basis of ECONOMIC cost, EIRR is 26.93% B/C Ratio is 8.78 and NPV is 99248, both shows that the project is economically viable.

Table 0.26: Economic Indicator Values (2046-47)

Swami Samarth Nagar – Vikhroli (Eeh)	(Completion Cost Basis)		(Economic Cost Basis)	
Economic Indicators	**Without Discount**	**With Discount (12%)**	**Without Discount**	**With Discount (12%)**
Cumulative cost (Cr.)	17335	6436	12765	4739
Cumulative benefit(Cr.)	112012	14101	112012	14101

Swami Samarth Nagar – Vikhroli (Eeh)	(Completion Cost Basis)		(Economic Cost Basis)	
Economic Indicators	Without Discount	With Discount (12%)	Without Discount	With Discount (12%)
Benefit Cost Ratio	6.46	2.19	8.78	2.98
NPV(Cr.)	94677	7665	99248	9362
EIRR	21.92%	8.86%	26.93%	13.33%

0.17 IMPLEMENTATION PLAN

World over Metro projects cannot be financially viable and depend upon generous concessions and subsidies. The financial rate of return for this corridor is **8.46%.**

The only Metro which has been implemented on BOT model so far is the Rapid Metro in Gurgaon. Financially this Metro has been a total failure since the revenues are not able to meet even the interest payment on the loans raised. It is therefore recommended that the project is implemented fully as a Government initiative. By this route the project can be completed at the shortest time and at the lowest cost. This is important because then only ticket can be priced low, affordable to the common citizens and make the system truly a popular public transport.

0.17.1 Implementation Schedule

A suggested project implementation schedule for Project Implementation on Turnkey Basis (Deposit Terms) is given in Table 0.27

Table 0.27 Project Implementation on Turnkey basis (Deposit Terms)

Sl. No.	Item of Work	Completion Date
1	Submission of Final DPR to State Govt.	D
2	Approval of DPR by State Government	D+15 days
3	Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+30 days
4.	Sanction of Project by GOI	D+60 days
5.	Appoint an agency on deposit terms	D+30 days
6.	Implementation of the project	D+46months
7.	Testing and Commissioning	D+47months
8.	CMRS Sanction	D+48months
9.	ROD	D+48months

0.17.2 Institutional Arrangements

The State Govt. of Maharashtra will have to approve the implementation of the project by MMRDA.

0.17.3 Legal Cover for Mumbai Metro

Implementation of proposed corridor can now be done under “The Metro Railways (Amendment) Act 2009”.

0.18 CONCLUSIONS

0.18.1 Mumbai is the Commercial Capital of India and it's fast growth especially in the suburbs is causing heavy stress on all infrastructure, especially the Transport. Being a linear city, the existing suburban rail services are very effective and the modal split in favour of public transport is about 70% as per Comprehensive Mobility Pan (CMP) 2015 prepared by M/s. Lee Associates for MCGM, which is very high. Since the existing transport infrastructure has been heavily loaded, it has been observed that the population of private vehicles 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. It is proposed to take a new Metro Rail Corridor from Swami Samarth Nagar to Vikhroli (EEH) immediately for implementation. Moreover, this corridor will connect across four corridors namely corridor 2, 7, 3 and 4 enabling public to change over and take advantage to its fullest.

0.18.2 The proposal of this corridor is technically feasible but involves acquisition of land as well as rehabilitation of some hutments and shops. This is a socio-economic problem and has to be tackled for execution of the project.

0.18.3 Project Cost

Estimated Cost of the project at October 2016 price level is 5567.00 Crore with all the taxes and duties and completion cost at 6.0% p.a. escalation is estimated to be Rs.6691 Crores including all the taxes and duties.

0.18.4 After examining the various options for execution of the project, it has been recommended that the project should be got executed through a SPV on DMRC funding pattern.

0.18.5 Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR):

While the Financial Internal Rate of Return (FIRR) for the project has been assessed as **8.46%.** The Economic Internal Rate of Return (EIRR) works out to **21.92%%**.


Index Plan
LINE NO.2
LINE NO.3
LINE NO.4
LINE NO.6
LINE NO.7
LINE NO.1
1.Swamy Samarth Nagar
2.Adarsh Nagar
3.Jogeshwari(W)
4.JVLR
5.Shyam Nagar
6.Maha Kali Caves
7.SEEPZ Village
8.Saki Vihar Road
9.Ramboug
10.Powai Lake
11.IIT, Powai
12.Kanjurmarg(W)
13.Vikhroli(EEH)
DAHISAR(E)
SHRINATH NAGAR
BORIVALI OMKARESHWAR
BORIVALI BUS STOP
THAKUR COMPLEX
MAHINDRA & MAHINDRA
BANDONGRI
KURAR VILLAGE
VITT BHATTI Jn.
AAREY ROAD Jn.
V.NAGAR
HUB MALL
BOMBAY EXHIBITION
SHANKARWADI
ANDHERI(E)
3.RUSHI SANKUL
4.JC COLONY
5.LIC COLONY
6.DON BOSCO
7.KASTUR PARK
8.EKATA NAGAR
9.KANDIVALI NAGAR
10.CHARKOP
11.MALAD METRO
12.KASTURI PARK
13.BANGUR NAGAR
14.OSHIWARA METRO
15.SAMARTHA NAGAR
18.ESIC NAGEAR
19.PREM NAGAR
20.INDRA NAGAR
21.NANAWATI HOSPITAL
22.KHIRA NAGAR
23.SARASWAT NGR
24.NATIONAL COLLEGE
25.BANDRA
DOMESTIC AIRPORT
JACOB CIRCLE
COLABA
32. KASARVADAVALI
31. VIJAY GARDEN
30. DONGARI PADA
29. TIKUJI-NI-WADI
28. MANPADA
27. KAPURBAWDI
26. MAJIWADA
25. CADBURY JUNCTION
24. MAHAPALIKA MARG
23. RTO THANE
22. TEEN HAATH NAKA(THANE)
21. MULUND NAKA
20. MULUND FIRE STATION
19. SONAPUR
18. SHANGRILA
17. BHANDUP METRO
16. BHANDUP MAHAPALIKA
15. NAVAL HOUSING
13. SURYA NAGAR
12. VIKHROLI METRO
11. GODREJ COLONY
10. SHREYES CINEMA
9. LAXMI NAGAR
8. PANT NAGAR
7. GARODIA NAGAR
CHEMBUR
3. ANIK NAGAR BUS DEPOT
2. WADALA TT
1. BHAKTI PARK
Sanjay Gandhi National Park
ARABIAN SEA
MAHIM BAY
BACK BAY
LEGAND -:
LENGTH (km)
Andheri To Dahisar(E) 18
Dahisar(E) to DN Nagar 18
DN Nagar to Mandale 24
JVLR Jn. to Kanjur Marg 10
BHAKTI PARK to KASARWADAVALI 32
WADALA to GPO 8
ANDHERI(E) to DOMESTIC AIRPORT 9
Proposed Station

Chapter - 1

INTRODUCTION

1.1 BACKGROUND

Mumbai has a very good transportation system but has not been able to keep pace with rising demand. The carrying capacity of the bus and rail system has increased considerably but has been always on lower side than what is needed. Though metro for Mumbai had been talked for last 50-60 years, but something concrete did not come up till MMRDA got prepared Master Plan of Mumbai Metro network in 2003. Master Plan was totaling to 146.5 kms comprising the under-mentioned corridors:

S. No.	Corridor	Length (km)		
		Total	Elev	U.G
1.	Varsova – Andheri – Ghatkopar	15.00	15.00	-
2.	Colaba – 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

DMRC prepared the DPRs for Line-1: Varsova – Andheri – Ghatkopar – 2005, Line-2: Colaba – Bandra – Charkop – 2008, Line – 3: Bandra – Kurla - Mankhurd – 2006. Subseqnently, the corridors 2 & 3 were rearranged and DMRC prepared another DPR for the corridor between Charkop – Bandra – Mankhurd

Inspite of above, the implementation of Mumbai metro remained very slow. So far only one line between Varsova – Andheri – Ghatkopar could be implemented. Another corridor presently under implementation is between Colaba and Aarey Colony via International Airport measuring to about 30 kms.

The status for other lines is as under:

In November/December, 2009, MMRDA awarded the work of preparing DPRs for the following corridors to the agencies as indicated herein:

S. No.	Corridor	Length (Km)	Agency
1.	Charkop – Dahisar	7.5	M/s SPAN Consultants Pvt Ltd.(August, 2010)
2.	Andheri(E)-Dahisar(E)	18.00	M/s SPAN Consultants Pvt Ltd.(May, 2010)
3.	Mahim – BKC – Kanjur Marg	12.5	M/s RITES & LASA (Sept, 2011)
4.	Ghatkopar-Mulund	12.50	M/s Consulting Engineering Services
5.	Bhakti Park- Wadala – Ghatkopar -Kasarvadavali	32	M/s RITES (following LBS Road) (September, 2014)

S. No.	Corridor	Length (Km)	Agency
6.	Wadala – Ghatkopar – Kasarvadavali	30.00	M/s CES (following Eastern Expressway) (March, 2013)
7.	Wadala – Carnac Bandar	13.1	M/s RITES (December, 2012)

The Government of Maharashtra is keen to implement expeditiously the Master Plan Corridors recommended by DMRC on a fast track mode and to complete them in the next 3-4 years. To start with, it is decided to take up the task of updation of DPRs and also preparation of new DPRs for the following potential elevated metro corridors:

Sr. No.	Alignment	Length in km
A*	**Updation of DPRs for Mumbai Metro Master Plan Corridors**	
	(a) D.N. Nagar – Dahisar	18.00
	(b) Dahisar (E) – Andheri (E) (Along WEH)	18.00
	(c) Bandra – Mankhurd (Via BKC)	13.00
	(d) Wadala – Ghatkopar – Thane	22.00
	(e) Thane - Kasarvadavali	10.00
	(f) Wadala – GPO along R.A. Kidwai Rd. – Barrister NathPai Rd. – P.D. Mello Rd	8.00
B	**Review of Metro alignment and updation /preparation of DPRs**	
	(a) D.N. Nagar - BKC	10.00
	(b) Jogeshwari Vikhroli Link Road – SEEPZ – Kanjur Marg	10.00
	(c) Andheri (E) – BKC (Via WEH)	9.00
	Total	**118.00**

1.2 DEMOGRAPHIC PROFILE AND TRANSPORT SCENARIO OF MMR:

Mumbai, the financial capital of India, has witnessed phenomenal growth in population and employment and the trend is expected to continue in the future. The job opportunities it offers have served as a major attraction for immigration from hinterland of Maharashtra as well as from all parts of the Country.

Mumbai Metropolitan Region (MMR) is one of the fast growing metropolitan regions in India. It comprises of 7 municipal corporations, 13 municipal councils and 996 villages and extends over an area of 4,355 sq. km. MMR is projected to have population and employment (both formal and in formal) as 34.0 million and 15.3 million respectively in the year 2031.

The dominant feature of the passenger movements in Mumbai is over whelming dependence of travel on public transport modes and walk. In MMR, public transport systems are over crowded and the road network is congested as there is a large gap between the demand and supply.

Four-fold growth of population since1951 has been largely accommodated in the suburbs while the highest concentration of jobs has remained in the Island City. The physical characteristics of the City are such that the suburbs have been constrained to spread north wards only, and all transport facilities are concentrated within three narrow corridors. Today's major challenge is to provide connectivity and promote growth by providing adequate in puts to the infrastructure which would improve the quality of life of the residents.

The population of MMR has increased from 7.73 million in 1971 to 18.77 million in the year 2011 (**Table 1.1**). However, the annual compound growth rate for population in MMR has declined from 3.71% during1971-81 to 2.58% in 991-2001.

TABLE1.1: POPULATION GROWTH OF MMR DURING 1971-2011

Sr. No.	Area	Population					Annual Compound growth rate (%)			
		1971	1981	1991	2001	2011*	1971-1981	1981-1991	1991-2001	2001-2011
A	**Municipal Corporation**									
	Greater Mumbai	5.97	8.24	9.93	11.91	**12.48**	3.28	1.88	1.83	**0.47**
	Thane	0.26	0.47	0.79	1.26	**1.82**	6.1	5.33	4.78	**3.75**
	Kalyan-Dombivali	0.24	0.44	0.82	1.19	**1.25**	6.25	6.42	3.79	**0.49**
	Navi Mumbai	0.12	0.2	0.39	0.7	**1.12**	5.24	6.91	6.02	**4.81**
	Mira Bhayandar	0.03	0.07	0.18	0.52	**0.81**	8.84	9.9	11.19	**4.53**
	Bhiwandi-Nizampur	0.08	0.12	0.38	0.6		4.14	12.22	4.67	
	Ulhasnagar	0.17	0.27	0.37	0.47	**0.51**	4.73	3.2	2.42	**0.82**
	Sub Total (A)	**6.54**	**9.69**	**12.79**	**16.67**		**4.01**	**2.81**	**2.68**	
B	**Municipal Council**									
	Thane District									
	Ambernath	0.06	0.1	0.13	0.2	**0.25**	5.24	2.66	4.4	**2.26**
	Kulgaon-Badlapur			0.05	0.1	**0.17**			7.18	**5.45**
	Nalasopara			0.07	0.18				9.9	
	Vasai			0.04	0.05				2.26	
	Virar			0.05	0.12				9.15	
	Navghar Manikpur			0.06	0.12				7.18	
	Sub Total (B)	**0.06**	**0.1**	**0.04**	**0.77**		**5.24**	**14.87**	**6.77**	
C	**Raigad District**									
	Alibag		0.01	0.02	0.02			7.18	0	
	Kajrat			0.02	0.03				4.14	
	Khopoli	0.02	0.03	0.05	0.06		4.14	5.24	1.84	
	Matheran	0.0034	0.004	0.0048	0.0052		1.64	1.84	0.8	
	Panvel	0.03	0.04	0.06	0.1		2.92	4.14	5.24	
	Pen		0.01	0.02	0.03			7.18	4.14	
	Uran			0.02	0.03				4.14	
	Sub Total(C)	**0.05**	**0.09**	**0.19**	**0.28**		**5.82**	**7.56**	**3.52**	

Sr. No.	Area	Population					Annual Compound growth rate (%)			
		1971	1981	1991	2001	2011*	1971-1981	1981-1991	1991-2001	2001-2011
C	Urban MMR (A+B+C)	6.65	9.88	13.38	17.72		4.04	3.08	2.84	
D	Rural MMR	1.08	1.25	1.16	1.05		1.47	-0.74	-0.99	
E	GrandTotal	7.73	11.13	14.54	18.77		3.71	2.71	2.58	

Source: CTS for MMR, Final Report, July 2008

Note: Figures highlighted in Grey forms Greater Mumbai (UA) as per Census 2001 and 2011

* http://www.census2011.co.in/census/metropolitan/305-mumbai.html

There is a continuous growth of population in absolute number however, the annual compound growth rate has reduced from that of 3.28% during 1971-81 to 1.83% in 1991-2001 to further 0.47% in 2001-2011.

1.3 ENVISAGED TRANSPORT NETWORK OF MMR

Comprehensive Transportation Study (CTS) for Mumbai Metropolitan Region estimated total daily demand of 34.3 million trips by all modes of which 60% are by walk. Among the total trips by mechanized modes, 73% trips are by public transport and 9%by para transit modes and balance 18% by private transport mode.

Mumbai Suburban Rail System is still the major source of long distance inter–intra region travel whereas BEST buses provide for the cross movements. Para Transit modes offers door to door service.

Due to extensive reach across the Mumbai Metropolitan Region, and intensive use by the local urban population, the Mumbai Suburban Railway suffers from severe overcrowding. Over 4,500 passengers are packed into a 9-carrake during peak hours, as against the rated carrying capacity of 1,700, having Dense Crush Load of14 to 16 standing passengers per square metre of floor space.

To decongest the existing suburban Rail Systems and provide connecting at macro and micro level within MMR, MMRDA envisaged a transit network of about 667 km in 32 transit links, **Figure 1.1**.

-Metro Network	251km
-Monorail Network	179km
-Suburban Rail Network	237km
Total	667 km

Of the total network, the metro corridors are being by MMRDA/MMRC are as under; **Figure 1.2**.

Corridors under Implementation by MMRDA/MMRC:

- Wadala – Ghatkopar – Mulund – Thane – Kasarvadavali
- Dahisar – D.N. Nagar – Bandra – BKC – Mandala

- Dahisar (E) – Andheri (E) (Along WEH)
- Colaba–Bandra–SEEPZ

1.4 STUDY OBJECTIVES

The objective of the assignment is to review, update & prepare Detailed Project Report (DPR) for the proposed Swami Samarth Nagar to Vikhroli (EEH) Metro Corridor with a view of cost reduction and speedy implementation.

1.5 SCOPE OF WORK

Phase-I: Review, update & prepare Detailed Project Report (DPR)

The services to be rendered under the proposed detailed study will include:

i. Traffic & Transportation surveys for estimation of Transport Demand and projection of sectional and station traffic loads for various horizon years. (Demand forecast will be provided by MMRDA)

ii. Preparation of alternative routes on Satellite Map/available standard maps in consultation with MMRDA. (Only for JVLR and D.N. Nagar to BKC)

iii. Multi modal Traffic integration, Station Area Traffic Dispersal Plans, planning for feeder bus service, public bike sharing and pedestrianisation in the influence area of stations as available in the existing DPRs; however the cost of updation shall be reimbursed on actuals in addition to fee stated in para 4.10.

iv. Filed Surveys and preparation of topographical survey plans for route alignments and assessment of land requirement for facilities like station areas, Electric sub stations (TSS and RSS) Maintenance Depot and Construction Depots, casting yard, labour camps, fire fighting facilities etc.

v. Field Surveys for identification of major above-ground utilities along the proposed Metro routes requiring diversion/relocation. Details of underground utilities shall be supplied by State Govt. through the concerned utility agencies. (Majority of Utilities are identified during earlier preparation of DPRs.)

vi. Geometric design of the route alignments covering horizontal as well as vertical profiles

vii. Identification of depots & preparation of its general layout plans, covering all facilities)

viii. Location of stations and general layout plans for stations and integration areas.

ix. EIA & SIA studies and preparation of EMP for negative impacts including air, noise, water if any.

x. Geo-technical investigations along the identified corridors, wherever earlier data is not available.

xi. Technology Selection – Board details of Traction and Signalling system, rolling stock, track, etc.

xii. Conceptual Plan for the rolling stock maintenance depots.

xiii. Laying down norms for disable friendly features to ensure accessibility to persons with disabilities.

xiv. Traffic Control, safety & diversion plans during construction stage and arrangement.

xv. Security measures and to ensure security for metro system.

xvi. Disaster management features and emergency evacuation plans for metro system plan.

xvii. Preparation of detailed Implementation Schedule including pre-construction, construction stage includes civil, system work.

xviii. Estimation of construction costs, operation and maintenance costs.

xix. Study on the Fare Structure.

xx. A separate note on underground vs. elevated metro system in Mumbai Scenario.

xxi. Financial and Economic analysis for the project.

xxii. Evolving a Funding Plan and Institutional arrangement for the Project.

xxiii. Preparation and submission of Detailed Project Report and executive summary.

1.6 STRUCTURE OF REPORT

The report is structured in under mentioned 18 chapters:

i. The first chapter discusses the study background, objectives and scope.

ii. Chapter two consists of travel characteristics in the study area, the traffic demand forecast carried out in CTS and ridership assessment on the Study Corridor.

iii. Chapter three is on system design and includes components like permanent way, traction system, signalling, telecommunication, fare collection and rolling stock.

iv. Chapter four presents civil engineering design.

v. Chapter five consists Station Planning and horizontal & vertical alignment of the proposed corridor.

vi. Chapter six presents the train operation plan.

vii. Chapter seven discusses the maintenance facilities /depots.

viii. Chapter eight relates to power supply and traction system.

ix. Chapter nine presents the environment impact assessment and social impact assessment of the proposed metro rail corridor.

x. Multi Model Traffic integration at metro station is presented in chapter ten.

xi. Chapter eleven consists friendly features for differently abled.

xii. Chapter twelve is on Security Measures for a metro system

xiii. Chapter thirteen is on Disaster Management Measures.

xiv. Cost estimate is in chapter fourteen.

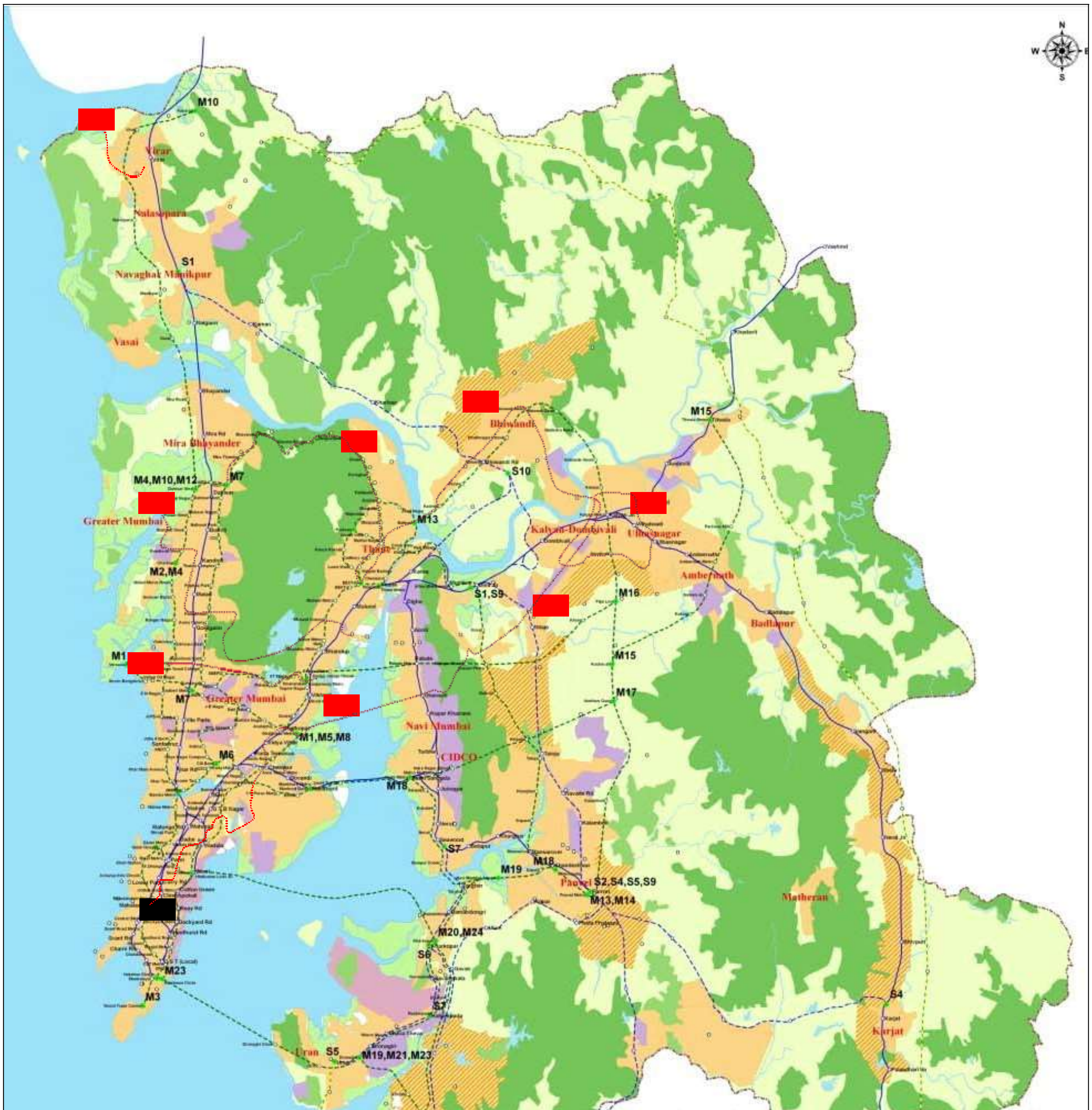
xv. Chapter fifteen presents the financial analysis, financial viability, financing options.

xvi. Chapter sixteen is on economic appraisal

xvii. Chapter seventeen is on implementation strategies.

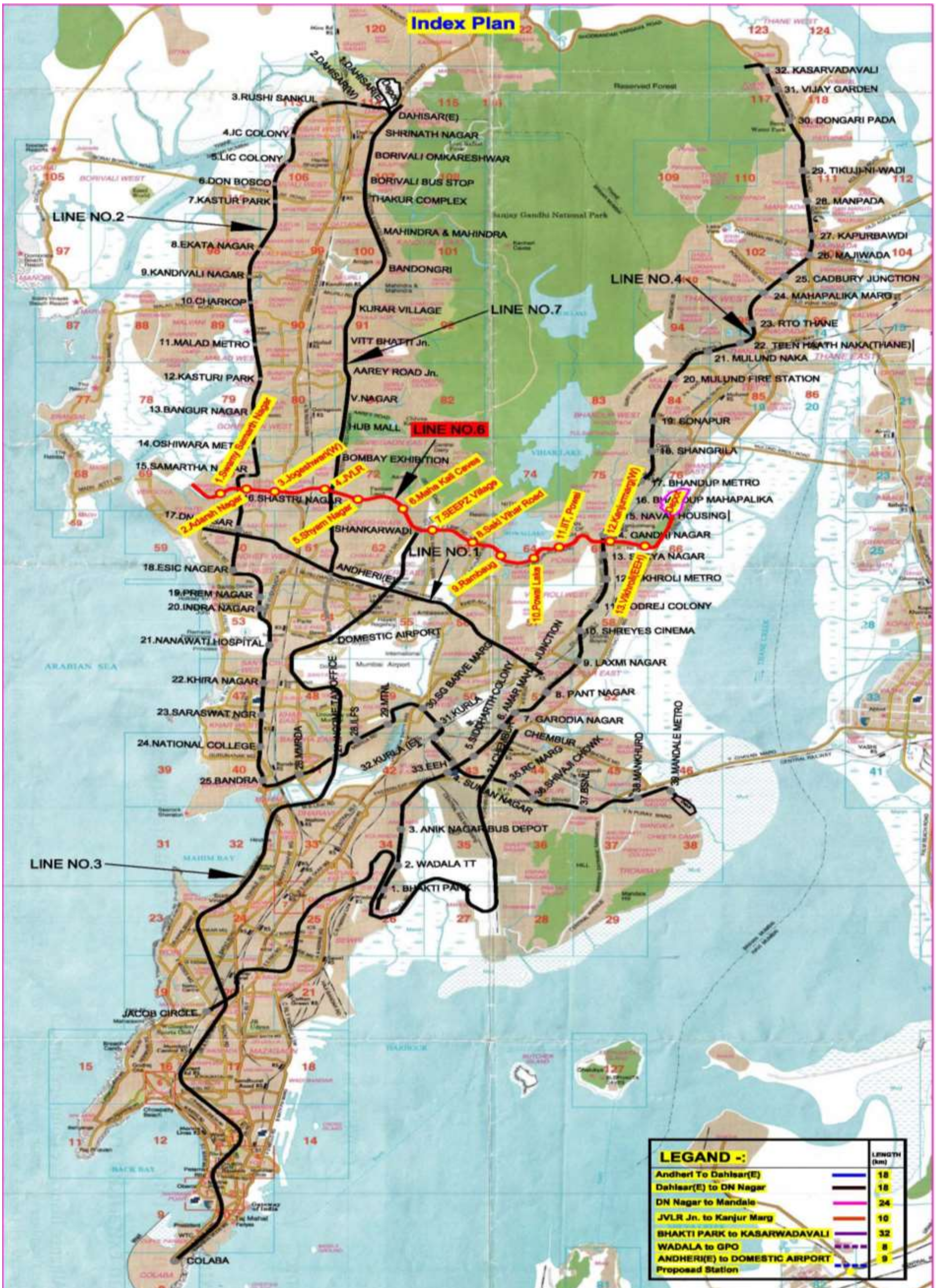
xviii. Chapter eighteen consists conclusions and recommendations

Figure 1.1



Priority	Sl. No.	Corridor Description	Length (Kms.)
1	M7	Andheri (East) - Dahisar (East)	15.9
2	M5	Ghatkopar-Mulund	12.4
3	M17	Mankhurd-Vashi-Narthen Gaon-Kalyan	37.1
4	M11/M13	Thane-Bhiwandi	15
5	M12	Thane-Ghodbander-Dahisar	27.2
6	M4	Charkope-Dahisar	7.5
7	M8	Hutatma Chowk-Ghatkopar	22.4
8	M10	Dahisar-Mira Road-Manikpur-Virar	29.9
9	M6	BKC-Marol Naka via Airport	8.5
10	M9	Sewri-Prabhadevi	3.5
11	M24	Sewri-Kharkopar	19.7
12	M19	Targhar-Kharkopar-Nhava Sheva-Dronagiri	18.7
13	M18	Vashi-Belapur-New Airport-Panvel	18.8
14	M20	Kharkopar-Dhutum-Pirkone	14.5
1	SR7	Ranjanpada-Kharkopar-Targhar-Seawood (new link)	13.9
2	SR1	Diva-Vasai Road	40.1
3	SR5	Panvel-Uran	26.9
4	SR9	Diva-Panvel	26.7
5	SR6	Kharkopar-Jite (new link)	22.9
6	SR4	Panvel-Karjat	27.6
7	SR8	Thal-Alibag (new link)	5.4
8	SR2	Panvel-Jite-Thal	60.9
9	SR10	Thane-Bhiwandi	12.5

Figure 1.2


Index Plan
LINE NO.2
LINE NO.3
LINE NO.4
LINE NO.6
LINE NO.7
LINE NO.1
1.DAHISAR
2.DAHISAR(W)
3.RUSHI SANKUL
4.JC COLONY
5.LIC COLONY
6.DON BOSCO
7.KASTUR PARK
8.EKATA NAGAR
9.KANDIVALI NAGAR
10.CHARKOP
11.MALAD METRO
12.KASTURI PARK
13.BANGUR NAGAR
14.OSHIWARA MET
15.SAMARTHA N
18.ESIC NAGEAR
19.PREM NAGAR
20.INDRA NAGAR
21.NANAWATI HOSPITAL
22.KHIRA NAGAR
23.SARASWAT NGR
24.NATIONAL COLLEGE
25.BANDRA
DAHISAR(E)
SHRINATH NAGAR
BORIVALI OMKARESHWAR
BORIVALI BUS STOP
THAKUR COMPLEX
MAHINDRA & MAHINDRA
BANDONGRI
KURAR VILLAGE
VITT BHATTI Jn.
AAREY ROAD Jn.
V.NAGAR
HUB MALL
BOMBAY EXHIBITION
SHANKARWADI
ANDHERI(E)
DOMESTIC AIRPORT
1.Swamy Samarth Nagar
2.Adarsh Nagar
3.Jogeshwari(W)
4.JVLR
5.Shyam Nagar
6.Maha Kali Caves
7.SEEPZ Village
8.Saki Vihar Road
9.Rambaug
10.Powai Lake
11.IIT, Powai
12.Kanjurmarg(W)
13.Vikhroli(EEH)
32. KASARVADAVALI
31. VIJAY GARDEN
30. DONGARI PADA
29. TIKUJI-NI-WADI
28. MANPADA
27. KAPURBAWDI
26. MAJIWADA
25. CADBURY JUNCTION
24. MAHAPALIKA MARG
23. RTO THANE
22. TEEN HATH NAKA(THANE)
21. MULUND NAKA
20. MULUND FIRE STATION
19. SONAPUR
18. SHANGRILA
17. BHANDUP METRO
16. BHANDUP MAHAPALIKA
15. NAVAL HOUSING
GANDHI NAGAR
13. SURYA NAGAR
KHROLI METRO
GODREJ COLONY
10. SHREYES CINEMA
9. LAXMI NAGAR
8. PANT NAGAR
7. GARODIA NAGAR
CHEMBUR
JUNCTION
AMAR MAHAL
SIDDHARTH COLONY
30.SG BARVE MARG
31.KURLA
32.KURLA (E)
33.EEH
SUMAN NAGAR
35.RC MARG
36.SHIVAJI CHOWK
37.BSNL
38.MANKHURD
39.MANDALE METRO
28.ILFS
29.MTNL
26.MMRDA
INCOME TAX OFFICE
3. ANIK NAGAR BUS DEPOT
2. WADALA TT
1. BHAKTI PARK
JACOB CIRCLE
COLABA
ARABIAN SEA
MAHIM BAY
BACK BAY
HARBOUR
Sanjay Gandhi National Park
Reserved Forest
THANE WEST
THANE EAST
BORIVALI WEST
LEGAND -:
LENGTH (km)
Andheri To Dahisar(E) 18
Dahisar(E) to DN Nagar 18
DN Nagar to Mandale 24
JVLR Jn. to Kanjur Marg 10
BHAKTI PARK to KASARWADAVALI 32
WADALA to GPO 8
ANDHERI(E) to DOMESTIC AIRPORT 9
Proposed Station

Chapter - 2

TRAFFIC DEMAND FORECAST

2.1 PLANNING PARAMETERS

MMRDA has carried out a Comprehensive Traffic Study (CTS) and the Study details have been used in assessing the ridership on the proposed Metro Corridor.

The CTS has examined a range of alternatives for distribution of population and employment in the MCGM and Rest of the Region (RoR) in order to determine the sensitivity of the road and transit system networks, in terms of both need and priorities, to significantly different land development options or strategies as summarized in **Table 2.1.**

TABLE 2.1: RANGE OF POPULATION AND EMPLOYMENT LEVELS

Clusters	Population (In lakh)					Employment (In lakh)				
	2005	2031 P1	2031 P2	2031 P3	2031 P4	2005	2031 E1	2031 E2	2031 E3	2031 E4
Island	33.9	54.4	47.8	40.8	37.4	22.6	40.3	36.2	28.4	20.5
Western	56.3	91.8	78.8	71.5	61.3	23.0	48.0	41.5	30.8	19.3
Eastern	38.4	61.2	53.6	47.6	40.8	11.4	21.5	19.3	14.4	11.1
Total MCGM	128.6	207.4	180.2	159.9	139.5	56.9	109.8	97.0	73.5	51.0
Thane	15.2	16.0	26.2	26.2	26.2	3.9	7.2	9.9	13.3	14.9
Navi Mumbai	15.0	22.8	33.0	33.0	39.8	5.9	10.0	12.1	17.5	22.3
Mira Bhayandar	6.3	13.6	13.6	13.6	13.6	1.5	2.6	2.5	3.9	5.0
Bhiwandi	6.8	13.1	13.1	13.1	13.1	2.1	4.3	4.3	4.5	4.5
Vasai-Virar	7.1	13.1	13.1	14.8	18.2	1.6	2.4	4.1	7.2	9.1
Pen-SEZ	1.2	18.8	13.7	27.2	37.4	0.2	8.5	12.8	18.6	31.2
Rural: Alibagh-Karjat khopoli	4.9	5.6	5.6	5.6	5.6	0.7	0.8	0.9	1.1	1.1
Total	**208.2**	**340.0**	**340.0**	**340.0**	**340.0**	**77.6**	**153.0**	**153.0**	**153.0**	**153.0**

Source: CTS for MMR, MMRDA

The major changes expected in socio economic parameters which will affect the overall development as well as transportation for the horizon year 2031 are summarized in the **Table 2.2.**

TABLE 2.2: EXPECTED CHANGES (2005-2031) IN SOCIO ECONOMICS FACTORS

2005	2031
• **Population 20 million** - 47% living in slums - 1,505,000 apartments - 4.42 persons/household	• **Population 34 million** - 14% living in slums - 6,400,000 apartments - 3.90 persons/household
• **Employment 7.5 million** - Employ. Partic. Rate 0.37 - 2.3 million working in offices - 1.5 million working in industries - 56% employed in formal sector - 40% walk to work	• **Employment 15.3 million** - Employ. Partic. Rate 0.45 - 6.4 million working in offices - 4.5 million working in industries -70-80% employed in formal sector - 25-30% walk to work

Source: CTS for MMR, MMRDA

The difference in work travel characteristics is shown in **Table 2.3** with the office workers travelling more than twice the distance than other employment. Over 70% of office workers use public transit as compared to 53% for the employees in industry and 37% for other types of employment.

TABLE 2.3: TRAVEL CHARACTERISTICS OF EXISTING EMPLOYMENT

	Office	Industry	Other
Average Trip Distance(km)	17.2	11.9	8.3
Mode to work			
Walk	18.3%	42.6	51.5%
Train	58.5%	39.2%	27.2%
Bus	16.0%	13.7%	9.9%
Car	2.9%	1.2%	1.4%
2W	2.4%	1.8%	8.3%
Taxi	0.4%	0.0%	0.1%
A/Rickshaw	1.4%	1.4%	1.7%

Source: CTS for MMR, MMRDA

In order to sustain a population level of 34 million and an employment of 15.3 million, the economy of Mumbai must be more broad-based and it was concluded that the Industrial proportion of 30% of the future total employment was appropriate and reasonable in terms of both landuse need and transportation planning. **Table 2.4** gives the expected changes in employment characteristics during 2005-2031.

TABLE 2.4: EXPECTED CHANGE IN EMPLOYMENT CHARACTERISTICS 2005-2031

Employment	Survey (2005)	Projected (2031)
Office	31.0%	42.0%
Industry/Factory Warehouse	18.0% 1.4%	28.0% 1.5%
Total Industry	19.4%	29.5%
Other Employment Residential Film Industry Shop Restaurant/Eating Place Hotel Entertainment/Tourism Place of Education Health Facility Agriculture Construction Site Varies day to day Others	12.1% 0.8% 14.6% 0.6% 1.2% 0.8% 2.0% 1.6% 0.7% 1.3% 8.4% 5.6%	5.0% 0.5% 8.0% 0.5% 1.3% 0.8% 2.0% 1.5% 0.2% 1.5% 5.2% 2.0%
Total Other Employment	49.6	28.5%
Total Employment	**100.0%**	**100.0%**

Source: CTS for MMR, MMRDA

The CTS screened 6 growth scenarios from the possible 16 combinations of population and employment to narrow down the selection to best characterize the range of possible futures for the MMR. The following set of criteria was adopted for evaluating the growth scenarios:

- Cost of transport network
- Pass- km, pass- hr and average speeds: bus and suburban rail and metro modes
- Vehicle- km, vehicle- hr and average speeds: private vehicles and IPT modes
- Average trip length of bus and suburban rail and metro modes

On comparative evaluation and short listing, P2E2, P3E3, P4E4 were shortlisted by MMRDA as the appropriate options to be carried forward in completing TRANSFORM, on the planning principle that the long term transportation strategies should respond to several futures rather than reflect a single development future. The ranking of these scenarios is given in **Table 2.5.** The P3E3 population/ employment scenario has been subsequently adopted as the preferred strategy.

TABLE 2.5: COMPARATIVE EVALUATION OF GROWTH SCENARIOS

Scenario	Cost of Transport Network	Average Speed of Bus, Suburban and Metro	Average Speed of PV and IPT Modes	Trip Length of Bus, Suburban and Metro
P1E2	2	1	3	2
P2E1	3	3	2	3
P2E2	2	1	2	2
P3E3	3	1	1	1
P3E4	1	2	2	1
P4E3	2	3	3	2

Source: CTS for MMR, MMRDA

2.2 MODEL DEVELOPMENT

The base year model (2014) was developed by first of all building a “best estimate” of the trip matrices (for both road-based personal vehicles and public transport). This was based on a combination of data from previous studies carried by MVA and recently collected traffic and trip making data. A process of matrix estimation was then used to further refine these matrices to match the observed vehicle and passenger flows as derived from the survey data and other sources.

The transport model includes the following different vehicle and user types:

- Car & 2-wheeler
- Goods Vehicle
- Auto rickshaw/taxi
- Buses
- Train

The base matrices for road-based vehicles were initially developed from the previous MVA Study and information available from recent studies such as the CTS. A matrix estimation process was then used to produce updated matrices for the base year (2014) using traffic survey data. Trip length distribution and journey times were monitored in this process.

A similar process of matrix estimation was used to build the public transport demand from existing information.

The derivation of travel demand in this manner then allowed detailed analysis to be carried out on the relationship between travel demand and the cost of travel by alternative modes. This was then applied to derive parameters to be used in the future year model.

2.2.1 Public Transport Assignment

For this aspect of the model, a detailed public transport sub-model has been developed. This is to ensure that the different existing and future public transport choices and costs of these choices are properly reflected in the modelling process. First of all it considers two main travel modes:

- Bus as main mode – road based PT only
- Rail as a main mode - commuter rail in the existing situation (with MRT included for the future)

The public transport network is defined as a set of individual routes each having their own service level characteristics – travel time, comfort, headway and fares. In the existing situation, the costs of travel by the two main modes are calculated based on the generalised cost (GC) of travel, comprising the following components:

- Public Transport GC = (In-Vehicle Time x In-vehicle time Factor)
  + (Walk Time x Walk Time Factor)
  + (Wait Time x Wait Time Factor)
  + (Number of Transfers x Interchange Penalty)
  + Fare / Value of Time (willingness to pay)

For the existing situation, the following parameters were adopted for the public transport assignment.

Walk factors, that is the perception of waiting time and transferring compared to in-vehicle time, were derived from the Stated Preference (SP) survey carried out by MVA for recent studies. Wait time factors were based on industry standards.

TABLE 2.6: PUBLIC TRANSPORT MODEL - KEY PARAMETERS (2014)

Item	Parameter Values				
	IVT Factor	Wait Time Factor	Interchange Penalty (min)	Walk Time Factor	Value of Time (Rs/hour)
Mode Specific Data					
Metro [FUTURE]	1.00	2.00	12		
Air-Con Bus	1.20	2.00	12		
Regular Bus	1.40	2.00	12		
Rail	Crowding	2.00	12		
Link Specific Data				1.5	
Person Value of Time by Income Group					
Low					10
Medium					31
High					92

In-vehicle time factors for public transport modes are based on assumed differences in perceptions of comfort and journey time unreliability. All in-vehicle time factors are based on an MRT reference case (future model) which will be providing optimal journey time reliability and comfort. The basic journey time unreliability penalty has been assumed as 20% of in-vehicle time for road based public transport, while additional discomfort has also been assumed as 20% of IVT for non-air conditioned modes.

The Interchange penalty represents the psychological disutility of transferring between services (as opposed to using a direct route) which is added to the actual cost involved during an interchange – walk, wait and possibly additional fare. Once the costs of each mode are calculated then the estimated passenger trips derived from the demand model are then assigned onto the public transport network whereby for a given origin – destination pair, the route taken will be based on the lowest generalised cost.

2.2.2 Future Model Development

The model is developed for future benchmark years which for this study have been selected as 2021 and 2031. This section describes the model structure for the future years and then the forecasting assumptions prepared for the benchmark years.

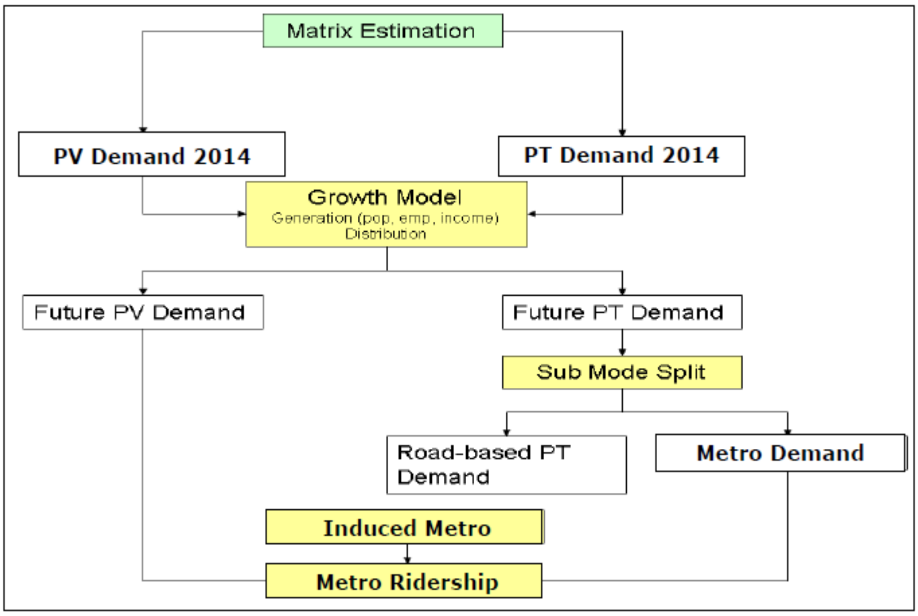
Figure 2.1 shows the progression of the model structure from the 2014 structure in which separate demand matrices for private and public transport were developed from observed data.

The basis for the future year travel demands is the growth model shown in the above figure between the 2014 and future model application. The model is calibrated in 2014 to develop a relationship between land use data (population and employment), income/vehicle ownership and trip making. This relationship is then used in the future to forecast total trip making and modal share between private and public transport in the future. Within public transport, the share between road and rail-based travel is then calculated. The costs for this split are derived from the detailed public transport sub-model.

The sub-model for rail needs to consider the following alternatives for the future situation:

- Rail commuter as main mode – existing rail commuter services with bus as feeder
- MRT as main mode – future MRT system, no rail service but bus as a feeder
- Mixed rail as main mode – future MRT system and rail commuter used together with bus as feeder.

FIGURE 2.1: OUTLINE OF FORECAST YEAR MODEL STRUCTURE



The public transport sub-model structure then becomes quite complex as shown in **Figure 2.2** as the different costs of alternatives (which combine to form Level of Service – LOS – or generalized cost), by different income groups needs to be considered.

The parameters feeding into the generalized cost (or LOS) calculation are largely the same as those shown in **Table 2.6**. The exceptions to this are the future year value-of-time some adjustments to the in-vehicle-time factors for buses to reflect the improvements in bus service provision (eg. better information, bus priority measures etc). Furthermore, it can be expected that in the future more of the bus fleet will be air conditioned compared to today.

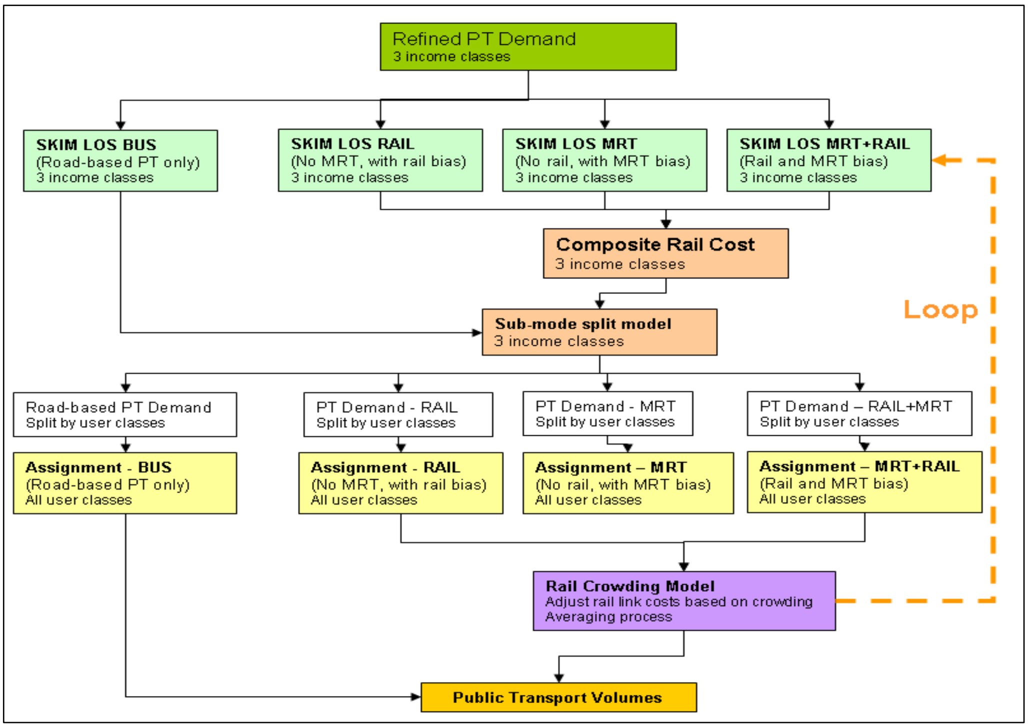
Road Network Assumptions

Future road network assumptions have been developed based on official sources such as road network Master Plan prepared by MMRDA (Mumbai Urban Infrastructure Project).

The following major road projects have been included in the horizon year road transport network in line with the recommendations of CTS.

- Eastern Freeway
- Elevated Link – Sewri – Worli
- Western Freeway Sea Link (WFSL)
- WFSL north extension – Bandra – Dahisar
- Santa Cruz-Chembur Link Road

FIGURE 2.2: FUTURE YEAR APPLICATION OF PUBLIC TRANSPORT SUB-MODEL



Note: LOS (level of service) refers to a set of variables such as in-vehicle time, waiting time, fares etc…

In addition to these committed road projects, there is also a programme of road network improvements including flyovers and junction improvements at a more local level. These should have the impact of generally providing some additional capacity/speed improvement on the road network. To reflect these local changes, road capacity on the existing road network has been assumed to grow at 1% per annum.

Public Transport Network Assumptions

Out of the total envisaged mass transit network in MMR, the assumed operational network in the transport model is set out in **Table 2.7**.

TABLE 2.7: RAILWAY NETWORK ASSUMPTIONS

Year	Rail Network Development
2014	Metro Line 1: Versova – Andheri – Ghotkopar Monorail Phase 1: Jacob Circle – Wadala – Chembur
2015	MUTP Rail Improvements
2021	Metro Line 3: Colaba – Bandra-SEEPZ
2021	Metro Line 2: Dahisar – Charkop – Bandra – Mankhurd
2022	Metro Line 5: Wadala – Ghatkopar – Thane – Kasarvadavali
2021	M 7: Dahisar – Andheri
2031	M10: Dahisar – Mira Road – Manikpur – Virar
2031	Mo6: Thane – Dahisar
2031	Mo 3: Mulund – Goregaon – Gorai

2.3 RIDERSHIP ON PROPOSED SWAMI SAMARTH NAGAR TO VIKHROLI (EEH) METRO CORRIDOR

While estimating the ridership figures for the proposed Metro corridor, following important considerations have been made:

- P3E3 landuse scenario is considered. This scenario allocates growth to MCGM and RoR in equal proportion.
- Future road and rail/ metro network as detailed in the previous section.
- Interchanges with other metro corridors have been considered;
    - Line 2 at Adarsh Nagar
    - Line 7 at JVLR
    - Line 3 at SEEPZ Village
    - Line 4 at Kanjur Marg(W)
    - Sub Urban Railways at Kanjur Marg(W)
- Metro Fare is considered as 1.5 times the ordinary bus fare.
- Speed of the metro is taken as 35 Kmph.
- Peak Hour Frequency of metro service is considered as 3.5 minutes for 2031.

The daily ridership, peak hour station loads and peak hour section loads for the proposed Metro Corridor are given in **Table 2.8** - **2.13**.

Table 2.8 Peak Hr. Ridership for Metro Line - 6 (Swami Samarth Nagar – Vikhroli (EEH)) for 13 stations (2021)

S. No.	Direction Swami Samarth Nagar to Vikhroli(EEH)	Sectional Loads	Boarding	Alighting	S. No.	Direction Vikhroli (EEH) to Swami Samarth Nagar	Sectional Loads	Boarding	Alighting
1	Swami Samarth Nagar		8964	0	13	Vikhroli (EEH)		5307	0
2	Adarsh Nagar	8964	2414	80	12	Kanjur Marg (W)	5307	13950	2009
3	Jogeshwari(W)	11298	1680	1368	11	IIT, Powai	17248	558	153
4	JVLR	11610	12250	831	10	Powai Lake	17653	86	232
5	Shyam Nagar	23029	2617	1491	9	Rambaug	17507	290	91
6	Maha Kali Caves	24155	844	283	8	Saki Vihar Road	17706	905	1020
7	SEEPZ Village	24716	1782	2660	7	SEEPZ Village	17592	2462	1686
8	Saki Vihar Road	23839	777	1726	6	Maha Kali Caves	18368	855	242
9	Rambaug	22890	146	167	5	Shyam Nagar	18981	2807	1455
10	Powai Lake	22869	301	511	4	JVLR	20333	970	10425
11	IIT, Powai	22653	240	812	3	Jogeshwari(W)	10878	756	2491
12	Kanjur Marg (W)	22081	4015	16200	2	Adarsh Nagar	9143	29	1144
13	Vikhroli (EEH)	9896	0	9896	1	Swami Samarth Nagar	8028		8028
	Peak Hour Ridership	65005							
	PHPDT	24716							

Table 2.9 Station to Station OD Matrix (Swami Samarth Nagar – Vikhroli (EEH)) for 13 stations (2021)

Stations	Swami Samarth Nagar	Adarsh Nagar	Jogeshwari (W)	JVLR	Shyam Nagar	Maha Kali Caves	SEEPZ Village	Saki Vihar Road	Rambaug	Powai Lake	IIT, Powai	Kanjur Marg (W)	Vikhroli (EEH)
Swami Samarth Nagar	0	80	194	460	423	61	658	329	31	98	204	4946	1481
Adarsh Nagar	29	0	1174	333	37	11	56	51	2	6	11	621	112
Jogeshwari(W)	349	407	0	38	88	14	101	57	7	20	32	1049	274
JVLR	626	264	80	0	943	185	1682	1027	89	313	488	4952	2572
Shyam Nagar	578	39	181	2009	0	12	125	123	12	16	30	1999	301
Maha Kali Caves	141	14	54	645	1	0	39	53	7	19	7	496	223
SEEPZ Village	475	29	123	1731	83	23	0	87	15	28	25	1344	284
Saki Vihar Road	173	32	64	462	84	16	76	0	4	11	10	477	276
Rambaug	59	6	25	145	17	4	25	9	0	6	6	76	58
Powai Lake	16	1	6	50	3	1	5	3	1	0	0	209	92
IIT, Powai	162	7	42	279	21	3	22	15	8	0	0	32	208
Kanjur Marg (W)	4570	303	1646	3865	1116	146	1287	807	63	130	17	0	4015
Vikhroli (EEH)	850	43	270	1240	131	50	271	186	19	102	136	2009	0

Table 2.10 Trip Distribution (2021)

Dist.	%	Trips
0-2	18.68	12143
2-4	10.93	7104
4-6	9.47	6155
6-9	8.96	5821
9-12	32.66	21230
>12	19.30	12546
	100.00	65000

Table 2.11 Peak Hr. Ridership for Metro Line - 6 (Swami Samarth Nagar – Vikhroli (EEH)) for 13 stations (2031)

S. No.	Direction Swami Samarth Nagar to Vikhroli(EEH)	Sectional Loads	Boarding	Alighting	S. No.	Direction Vikhroli (EEH) to Swami Samarth Nagar	Sectional Loads	Boarding	Alighting
1	Swami Samarth Nagar		11493	0	13	Vikhroli (EEH)		3317	
2	Adarsh Nagar	11493	2802	72	12	Kanjur Marg (W)	3317	20324	1109
3	Jogeshwari(W)	14223	1776	1614	11	IIT, Powai	22532	5237	108
4	JVLR	14385	12828	823	10	Powai Lake	27661	75	311
5	Shyam Nagar	26390	3193	1708	9	Rambaug	27425	363	109
6	Maha Kali Caves	27875	939	330	8	Saki Vihar Road	27679	852	1078
7	SEEPZ Village	28484	2053	2852	7	SEEPZ Village	27453	2623	2037
8	Saki Vihar Road	27685	723	1556	6	Maha Kali Caves	28039	1007	357
9	Rambaug	26852	119	165	5	Shyam Nagar	28689	3271	2302
10	Powai Lake	26806	411	487	4	JVLR	29658	1097	13356
11	IIT, Powai	26724	156	5172	3	Jogeshwari(W)	17399	940	3144
12	Kanjur Marg (W)	21708	1318	17824	2	Adarsh Nagar	15195	36	1390
13	Vikhroli (EEH)	5202	0	5202	1	Swami Samarth Nagar	13841		13841
	Peak Hour Ridership	76953							
	PHPDT	29658							

Table 2.12 Station to Station OD Matrix (Swami Samarth Nagar – Vikhroli (EEH)) for 13 stations (2031)

Stations	Swami Samarth Nagar	Adarsh Nagar	Jogeshwari (W)	JVLR	Shyam Nagar	Maha Kali Caves	SEEPZ Village	Saki Vihar Road	Rambaug	Powai Lake	IIT, Powai	Kanjur Marg (W)	Vikhroli (EEH)
Swami Samarth Nagar	0	72	231	490	439	64	818	327	32	104	1569	6231	1116
Adarsh Nagar	36	0	1383	293	39	25	59	54	2	6	243	642	56
Jogeshwari(W)	499	441	0	40	90	14	104	56	6	19	427	873	147
JVLR	812	217	68	0	1140	213	1713	902	92	286	1523	5175	1784
Shyam Nagar	690	41	196	2344	0	14	125	120	10	16	651	2094	163
Maha Kali Caves	170	16	53	767	1	0	33	33	6	18	145	545	159
SEEPZ Village	632	31	140	1692	102	26	0	64	13	27	399	1404	146
Saki Vihar Road	200	32	66	412	85	18	39	0	4	11	140	441	127
Rambaug	91	4	29	184	14	4	27	10	0	6	75	13	25
Powai Lake	17	1	5	41	2	1	5	2	1	0	0	370	41
IIT, Powai	2010	125	663	1303	430	51	382	189	84	0	0	36	120
Kanjur Marg (W)	7994	456	1776	5783	1591	213	1459	768	13	251	20	0	1318
Vikhroli (EEH)	690	26	148	830	77	44	125	109	11	60	88	1109	0

Table 2.13 Trip Distribution (2031)

Dist.	%	Trips
0-2	12.18	9368
2-4	10.35	7959
4-6	8.18	6296
6-9	9.81	7545
9-12	38.16	29357
>12	21.33	16408
	100.00	76934

Chapter - 3

SYSTEM DESIGN

3.0 INTRODUCTION

3.0.1 Swami Samarth Nagar – JVLR – SEEPZ – Kanjur Marg – Vikhroli (EEH) Metro Corridor starts from Swami Samarth Nagar runs eastward via Adarsh Nagar, Jogeshwari (W), JVLR, Shyam Nagar, Mahakali Caves, SEEPZ Village, Milind Nagar, Ram Baug, Pawai, Kanjur Marg and terminates at Vikhroli (EEH).

3.0.2 The entire corridor will be elevated and total length is 14.477km. (Dead-end to dead end).

3.0.3 Thirty thirteen stations have been proposed on the corridor. Efforts have been made to keep the inter station distance about a kilometer. However the closest inter-station distance is 728.80m and farthest 1658.0m.

3.0.4 13 stations will be two level stations with the concourse and station facilities on the lower level and platforms on the higher level. Two stations are one level station due to flyover, concourse of these stations will be constructed at ground.

3.0.5 Maintenance Depot has been proposed western end of the corridor after Vikhroli (EEH) station in the open land by the side of the Eastern Express Highway.

3.1 PERMANENT WAY

3.1.1 Choice of Gauge

The issue of Broad Gauge vs. Standard Gauge for Metro in India has been debated widely and the decision has been in favour of Standard Gauge. Even Delhi Metro which started with Broad Gauge has switched over to Standard Gauge. It is advantageous for many reasons as indicated below:

(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 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 minimize 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. Land requirement for depots, where a large number of lines are 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, optimized 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 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 gets absorbed and 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 sometime argued that adoption of Broad Gauge for metros would enable inter-running of metro trains with Indian Railways since the latter use Broad Gauge. Inter-running is, however, technically and / or operationally not feasible as the two systems have different:

- Rolling Stock characteristics,
- Signaling 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 system.

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

It will thus be 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 in the country and as well create an export potential for such coaches.

3.1.2 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.

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 as the regular cleaning and replacement of ballast at such location will not be possible. Only in case of the depot, normal ballasted track is proposed for adoption.

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.

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 main lines will have sharp curves and steep gradients, 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.

Ballastless Track on 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.**3.1**). It is proposed to adopt suitable Fastenings System with a base-plate to base-plate spacing of 65 cm, on viaducts complying of performance criteria laid down by Railway Board vide letter Circular No. 2009/Proj/InAs/9/2, dated 02.05.2010.

Ballastless Track in Depot

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

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

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. 3.2**).

ii) On Depot lines, 1 in 7 type turnout with a lead radius of 190 metres and permissible speed on divergent track as 25 km/h (shown in **Fig. 3.3**).

The Scissors crossovers on Main Lines (1 in 9 type) will be with a minimum track centre of 4.5 m (shown in **Fig. 3.4**).

- 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 section, 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.

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.

3.1.3 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.

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.

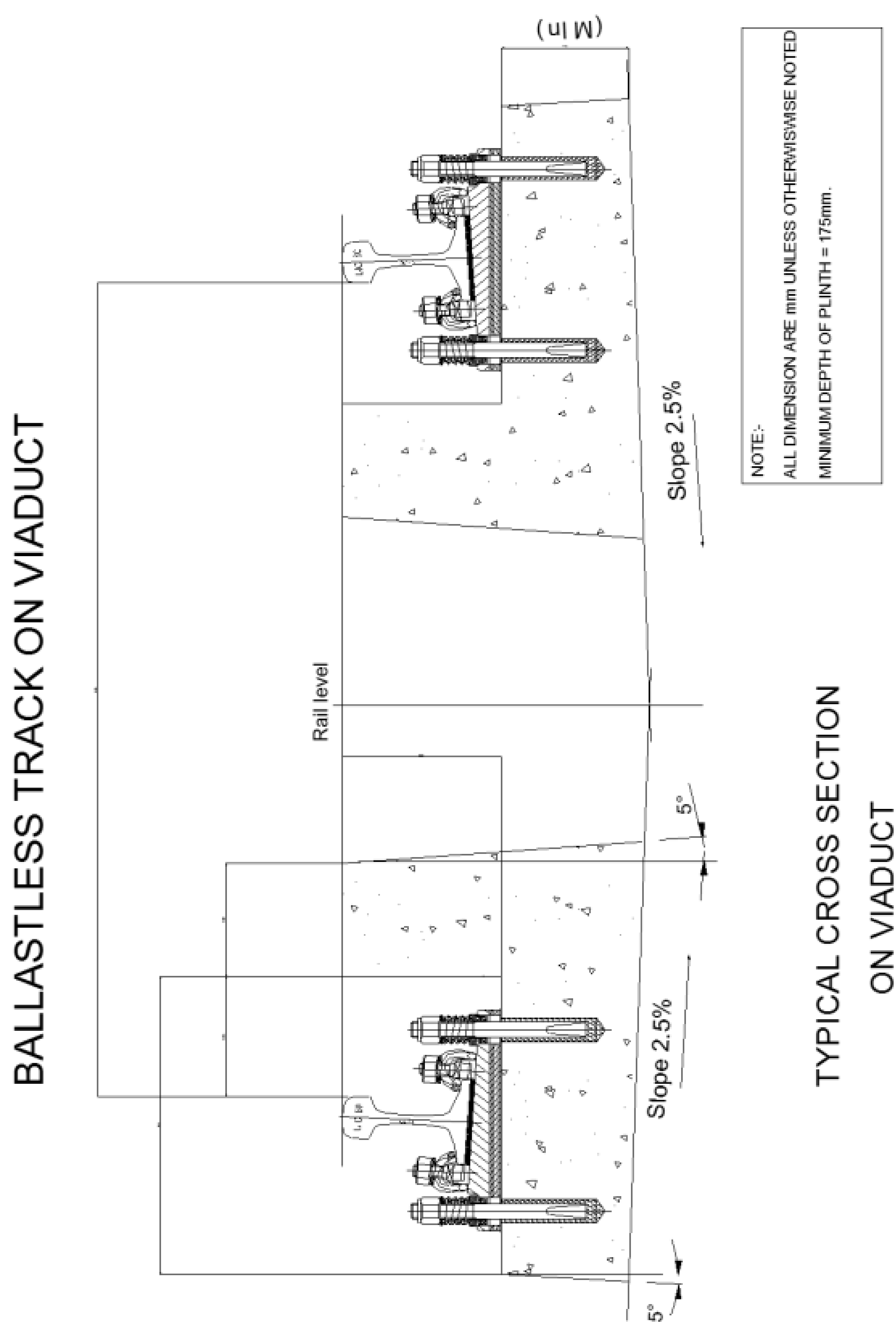
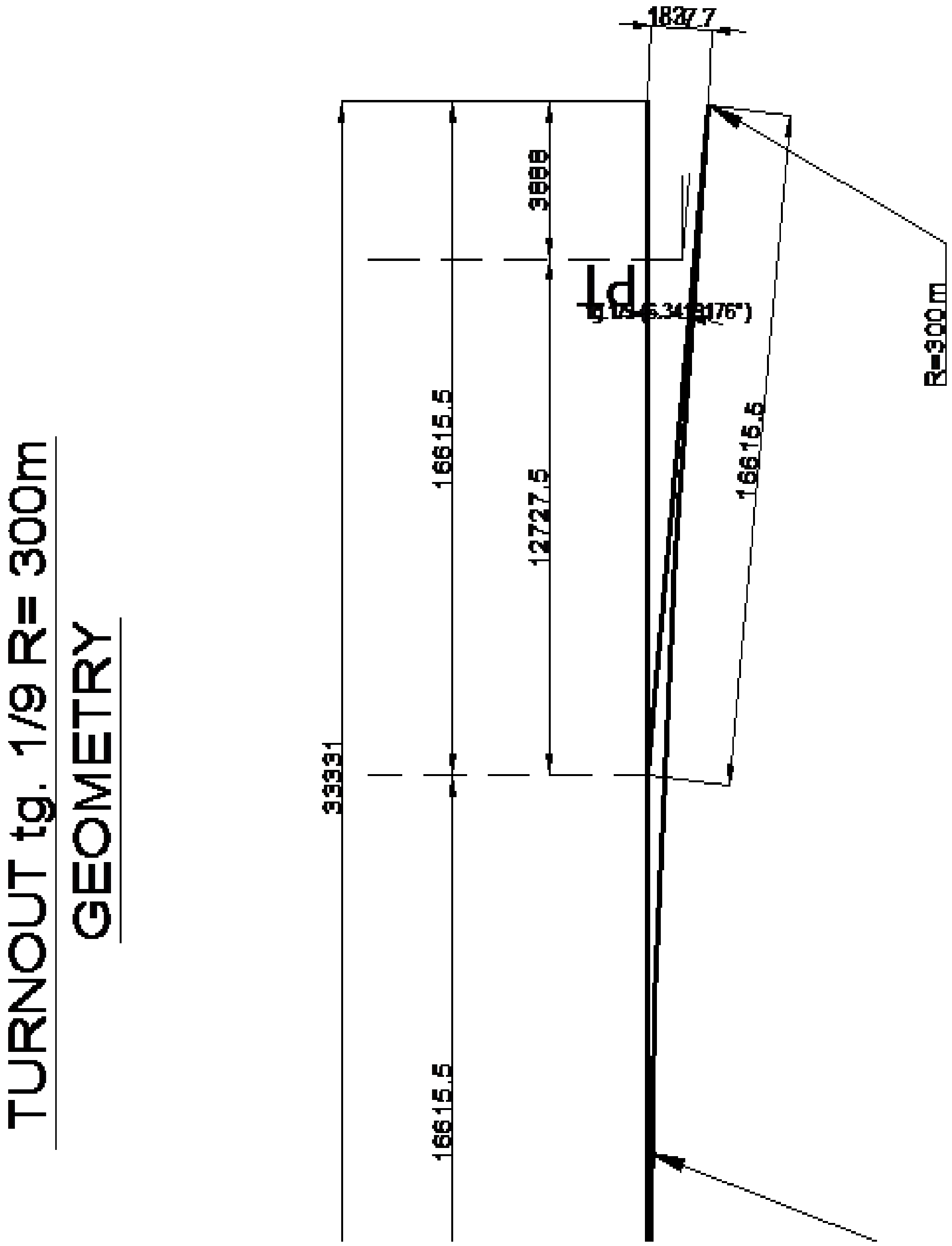

BALLASTLESS TRACK ON VIADUCT
Rail level
Slope 2.5%
Slope 2.5%
5°
5°
(M In)
NOTE:-
ALL DIMENSION ARE mm UNLESS OTHERWISWSE NOTED
MINIMUM DEPTH OF PLINTH = 175mm.
TYPICAL CROSS SECTION
ON VIADUCT

Fig No. 3.1

Fig No. 3.2


TURNOUT tg. 1/9 R= 300m
GEOMETRY
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12727.5
33331
16615.5
16615.5
R=300m

TURNOUT tg. 1/7 R=190m

GEOMETRY

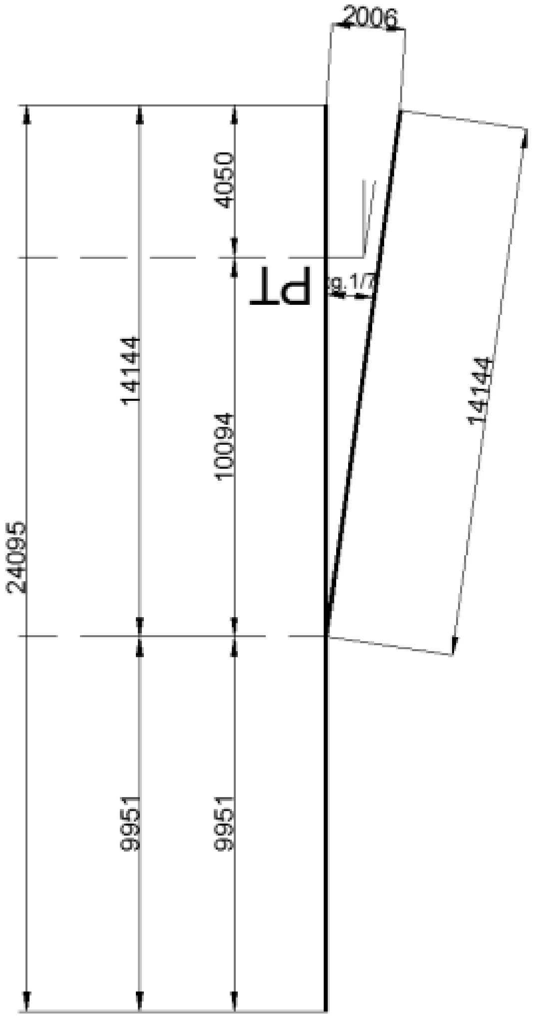


Fig No. 3.3

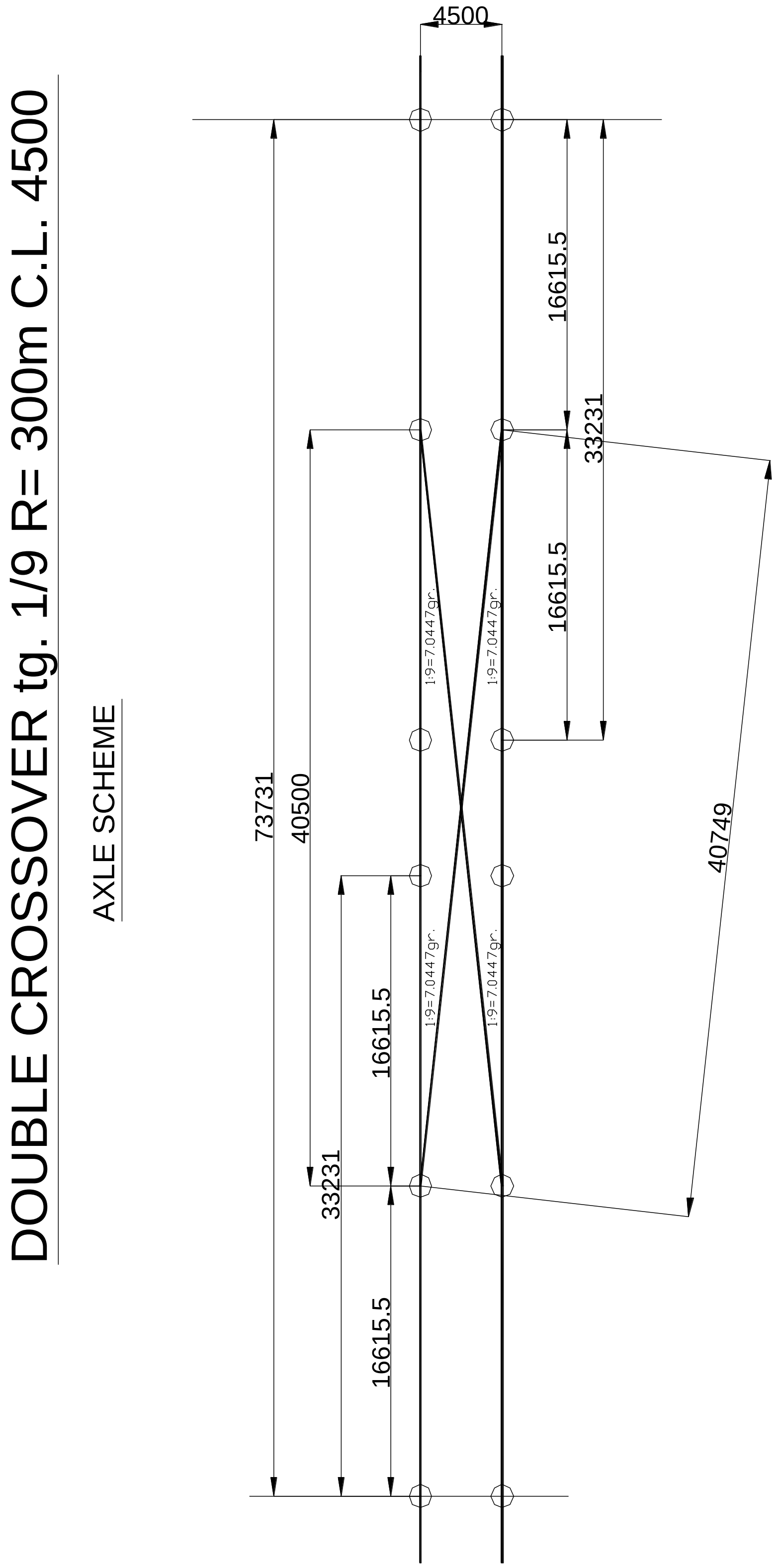

DOUBLE CROSSOVER tg. 1/9 R= 300m C.L. 4500
AXLE SCHEME
4500
16615.5
33231
16615.5
73731
40500
16615.5
33231
16615.5
40749
1:9=7.0447gr.
1:9=7.0447gr.
1:9=7.0447gr.
1:9=7.0447gr.

Fig No. 3.4

3.2 TRACTION SYSTEM

3.2.1 Introduction

3.2.1.1 Traditionally, electric traction is used in Indian Railway system as a pre-requisite, for requirements of high acceleration and pollution free services in Urban areas. The system of electric traction selected for the Metro corridors of Mumbai Metro Rail Corporation Ltd. (MMRCL) is of 25 kV AC 50 Hz, single phase for feeding power to the Metro trains. 25 kV AC Electric Traction has the advantage of a considerable low electric energy consumption and also affords considerable safety features. Further, the number of Receiving Sub-Stations for feeding the power supply to overhead traction system also gets reduced with a larger length of feed without the problem of low voltage. Another special feature of going in for 25 kV AC traction is by way of adoption of a very low size of overhead conductors thereby resulting in lighter OHE structures and reduced capital cost as well as running cost. For the purpose of running additional trains at increased frequency, existing 1500 V DC system on Central and Western Railways is under conversion into 25 kV AC system on a programmed basis. This will also result in considerable saving of Electrical Energy and reduction in running cost of the system.

3.2.1.2 The proposed metro corridor from Swami Samarth Nagar to Vikhroli (EEH) i is on the elevated viaduct. Keeping in view the ultimate traffic requirements, uniformity, standardization and other techno-economic considerations, 25 kV AC traction system is considered to be the best alternative and has been adopted for Metro Railway system. However suitable measures shall have to be taken for reducing the effect of Electro Magnetic Induction (EMI) caused by traction return currents. EMI Mitigation measures are simple & well known compared to DC Stray current corrosion protection.

3.2.1.3 25 kV AC traction has the economical advantages of minimal number of traction sub-stations and potential to carry large traffic. The proposed Mumbai Metro System is being designed to handle PHPDT of around 20000 when trains are expected to run at 3 minutes frequency during peak hours.

3.2.2 Salient Features of the System

3.2.2.1 25 kV AC OHE shall be of flexible type. It shall comprise of one cadmium copper catenary wire of size 65 Sq.mm and one hard-drawn copper contact wire of size 150 sq.mm. duly supported by copper wire droppers of size 5 mm dia. Normally OHE masts supporting the OHE wires shall be independent cantilever masts on which swiveling type bracket assembly is provided. On portal structures bracket assembly for the intermediate tracks is erected on drop arms. The traction power is distributed through overhead catenary system both for the mainline and the Car Depot.

3.2.2.2 The electrical sections on OHE known as 'Sectors' are switched "ON" and "OFF" by 25 kV interrupters controlled and monitored from Operation Control Centre (OCC). An electric section comprising of catenary wire and contact wire is fed by a Receiving Sub-Station (RSS) and it consists of several electrically connected elementary sections, like Sectioning Posts (SP) and Sub-Sectioning and Paralleling

Posts (SSP). The sectionalizing is indispensable from the operation point of view as it would allow de-energizing some portion of the line when any unusual occurrence takes place. This helps in isolation and restoration of the traction power on the affected part of the line.

3.2.2.3 Span of OHE Mast

The distance between the central line of the adjacent supporting structures for the overhead equipment lines is known as span. The standard spans vary in steps of 4.5 m from a minimum of 25 m to a maximum of 72 m. The span of OHE masts shall generally be 50 m.

3.2.2.4 Height of Contact Wire

Normally the height of the contact wire (under side the surface) above the track plane shall not be less than 5.50 M at any point in the span under the worst temperature conditions. To ensure this, the normal height of the suspension point shall be 5.60 M. At car-shed-cum-workshop the minimum height shall be 5.80 M. However, in order to reduce construction cost of Metro Railway system, it is recommended to keep the contact wire height at 5 M against the normal height of 5.5 M and encumbrance at 0.9 M against normal 1.4 M.

3.2.3 Earthing Arrangements

3.2.3.1 Earthing of Over Line Structures

The metallic parts of foot or road-over-bridges or other over-line structures over wired tracks shall be connected either to a traction rail or to an earth by means of two mild steel strip/flats of cross-section not less than 200 mm^2 each.

3.2.3.2 Earthing of Exposed Metallic Parts

All exposed metallic parts which are not likely to come in direct contact with 25 kV overhead equipment, such as platform structures/sheds, metallic fencing, wires, pipes and such other items but which are located within a distance of 20m from the nearest railway track shall be connected to an earth or traction rail.

3.2.3.3 Earthing Heel of Isolator Switch

The earthing heel of an isolator switch shall be connected by two mild steel flats of cross-section not less than 200 mm^2 each to the supporting metallic traction mast or structure or support. Such a traction mast or structure or support shall, in turn, be connected to a traction rail or an earth wire and, in addition to an earth.

3.2.3.4 Provision of Overhead Protection Conductor

One overhead protection conductor connecting all the traction masts shall be erected over the traction line. Also track rail of the same track to be connected to overhead protection conductor intermittently for proper earthing.

3.2.4 OHE Sectioning

3.2.4.1 Purpose

The overhead equipment between two RSS is divided electrically into sections with sectioning post & sub – sectioning posts, with insulated overlaps, with section insulators at turn-outs and cross overs. Under normal working conditions, electrical continuity is maintained by bridging the insulated overlaps by means of interrupters or isolators. Isolation of small sections of OHE is necessary for maintenance and repair. Sectioning of OHE should be kept to a minimum, consistent with operational requirements.

3.3 SIGNALLING AND TRAIN CONTROL SYSTEM

3.3.1 Introduction

This Chapter provides the main design features of the signalling and train control for the operation of the Mumbai Metro Corridor Swami Samarth Nagar to Vikhroli (EEH), taking into account the proven and advance system being used worldwide.

The Signalling and Train Control System shall provide the highest security level for means of an efficient Train Control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.

The Proposed Mumbai Metro rail corridors between Swami Samarth Nagar to Vikhroli (EEH) is planned to be operated at 85 Km/hr.

As per traffic report, Mumbai Metro rail corridor between Swami Samarth Nagar to Vikhroli (EEH), trains are to be maintained headway at every about 100 second i.e. However, the signaling System shall be designed at minimum 90 second headway in one direction.

3.3.2 Signalling

The Signalling shall provide the highest security level to ensure that the operational activities are developed following strict safety requirements. At the same time it shall meet the requirements for efficient train operations and high quality of service. The proposed signaling system design for metro line corridor is as under:

- Continuous Automatic Train Control System (CATC)
- Automatic Train Operation System (ATO)
- Radio based Automatic Train Control (ATC) System
- Automatic Train Protection (ATP) System
- On board Equipments
- Cab Signalling
- Fall-Back Block System
- Interlocking device
- Track side Radio equipments
- Track Vacancy Detection System
- Electric Point Machine
- Track side Signals
- Centralized Traffic Control System
- Power Supply of signaling
- Cable for signalling
- Half Height Integrated Platform Gate (PG)

3.3.3 Overview of Signalling System

It is expected to carry large number of passengers by maintaining shorter spacing between trains 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 people.

The requirements of the Mumbai Metro Corridor planned to be achieved by adopting following basic principles of signaling System:-

- The Train Control and Monitoring shall be ensured from Centralized Traffic control System located at Operation Control Centre (OCC). OCC equipments shall be connected to station equipment room through optical fiber network.
- Computer Based Interlocking System shall be designed on failsafe philosophy. In case of failure of any equipment, the equipment shall fail on safe side or more restrictive state. In such case the signaling System shall authorized movement of train in normal and degraded operations.
- Track side equipments shall be connected through Electronic Interlocking (to Station Equipment Room) by secure links to ensure safe movement of train.
- Provide high level of safety with trains running at shorter headways 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.
- Provide safety and enforce speed limit on the sections having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed 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 borne equipments and enabling preventive maintenance.
- To avoid any accident at platform, Integrated Passenger Gate shall be provided, which will be a barrier between the track and platform accessible to passengers. Signaling and Rolling Stock interfaces shall be provided for Passenger Gate System.
- Signalling & Train Control System on the line shall be designed to meet the required headway during peak hours.

3.3.4 System Description and Specifications

The requirements of the metro are planned to be achieved by adopting ‘CATC’ (Continuous Automatic Train Control System) based on “CBTC” (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

Radio for CBTC shall work in License free ISM band. The Signaling and Train Control system shall be as below and Sub-system/ components will conform to international standards like CENELEC, IEC, IEEE, IS, ITU-T etc:

3.3.5 Continuous Automatic Train Control

Continuous Automatic Train Control based on CBTC will consist of - ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems. The Train- borne Automatic Train Control System will consist of Automatic Train Operation (ATO) and Automatic Train Protection (ATP). This will work on moving block principle.

3.3.6 Automatic Train Protection (ATP)

Automatic 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. Line side signals will be provided at diverging routes (i.e. at points & crossings) as well as other required locations, which shall serve as backup signalling in case of failure of ATP system.

- Cab Signalling
- Moving block
- Track Related Speed Profile generation based on line data and train data continuously along the track
- Continuous monitoring of braking curve with respect to a defined target point
- Monitoring of maximum permitted speed on the line and speed restrictions in force
- Detection of over-speed with audio-visual warning and application of brakes, if necessary
- Maintaining safety distance between trains
- Monitoring of stopping point
- Monitoring of Direction of Travel and Rollback

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

3.3.7 Automatic Train Operation (ATO)

This system shall operate the trains automatically from station to station while remaining within the safety envelope of ATP & open the train doors. Driver will close the train doors and press a button when ready to depart. In conjunction with ATP/ ATS, ATO can control dwell time at stations and train running in accordance with headway/ timetable.

3.3.8 Automatic Train Supervision (ATS)

A train supervision system will be installed to facilitate the monitoring of train operation and also remote control of the station. 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.

The centralized system will be installed in the Operation Control Centre. The OCC will have a projection display panel showing a panoramic view showing the status of tracks, points, signals and the vehicles operating in the relevant section/ whole system. ATS will provide following main functionalities:

- Automatic Route setting
- Automatic Train Regulation
- Continuous Tracking of train position
- Display Panel & Workstation interface
- Link to Passenger Information Display System for online information
- Computation of train schedules & Timetable.

3.3.9 Computer Based Interlocking System (CBI)

The entire line including turn back track, transfer track, sidings will be equipped with CBI system for operation of points and crossings and setting of routes. The setting of the route and clearing of the signals will be done by workstation, which can be either locally (at station) operated or operated remotely from the OCC.

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 interlocking system design will be on the basis of fail-safe principle.

The equipment will withstand tough environmental conditions encountered in a Mass Transit System. 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, axle counters, relays, point operating machines, power supply etc.

3.3.10 Track Vacancy Detection

Primary mode for track vacancy detection system on main line may be through Radio and for secondary detection, can be through Axle Counter.

In view of above advantages and dis- advantages of Axle counter and AFTC Track Circuit, the Axle counters have been used in vital train detection schemes on a large scale in Europe and outside of Europe. Also, an Axle counter is a cost effective alternative to track circuits when applied correctly and are available from several manufacturers. As per site conditions prevailing (like rainy weather, hilly area) in the section, Axle counter track detection system is recommended.

Axle counter is used to detect the track occupancy and to count the number of axles, and which train detection is discontinuously performed. It is not affected by weather conditions, and achieves reliable train detection. It interfaces with interlocking system in order to respond to functional errors on the basis of self-diagnosis as well as to transmit the information.

The axle counter consists of the following equipment: -

- Detection Point (or counting head)
- Evaluator

3.3.11 Wayside Signals

Multi Aspect Colour Light (LED) type Line side signals shall be installed on the Main Line at stations with point and crossing for point protection catering for bidirectional working and depot entry/ exit.

3.3.12 Cab Signaling

Cab signalling is a railway safety system that communicates track status information to the cab, crew compartment or driver's compartment of a train. The train driver can see the information continuously. The DMI (Driver Machine Interface Display) is the device that displays driving information in the driver cab. Information are transmitted by the wayside to Radio equipment & Radio equipment to On-board equipment. The data is computed by the on-board equipment and displayed on a screen on driver desk.

Vital information concerning the safe working of the train are displayed directly in the driving cab on the DMI. The DMI displays:

- Brake details: distance to first brake application.
- Speed information: current train speed, permitted speed, target speed (left side of DMI, respectively on circular speed gauge: speed pointer, light grey circular bar, dark grey circular bar).
- Auxiliary driving information: state of brakes (service brake, emergency brake), state of the connection between the on-board and the RBC.

The DMI is also the interface between the driver and the on-board equipment to get driver information, train characteristics or request for shunting operation.

3.3.13 Point Machines

Non-Trailable Electrical Point Machine capable of operating with 3-phase, 50 Hz. 380V AC will be used on main line and the depot point machine will be trailable type electrical point machine capable of operating with either 3 phase, 50 Hz. 380V AC or 110V DC.

3.3.14 Train Depot: Signalling

All depot lines except the one which is used for shunting and lines in the workshop shall be interlocked. A workstation shall be provided in the Depot Control Centre for electrical operation of the points, signals and routes of the depot yard. Axle Counter will be used in the depot as well. A test track with similar Signaling and Train control system as adopted in Main Line shall be provided at Depot.

3.3.15 Signaling Mode of Operation

There are five signalling modes of operation which shall be available but only one single signaling mode shall be active at any one instant of time. These five Modes are mentioned as under:-

a) Restricted Manual (RM) Mode for Depot.
b) Automatic Train Protection (ATP) Mode
c) Automatic Train Operation (ATO) Mode
d) Run on Sight Mode (ROS) Mode
e) Automatic Turn back Mode

3.3.16 Half Height Integrated Platform Gate (PG)

The Integrated Platform Gate system shall provide a barrier between the track and the platform accessible to passengers. The system shall improve the safety of passengers by isolating the platforms from the track unless there is a train stopped at its correct position. PG system shall be around 1.5 Metre heights and it shall consist of sets of bi-parting doors installed along the full length of platform.

The PG system shall comprise Automatic Sliding Gates (PGs), Platform End Doors (PEDs), Emergency Escape Doors (EEDs) and Fixed Screens (FSS) to form a barrier along the edge of the platform adjacent to the track. Platform Gates shall correspond to the location of each of the train doors when the train has berthed at its correct position. Each platform end shall be closed by a Platform End Door. The remaining portion of PG facade shall be provided with manually openable Emergency Escape Doors and Fixed Screens.

The PG system shall be integrated with structure and architecture of the station and operationally with Signalling System as well as Rolling stock System. The interface between Signalling System and PG shall be designed to fail safe signalling standards and according to relevant International standard. All vital control and detection circuits of PG system shall be double cut.

Opening and closing of PG and Train doors shall be synchronous. Train movement should not be permitted until it is confirmed that both Train doors and Platform Gates are properly closed. The PG shall be quiet in operation and all the elements of the PG installations (fixed and moving) shall be sufficiently rigid to avoid generation of noise by panel excitation

3.3.17 Centralized Traffic Control (CTC)

The Railway Operation shall be managed from the Central Traffic Control that located in Operation control Centre (OCC) that is in charge of managing real time traffic, safety of movement, rolling stock, on-board staffing, and work maintenance. The primary objective of the CTC system is to construct the routes of the trains from the origin up to the destination automatically and to supply all the information required to the centralized traffic control operator in order to check the normal operations of the trains. In addition, under its abnormal condition, the CTC system will provide effectively alternatives to minimize the delay of the train.

The CTC system interfaces to the external systems (interlocking, Radio equipments, SCADA, PIDS and PAS, etc.) so as to monitor and control the traffic and to ensure the safe operations of trains.

The CTC system shall meet the following requirements:

- The systems and communication lines shall be in redundant configuration and will ensure reliability and safety through continuous operations of the system.
- The CTC is interfaced with signalling devices set along the railway line and allow the operator to access different functionalities for traffic management with a man-machine interface (MMI).

- MMI allows the command acquisition, alarms display, and the viewing of control images.
- Each equipment units used for servers and industrial MMIs will be suitable for the Railway environment with high MTBF. The servers for the CTC shall be self diagnostic and fault noticing functions.
- It shall prepare the emergency situation through the construction of the back-up CTC.
- The suitable software for each operator workstation and server is configured to achieve the convenience of the operation.

Operational Room at OCC shall monitor the train operations and control the operations of train so that the trains can operate safely. The functions of the operating room will be supported by the LDP (Large Display Panel), and Workstations for the operators. The LDP in the operating room shows the entire track line of the Metro Rail in real-time so as to monitor it any time.

3.3.18 The CTC is composed of several rooms that have specific functions. In a basic configuration, four rooms are directly concerned by the Signalling System: the Operation Room, the Central Signaling Equipment room, the maintenance room and power supply room**.**

A) Operation Room

The Operational Room is the place from where the operators can monitor and control the traffic on the Line, using dedicated workstations and LDP (Large Display Panel).

B) The Central Signalling Equipment Room

This room includes all equipment managing the Signalling System included in the CTC control area.

As per site requirement, additional devices (other than signaling i.e Telecom and AFC System) can be considered in the Central signalling room. Also, this room shall be available at Central location as well as interlocking stations (SER, Station Equipment Room).

C) The maintenance room

All signalling devices information and technical alarms are displayed on workstations, and manual or automatic commands are possible from these workstations. This room shall be available at Central location as well as interlocking stations.

D) The power supply room

The room contains Uninterrupted Power Supply (UPS) necessary for the signalling technical room, the maintenance room and the operation room. The power supply arrangement is designed in order to provide uninterrupted power in case of general power breakdown. It includes all the equipment that provides power supply for CTC rooms. UPS room should be available adjacent to Signaling Equipment rooms at Stations and OCC. This room shall be available at Central location as well as interlocking stations.

The minimum surface areas required for each room at stations are:

- The signalling technical room: 40 m2
- The maintenance room: 30 m2
- The power supply room: 50 m2

At the OCC, BCC and the Depot, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

3.3.19 Back Up of The OCC (BCC)

In order to decrease the risks of disruption due to a local disaster such as fire, flood, building collapse, etc. a Main CTC (OCC) and a fall-back CTC (BCC) shall be provided, both shall be located in different areas.

The main CTC (OCC) could be located in one terminal station inside the premises of the passenger station. The fallback CTC (BCC) could be located around other terminal station or inside the future depot. The BCC shall be similar to OCC and also, BCC shall provide full redundancies of all systems and communications.

- The Main CTC (OCC), normally on-line and used by the Operators to control the Metro Line traffic. Operation & Maintenance Control,
- The fall-back CTC (BCC), normally off-line. The fall-back CTC will be used to control the Line only in case the Main CTC is accidentally unavailable. Besides, this CTC, being normally off-line, will be also available for other purposes such as training, testing, replay without disturbing the live traffic.

3.3.20 Standards

The following standards will be adopted with regard to the Signaling system;

Table 3.1

Description	Standards
Interlocking	Computer based 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 workshop lines, inspection shed lines etc.
Block Working	Moving Block working concept may be followed.
Operation of Points	Non-Trailable Electrical Point Machine capable of operating with 3-phase, 50 Hz. 380V AC will be used on main line and the depot point machine will be trailable/ non -trailable type electrical point machine capable of operating with either 3 phase, 50 Hz. 380V AC or 110V DC.
Track Vacancy Detection System	Primary mode for track vacancy detection system on main line and test track in depot may be through radio and for depot and secondary detection it can be through Axle Counter.
Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
Uninterrupted power Supply at stations as well as for OCC	For Signalling, Telecommunications and AFC.

Description	Standards
Train protection system	Train Protection system shall be based on CBTC (Communication based Train Control) System. The system architecture shall provide for redundancy. The system will conform to IEEE 1474 standards.
Train Describer System	Automatic Train Supervision 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. The system architecture shall provide for redundancy.
Fall Back CTC	Backup OCC (BCC)
Platform Gate	Integrated Platform Gate System
Cables	Outdoor cables will be steel armoured as far as possible.
Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for Signal and Train Control System.
Immunity to External Interface.	All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables as per standard. CENELEC standards to be implemented for EMC.
Train Working under emergency	Running on site with line side signal with speed automatically restricted between 15-25 Kmph.
Environmental Conditions	Air-conditioners for all equipment rooms.
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.

3.3.21 Space Requirement for Signaling Installations

Adequate space for proper installations of all Signalling equipment and Platform screen doors 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 Interlocking stations for Signalling Equipment Room shall be generally 40 sqm. For UPS Room (common for signaling, AFC and Telecom) at each of the stations the area required 50 sqm.

For Non interlocking stations, Signaling Equipments can be installed in the Telecommunication Room available at that 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.

3.3.22 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 centralized S&T repair lab suitably located in the section/depot. 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.

3.4 TELECOMMUNICATION SYSTEM

3.4.1 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 the metro network.

3.4.2 Overview

The Telecommunication facilities proposed are helpful in meeting the requirements for operation of trains

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:

- Radio System
- Backbone network using Optical Fiber Cable (OFC)
- Ethernet over SDH & WAN Network.
- Station to Station dedicated communication
- Telephone System with Telephone Exchanges, Telephones and their Recording
- Centralized Recording System (CDRS)
- Centralized Clock System
- Closed Circuit Television (CCTV) System
- Passenger Information & Display System within the station & trains and from Central Control to each station, Integrated Passenger Announcement System
- Train Traffic Control
- Assistance to Train Traffic Control
- Maintenance Control
- Emergency Control
- Data Channels for Signalling, SCADA, Automatic Fare Collection
- Power Supply of Telecommunications, and
- Cables for Telecommunications etc.

3.4.3 Telecommunication System and Transmission Media

3.4.3.1 Fibre Optic System (FOTS) - Main Telecommunication Bearer

The main bearer of the bulk of the Telecommunication network is proposed with optical fiber cable system. An OFC system shall provide a transmission network of Voice, Data, Ethernet, Video, and Signals among all Stations, Depot and OCC with sufficient transmission bandwidth to cater for the operational need of Metro line. The size of the OFC will fully meet with the applications need of the Metro line and commercial exploitation of the Telecommunication Network of Metro line. A minimum 96 / or 144 Fibers optical fiber cable with redundancy (cable on both side of track) is proposed to be laid. The optical fiber cable shall provide common transmission backbone network for Telecom and other systems which are formed by the two outdoor single mode optical fiber cables, one laying along the up-track and other one along the down-track. Additional 244 fiber optical fiber cables may be laid along track as per present commercial requirement for revenue.

3.4.3.2 Synchronous Digital Hierarchy Network (Ethernet Over SDH)

This network is SDH network by Fiber Optic Transmission (FOT) with Optical Fiber Cable (OFC), which consists of STM-64 as main communication network. Network using OFC has a feature that data can be transmitted with low loss so that there are no repeaters between SDH equipment. The SDH Equipment shall support "Ethernet Over SDH" (EOS) transport capability at Fast Ethernet Interface and Optical Gigabit Ethernet Interfaces. IP network shall have important data like transmission of train control signal therefore the network requires high reliability.

Main communication network provides a high reliable multiple single paths in 4-fiber MS-SPR (Multiplex Section Shared Protection Ring) topology with STM-16/64 covering signal equipment rooms in stations and depots and OCC. The 4-fiber MS-SPR topology can be used by 100% for protection channel or for extra traffic and support ring switch and span switch.

Therefore, SDH (minimum STM 16/64) based system will be adopted with SDH nodes at every station and OCC. 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 stations. Alternatively a totally IP Based High Capacity, highly reliable and fault tolerant, MPLS Ethernet Network can be provided in lieu of SDH/MUX

3.4.3.3 Gigabit Ethernet Network (WAN)

Considering the rapidly increased demand during the operation for top-level backbone network to 10 Gbps SDH Equipment is proposed. The communications network shall be configured as LAN and WAN – LAN shall be responsible for train operations and maintenance tasks within each passenger station and WAN shall be responsible for mutual communications between the stations and between depot and the central computer system. To maximize the reliability and survivability, each equipment and each transmission line are configured as a dual system.

Redundant Layer-3 switch at each station, depot OCC shall be provided to meet requirement of other Telecom systems (like CCTV, ticketing system maintenance management system and Wi-Fi network at station, PA, Clock, PIDS , Telephone System, SCADA etc.) and to support comparatively unimportant facilities for the operation.

Layer-3 Core switch at OCC shall be provided to cover all requirements for Centralized Management and Control facility of all equipment used in line. This network shall use the same OFC as the SDH network. Data lines of sufficient quantity and bandwidth shall be provided to other systems between Central Terminal Unit and Remote Terminal Unit.

3.4.3.4 Synchronization Network

The equipment receives standard synchronous signals from upper level stations or GPS at OCC, creates a synchronous clock, and then supplies synchronous signals to various digital communication equipments and lower level stations. 1+1 or N:1 protection switching functions are provided for the synchronous signal outputs.

The GPS receiver, standard input receiver, clock generator, and channel parts are into complete duplexes. In case of malfunctioning of any of these units, 1+1 non-blocking automatic switching is executed to minimize negative impact on services. This automatic switching provides reliability and stability. Clock reception signal for each equipment should be 2.048Mbps or 2.048MHz Clock signal. Clock synchronization mode shall be External Clock, Loop Timing Clock, Free-run, Holdover Clock.

The DOTS shall be configured to receive GPS signals through GPS satellites. Along with the DOTS, Network Time Servers (NTS) are also installed at each station. NTS provides standard clocks to all Metro systems. NTS of each station is physically configured as a dual.

3.4.4 Telephone Exchange

The System shall be IP Based with some of the extensions being Analog. For an optimized cost effective solution small exchanges of 30 port each shall be planned at each station and a 60 Port Exchange at the Terminal Stations and Depots shall be provided. The station exchanges will be connected to the Centre OCC main exchange. The Exchanges will serve the subscribers at all the stations and Central Control. The exchanges will be interconnected at the channel level on optical backbone. The exchanges shall be software partitioned for EPABX and Direct Line Communication from which the phones shall be extended to the stations. For the critical control communication, the Availability & Reliability should be high. Alternatively only for non-operational (other than Direct Line Communication) a separate IP Based Phone System can be implemented.

3.4.5 Mobile Radio Communication

Mobile Radio communication system having minimum 8 logical 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. All the stations, depots and the OCC 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.

The frequency band for operation of the system will be in 400/800 MHz band, depending on frequency availability. The system shall provide instant mobile radio communication between the motorman of the moving cars from any place and the Central Control. 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.

To provide adequate coverage, based on the RF site survey to be carried out during detailed Design stage, base stations for the system will be located at sites conveniently selected after detailed survey. Tentatively minimum 6 sites with rooftop towers with Base Stations shall be required along the proposed Swami Samarth Nagar to Vikhroli (EEH) Metro Corridor Mumbai.

3.4.6 Passenger Announcement System

The PAS shall be provided to broadcast voice messages to passengers /staff in all stations/ Depot from the locally as well as from OCC. It includes a network of amplifier and speakers linked to the station. The system capable of announcements from Station level will have over-riding priority in case of emergency announcements. The System shall be linked to Signalling System for automatic train actuated announcements.

The PAS and Passenger Information Display System (PIDS) shall be coordinated automatically to provide real time passenger audio broadcast and visual information at each station. Live audio broadcast relating to emergency, fire and evacuation messages from OCC and Station Control Room shall be recorded in the Centralised digital recording system at OCC. FOTS WAN network shall be used for transportation of data from Station/Depot to OCC vice versa.

3.4.7 Passenger Information Display System

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 all stations. The System shall be integrated with the PA system and available from same MMI. For the Platform Area, high intensity LED Boards will be used in Evaluated Section. For all the concourses and Platform Area of underground Stations, HDLED Panels shall be used, which can also provide Audio/Visual Advertisements apart from Trains running status.

3.4.8 Centralized Clock System

This will ensure an accurate display of time through a synchronization system of slave clocks driven from the GPS Based Master Clock at the Operation Control Center. The Master Clock signal shall also be required for synchronization of FOTS, Exchanges, Radio, Signaling, etc. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Master's Room, Depots and other service establishments.

3.4.9 Closed Circuit Television (CCTV) System

The CCTV system shall provide video surveillance and recording function for the operations to monitor each station. The monitoring shall be possible both locally at each station and remotely from the OCC on the Video Wall.

The CCTV System shall be end to end IP based Full HD IP cameras using backbone of FOTS WAN network and shall consist of a mix of Fixed Cameras and Pan/Tilt/Zoom (PTZ) Cameras. Cameras shall be extended /located at areas where monitoring for security, safety and crowd control purpose is necessary. All Videos shall be extended at Video Wall located at security control room at OCC.

Intelligent Video Analytic (Track protections, abandoned object detection, Perimeter protection, Movement detection, Platform track protection from falling object, Camera Tempering, Overcrowding / Consation detection, Excessive Queuing, Rule based detection, etc.) shall be provided in cameras of specific locations like Platforms, Vulnerable locations, etc. Alarm shall be generated and relevant data and video shall be transfer to OCC/Stations/Security Rooms through optical fiber network.

3.4.10 Access Control System

An Access Control System shall be provided for entering into important areas like SCR, SER, TER, OCC, DCC, TOM Rooms, etc. The System shall use the same AFC Smart Card as barring used for Travel on the system but giving Access to only the Authorized Personnel of the Metro. The System Shall be controlled and monitored centrally from the OCC.

3.4.11 Network Monitoring and Management

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide an Integrated Network Control System, 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, Telephone Exchange and summary alarms of PA/PIDS, CCTV and Clock System. The Integrated NMS will collect and monitor status and alarms from the individual NMS of the respective sub-systems and display on a common Work Station.

3.4.12 Technology

The Technologies proposed to be adopted for Telecommunication systems are shown in Table below:

Table 3.2 Technologies for Telecommunication Systems

System	Standards
Transmission Media	Optical Fibre system as the main bearer for bulk of the Telecommunication network
Telephone Exchange	IP PABX of minimum 30 ports is to be provided at all Stations, an Exchange of 60 Ports to be provided at Terminal 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 on Elevated and LED Panels in concourse 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 synchronization system of slave clocks driven from a GPS master clock at the OCC and sub – master clock in station. This shall also be used for synchronization other systems.
Passenger Announcement System	Passenger Announcement System covering all platform and concourse areas with local as well as Central Announcement.
Redundancy (Major System)	Redundancy on Radio's in the Base Stations, Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
Environmental Conditions	All equipment rooms to be air-conditioned.
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.

3.4.13 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 Telecom equipment shall be generally 40 sqm each for Telecom Room (Common for Signaling & Telecom equipments at none interlocking stations) and 50 sqm. For UPS Room (common for signal, Telecom and AFC). These areas shall also cater to local storage and space for maintenance personnel to work.

At the OCC, the areas required shall be as per the final configuration of the equipment and network configuration keeping space for further expansion.

3.4.14 Maintenance Philosophy for Telecom 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 the existing 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 / equipment requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

3.5 AUTOMATIC FARE COLLECTION SYSTEM

3.5.1 Introduction

Metro System handles large number of passengers. Ticket issue 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 less manpower. In view of the 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 of 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.

Seamless ticketing is now being thought of for Mumbai Metro Rail. This system is recommended to be adopted as this will enable the commuters to travel hassle free by different modes of transport viz. Metro, suburban trains, buses, water transport (whenever introduced) and even taxies without purchasing multiple tickets for each mode separately.

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 it 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 leakages of revenue due to 100% ticket check by control gates.
3. Recycling of ticket fraudulently by staff avoided.
4. Efficient and easy to operate.
5. System is amenable for quick fare changes.
6. Management information reports generation is easy.
7. System has multi operator capabilities. Same Smart Card can be used for other applications also.
8. AFC systems are the world wide accepted systems for Metro environment.

The proposed ticketing system shall be of Contact less Smart Token / Card type. The equipments for the same shall be provided at each station counter / booking offices 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 prone to dusty environment.

3.5.2 Gate

Retractable Flap Type/Paddle Type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern systems

3.5.2.1 Gate Function

a) Gate arrays shall be the normal-means of controlling entry to and exit from the paid areas. Control shall be by means of actuating a physical barrier on recognition of a valid ticket or card by the gate. The barrier may be a bi-parting leaves, centre flaps, end flaps or other configuration however the use of tripod or turnstile type gates is not acceptable. The gate shall be capable of operating either in normally open or normally closed mode.

b) Where required, barriers shall be provided to separate paid and unpaid areas of the concourse. The barriers shall meet local public safety requirements and be aesthetically merged with station engineering.

3.5.2.2 Features

a) **Power Failure** - In the event of a total power failure to the gates, the gates shall open to allow unrestricted user access. All latch gates shall automatically unlatch where electric locks are installed.

b) **Concourse Emergency Mode** - All AFC gates shall open whenever the Concourse Operating Mode is in emergency. An Emergency Push Button independent of the SC shall be provided in each Excess Fare Office.

c) **Ergonomics** - The engineering of the gate arrays should be such that the passenger uses reader placed on the right hand side while passing through the gate. The display and Contact less Smart Card (CSC) reader associated with each gate shall be grouped such that they bias the passenger towards the aisle through which the passenger should pass.

3.5.2.3 Types of Gates

(a). **Passenger Entry Gate**: - The Passenger Entry Gate shall control the entry of passengers into the paid area by validating the fare media.

(b). **Passenger Exit Gate**: - The Passenger Exit Gate shall control the exit from the paid area by validating the fare media.

(c). **Passenger Reversible Gate**:- The Passenger Reversible Gate shall combine the features of the Entry and Exit gates. It shall be capable of being switched by the Station Computer from entry mode to exit mode and vice-versa depending on the operational requirements of passenger flow. Reversible Gates shall also function automatically, based on the side from where the Passenger approaches first.

(d). **Staff / Emergency Gate**: - Normally situated adjacent to the Excess fare Office and kept open during emergency situations.

3.5.2.4 Spacing

Spacing for passenger gates shall be based generally on the following dimensional criteria:

A) Gate centre spacing: - Standard gates 880mm

b) Aisle width: - Standard gates 465 - 580mm

3.5.2.5 Gate Enclosure

a) The gate enclosure shall be fabricated of stainless steel. The gate shall be finished to conform to the architectural requirements of the station.

b) The degree of protection provided by the enclosure against dust, splashing, intrusion of foreign objects shall meet or exceed the standard IP54 (IP43 for token acceptor slot, if any), as defined by British Standards.

3.5.2.6 Tail Gating Prevention

Minimum distance for detection shall be less than 20 cm and methodology shall be in accordance with that being used in AFC operations.

3.5.3 Ticket Vending Machine (Tvm) & Self-Service Ticketing Kiosks

The self-service ticket kiosks and TVM should provide the convenience for the passengers to procure ticket on their own, without the need to queue at the ticket sale counter.

At all stations, Passenger Operated Ticket Vending Machines (Automatic Ticket Vending Machines) are proposed. The TVM's will provide convenience to passengers to avoid standing in queues at ticket booths and provide them international standard service. This will be used for:

1. Dispensing Smart Tokens for single journey
2. Add Value in Smart card by paying money using Bank Notes or through Credit Card /Debit card /pre Paid card.
3. Return the remaining money through Bank Notes and Coins (Min 2 types)

3.5.4 Function

a) Enable passengers to purchase tickets for journey.
b) The touch-point including the screen interface should be customizable in terms of the text, graphics and video. It should be able to support the promotion of any preferred products.
c) The machines shall accept payment in the form of bank notes, coins and credit / debit cards and shall interact with the passengers via a touch screen display and receipt printer.
d) A reject button shall be provided to enable a passenger to abort a transaction before a token issue cycle has commenced.
e) The bank note reader shall accept notes inserted in any orientation (any way up or round) and change shall be provided via a combination of note and coin re-circulating mechanism, which minimises the number of times the station staffs need to replenish the machines with change.

3.5.5 Physical

The TVM's hardware and peripherals should come equipped with durable housing. It shall be made from stainless steel and shall be freestanding or recessed into the walls of the TVM rooms as required by the station architecture. Separate tamper-proof coin boxes and note vaults shall be provided.

Minimum 2 TVM machines shall be provided at every entry to station to dispense journey ticket.

3.5.6 Types of Ticket

(a) The system shall provide, or be capable of processing, the following types of ticket:

- Single Journey Ticket (SJT)
- Daily Pass
- Staff/Employee Pass (EP)
- Stored Value (SV) (at least 16 configurable types)
- Period Pass (PP)

(b) Each ticket type shall be capable of being associated with at least four fare tables (One full fare and two concession fares).

3.5.7 Ticket Media

(a) CSC (for Stored Value, Employees Pass etc.)

Contactless media shall be to ISO/IEC 14443 & ISO 18092 standard (minimum EAL4 Security Criteria for CSC) and also to support common mobility card specifications of Ministry of Urban Development (GOI).

(b) Other Media (for Single Journey Tickets)

Media for Single Journey Tickets shall be determined by the Contractor, which can be a token. Choice of SJT media shall take financial and usage constraints into account.

3.5.8 Ticket Reader/Add Value Machines

These machines will be used to know the Card/Token balance and can also be used as Add value device in case payment for Card top up is made through alternate Internet based channel like net banking, Credit/Debit card (Payment gateway) etc.

3.5.9 Recharge Card Terminal Machine (RCTM)

RCTM will be used to recharge the Card using Credit Card /Debit card /Pre Paid card as well as bank Note

3.5.10 Security

(i) Revenue Protection

The AFC machines shall resist tampering by either passengers or unauthorized staff.

(ii) Revenue Security

(a) The AFC machines and system shall provide a complete audit trail of all transactions, transfers of cash and other payments.

(b) Cash handling equipment and systems shall be an integral part of the audit trail.

(c) Data & Revenue Security shall be ensured by a Key Management System (KMS) which needs to issue a Hardware SAM for each AFC equipment in use in the system. The SAM shall be used to authenticate the equipment and the transaction integrity.

(iii) Data Security

(a) In the event the SC fails, each item of equipment shall be able to operate autonomously without loss of data.

(b) Security of communications between the AFC equipment, SC and CC system shall ensure no loss of data in transmission.

3.5.11 Station Computer (SC)

a) Station Computer (SC) enables the overall control and monitoring of each item of AFC equipment within the station and transfer of data to the Central Computer (CC).

b) The SC shall include the power and data communication links to each item of AFC equipment and CC system interface.

c) It shall enable printing of reports at stations. The reports shall include accounting and statistical information. It shall include any other reports required for AFC operation.

d) The SC shall be able to download data to the AFC machines individually or as groups.

e) The SC shall receive maintenance data from AFC equipment and transmit the same to CC for monitoring and use of the same as an effective maintenance tool.

f) The SC shall be able to monitor certain critical functions of the AFC system and collect data for warnings and alarms.

g) If there is loss of communication between the SC and AFC equipment (Gates, TOM etc.) then the equipment shall operate in stand-alone mode utilizing the most recent data from the SC. AFC equipment (Gates, TOM etc.) shall store data up to seven days for transmission when SC communication is restored.

h) In the event of loss of communication with the CC the SC shall utilize the most recent operational data received from the CC and shall be capable of storing at least thirty days of transaction data.

3.5.12 Equipment Control

The normal method of control of the equipment shall be by the SC. The SC shall enable all AFC equipment control (put in service, taken out of service and initiated etc.) without the requirement for communication with the CC.

3.5.13 Central Computer System

Central Computer System shall be redundant configuration and placed at OCC. It is connected to Station Computer and equipments via redundant secured link provided in Telecom Chapter.

a) The Central Computer System (CC) shall collect and analyze information received from the station computers. It shall produce network-wide revenue and traffic data and monitor the performance of all AFC equipment..
b) A Central Computer (CC) System shall generate the necessary management reports from the CST, CSC and transaction information received from the Station Computer Systems.
c) The CC shall hold and download CST and CSC parameters, Configuration Data (CD), AFC device software and fare table information to each SC from where they shall be distributed to the station AFC equipment.
d) The CC shall automatically collate all CST, CSC and usage data (UD) from the SC to provide accurate audit and traffic statistics for the line.
e) The CC shall be located in a dedicated computer room in the Administration Building or Operations Control Centre.
f) The CC shall maintain a blacklist of invalid tickets. Blacklisted tickets shall be rejected by the AFC Gates.
g) The CC shall support a Fare Table with adequate number of stations.

3.5.16 AFC Equipment Requirement

The AFC equipment required at various locations of Mumbai Metro corridor are tabulated at Annexure 3.1 and 3.2 for year 2021 and 2031 respectively. However the exact number and type shall depend on the final station layout and traffic being catered to.

3.5.17 Standards

The standard proposed for AFC systems are as under:

Table 3.3

Standards	Description
Fare media	a) Contactless Smart Token – For single journey. Token are captured at the exit gate. b) Contactless Smart Card – For multiple journeys. Contactless readers shall be as per ISO 14443 standards.
Gates	Computer controlled retractable flap / turnstile type automatic gates at entry and exit. There will be following types of gates : - Entry - Exit - Reversible
Station computer, central computer and AFC Network	All the Fare Collection Equipment shall be connected in a local area network with a station server controlling the activities of all the machines. The station servers will be linked to the AFC central computer situated in the operational control center through the optic fiber communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.

Standards	Description
Ticket office machine (TOM/ EFO)	Manned Ticked Office Machines shall be installed in the station for selling cards / token to the passengers. Also TVM's shall be provided for Automatic Ticket Vending.
Ticket Readers	Ticket Reader shall be installed near EFO for passengers to check information stored in the token / cards.
Portable ticket decoder(PTD)	PTD will be used to check the card/token during travel
Recharge card terminal machine	RCTM will be used to recharge the card using bank note/debit card/credit card/pre paid card
UPS	Common UPS of S&T system will be utilized.
Maintenance philosophy	Being fully Contactless system, 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.

3.5.18 Integration of AFC with other Lines and Modes of Transport

In Mumbai, different mode of transport are being constructed and operated by different operators. In view of passenger convenience and operational efficiency, it is proposed that AFC for different metro lines should be integrated and smart card based fare products should be inter-operable. AFC system shall take into account revenue sharing mechanism among different operators based on journeys performed at each system. The single ride tickets (tokens) may not be inter-operable and may be limited to each operators system.

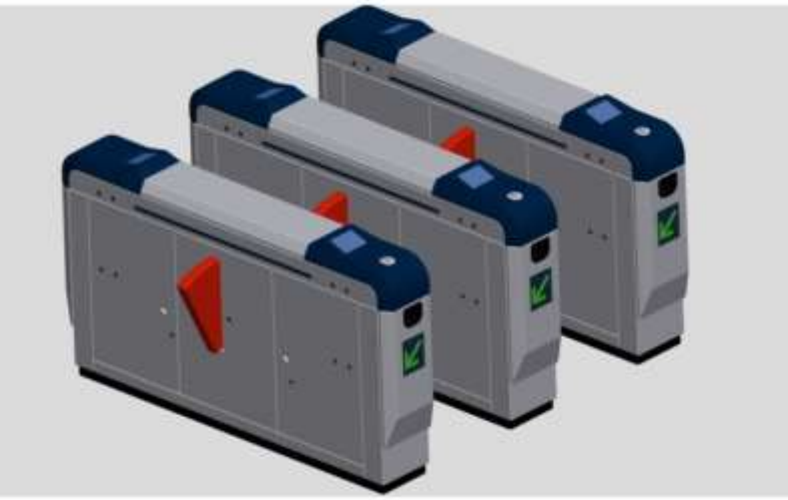


Fig 12.1 Entry/Exit Gates

The proposed AFC system shall provide interfaces to other operators such as Suburban Rail, Bus, Parking, Toll etc. so that these systems may also be integrated with common smart card based fare products. This will facilitate the passengers as they need not carry different cards for different applications.

Fig 12.2: Ticket Office Machine

Fig 12.3: Ticket vending machine

Fig. 12.4 Ticket Reader/Add Value Machine

Annexure 3.1

AFC Equipments for Mumbai Metro Corridor Swami Samarth Nagar to Vikhroli (EEH) (Projection for 2021)

S. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
1.	Swami Samarth Nagar	8963	8028	149	134	6	5	7	2	4	2	2
2.	Adarsh Nagar	2442	1224	41	20	2	2	2	2	4	2	2
3.	Jogeshwari (W)	2435	3857	41	64	2	3	2	2	4	2	2
4.	JVLR	13219	11256	220	188	9	8	11	2	4	2	2
5.	Shyam Nagar	5423	2943	90	49	4	2	5	2	4	2	2
6.	Maha Kali Caves	1699	523	28	9	2	2	2	2	4	2	2
7.	SEEPZ Village	3398	2438	57	41	2	2	3	2	4	2	2
8.	Saki Vihar Road	820	795	14	13	2	2	2	2	4	2	2
9.	Rambaug	434	258	7	4	2	2	2	2	4	2	2
10.	Powai Lake	387	748	6	12	2	2	2	2	4	2	2
11.	IIT, Powai	797	964	13	16	2	2	2	2	4	2	2
12.	Kanjur Marg(W)	17963	18210	299	304	12	12	15	2	4	2	2
13.	Vikhroli (EEH)	5307	9894	88	165	4	7	4	2	4	2	2
	TOTAL					**51**	**51**	**59**	**26**	**52**	**26**	**26**

Assumptions:

- **A.** Each Station has only 2 access
- **B.** Minimum AFC equipments at a station with "2 access-1 for entry , 1 for exit": 2 entry gates, 2 exit gates, 2 EFO, 2 TOM, 4 AVM/TR, 2 TVM
- **C.** Throughput of gate: 25 passengers per minute, TOM : One per access
- **D.** 50% passenger are assumed on Smart card and 50% on single journey token

Annexure 3.2

AFC Equipments for Mumbai Metro Corridor Swami Samarth Nagar to Vikhroli (EEH) (Projection for 2031)

S. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
1.	Swami Samarth Nagar	11493	13839	192	231	8	9	10	2	4	2	2
2.	Adarsh Nagar	2836	1463	47	24	2	2	2	2	4	2	2
3.	Jogeshwari (W)	2717	4759	45	79	2	3	2	2	4	2	2
4.	JVLR	13923	14179	232	236	9	9	12	2	4	2	2
5.	Shyam Nagar	6461	4008	108	67	4	3	5	2	4	2	2
6.	Maha Kali Caves	1944	686	32	11	2	2	2	2	4	2	2
7.	SEEPZ Village	3926	3116	65	52	3	2	3	2	4	2	2
8.	Saki Vihar Road	824	824	14	14	2	2	2	2	4	2	2
9.	Rambaug	480	272	8	5	2	2	2	2	4	2	2
10.	Powai Lake	485	802	8	13	2	2	2	2	4	2	2
11.	IIT, Powai	5393	5279	90	88	4	4	5	2	4	2	2
12.	Kanjur Marg (W)	21642	18933	361	316	14	13	18	2	4	2	2
13.	Vikhroli (EEH)	3317	5201	55	87	2	3	3	2	4	2	2
	Total					**56**	**56**	**68**	**26**	**52**	**26**	**26**

Assumptions:

A. Each Station has only 2 access

B. Minimum AFC equipments at a station with "2 access-1 for entry , 1 for exit": 2 entry gates, 2 exit gates, 2 EFO, 2 TOM, 4 AVM/TR, 2 TVM

C. Throughput of gate: 25 passengers per minute, TOM : One per access

D. 50% passenger are assumed on Smart card and 50% on single journey token.

3.6 ROLLING STOCK

3.6.1 Introduction

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. The forecasted Peak Hour Peak Direction Traffic calls for an Medium Rail Transit System (MRTS).

3.6.2 Optimization of Coach Size

The following optimum size of the coach has been chosen for this corridor as mentioned in Table 3.4.

Table 3.4 Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)/DTC	**21.84 m**	**3.2 m**	**3.9 m**
Trailer /Motor car (TC/MC)	**21.74 m**	**3.2 m**	**3.9 m**

**Maximum length of coach over couplers/buffers = 22.6 m*

3.6.3 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, for the Medium Rail Vehicles (MRV) with 3.2 m maximum width and longitudinal seat arrangement, conceptually the crush capacity of 42 seated, 240 standing thus a total of 282 passengers for a Driving motor car and 50 seated, 248 standing thus a total of 298 for a trailer car/motor car is envisaged.

Following train composition is recommended:

6-car Train: DMC + TC + MC+MC+TC+DMC

Table 3.5 shows the carrying capacity of Medium Rail Vehicles.

Table 3.5 Carrying Capacity of Medium Rail Vehicles

	Driving Motor car/ Driving Trailer car		Trailer car/Motor car		6 Car Train	
	Normal	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**
Seated	42	42	50	50	284	284
Standing	120	240	124	248	736	1472
Total	162	282	174	298	1020	1756

NORMAL-3 Person/sqm of standee area
CRUSH -6 Person/sqm of standee area

3.6.4 Weight

The weights of motorcar and trailer cars have been estimated as in Table 3, referring to the experiences in Delhi Metro. The average passenger weight has been taken as 65 kg.

Table 3.6 Weight of Light Rail Vehicles (TONNES)

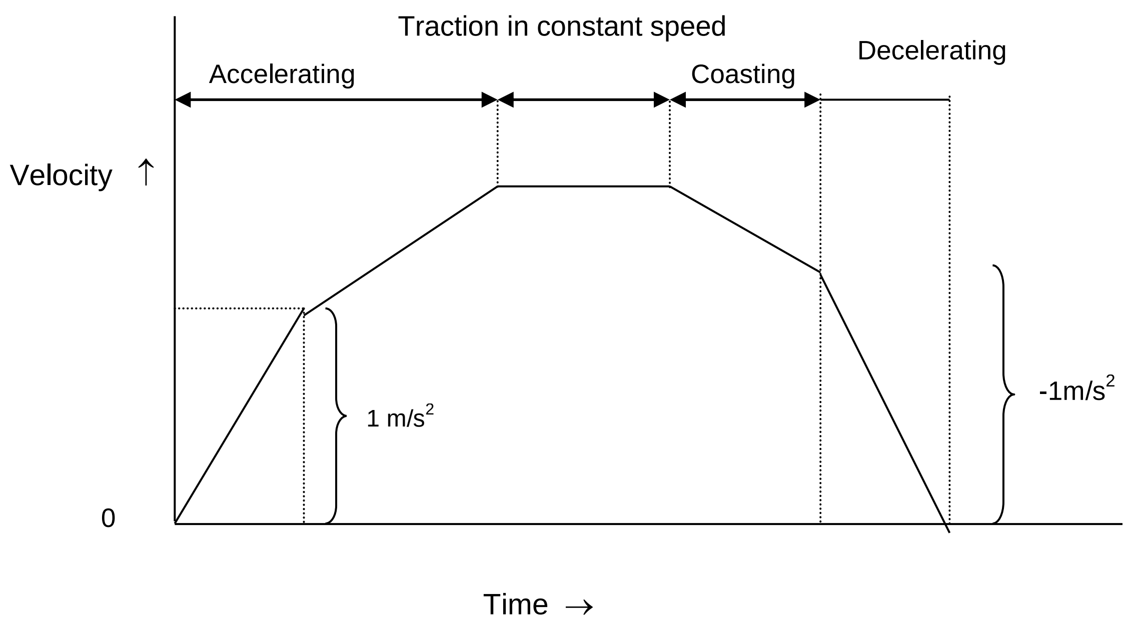
	DMC/DTC	TC/MC	6 Car train
TARE (maximum)	42	41.5/42	251
Passenger			
(Normal)	10.5	11/11	65
(Crush @6p/sqm)	18	19/19	112
(Crush @8p/sqm)	23	25/25	146
Gross			
(Normal)	52.5	52.5/53	316
(Crush @6p/sqm)	60	60.5/61	363
(Crush @8p/sqm)	65	66.5/67	397
Axle Load @6 person/sqm	15	15/15	
Axle Load @8 person/sqm	16.25	16.5/16.75	

The axle load @ 6persons/sqm of standing area works out in the range of 15T. Heavy rush of passenger, having 8 standees per sq. meter can be experienced occasionally. It will be advisable to design the coach with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should, therefore, be designed for **17 T axle** load.

3.6.5 Performance Parameters

The recommended performance parameters are:

Traction Power Supply	: 25Kv ac
Motoring capacity	: 67%
Maximum Design Speed	: 90 kmph
Maximum Operating Speed	: 80 kmph
Max. Acceleration	: 1.0 m/s^2 @ AW3
	: 1.2 m/s^2 @ AW2
Max. Deceleration	: 1.0 m/s^2 @ AW3
	: 1.1 m/s^2 @ AW2
	: 1.3m/s^2 (Emergency Brake)



3.6.6 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) Optimized scheduled speed
(vi) Aesthetically pleasing Interior and Exterior
(vii) Low Life cycle cost
(viii) Flexibility to meet increase in traffic demand
(ix) Anti-telescopic

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

3.6.7 Selection of Technology

3.6.7.1 Low life cycle cost

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. Selection of following technologies has been recommended to ensure low life cycle cost-.

3.6.7.2 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 a standard practice to adopt stainless steel or aluminum for carbody.

Stainless steel/Aluminum car body leads to energy saving due to its lightweight. It also results in cost saving due to easy maintenance and reduction of repair cost from excellent anti corrosive properties as well as on improvement of riding comfort and safety in case of a crash or fire.

3.6.7.3 Bogies

Bolster less lightweight fabricated 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 4,20,000 km. 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. Perturbation 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 improve 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.

3.6.7.4 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 and thus fully utilize 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, preferably a wheel disc brake.

3.6.7.5 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 has 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 this corridor, three phase a.c. traction drive that are self-ventilated, highly reliable, robust construction and back up by slip/slid control have been recommended for adoption.

The AC catenary voltage is stepped down through a transformer and converted to DC voltage through converter and supply voltage to DC link, which feeds Inverter operated with Pulse Width Modulation (PWM) control technology and using Insulated Gate Bipolar Transistors (IGBT). Thus three-phase variable voltage variable frequency output drives the traction motors for propulsion.

Recently advanced IGBT has been developed for inverter units. The advanced IGBT contains an Insulated Gate Bipolar Transistor (IGBT) and gate drive circuit and protection. The advanced IGBT incorporates its own over current protection, short circuit protection, over temperature protection and low power supply detection. The IGBT has internal protection from over current, short circuit, over temperature and low control voltage.

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

3.6.7.6 Interior and Gangways

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.

Interior View

3.6.7.7 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 within least possible time without conflicting movement .As the alignment passes through elevated section 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.

The door shall be of Bi-parting Sliding Type as in the existing coaches of DMRC.

Passenger Doors

3.6.7.8 Air–conditioning

With heavy passenger loading of 6 persons/sqm for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid

transmission of noise, air conditioning of coaches has been considered essential. Each coach shall be provided with two air conditioning units capable of cooling, heating and dehumidifying and thus automatically controlling interior temperature throughout the passenger area at 25°C with 65% RH all the times under varying ambient conditions up to full load. For emergency situations such as power failure or both AC failures 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.

3.6.7.9 Cab Layout and Emergency Detrainment Door.

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

An emergency door for easy detrainment of the passenger on the track has been provided at the center of the front side of the each cabin which has a easy operation with one handle type master controller.

3.6.7.10 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.

3.6.7.11 Noise and Vibration

The trains will pass 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.

3.6.7.12 Passenger Safety Features

(i) ATP

The rolling stock is provided with Continuous Automatic Train Protection to ensure absolute safety in the train operation. It is an accepted fact that 60-70% of the accidents take place on account of human error. Adoption of this system reduces the possibility of human error.

(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) Emergency door

The rolling stock is provided with emergency doors at both ends of the cab to ensure well directed evacuation of passengers in case of any emergency including fire in the train,

(iv) 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.

(v) Gangways

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

Gangways

Table 3.7: Salient Features of Standard Gauge Rolling Stock

S. No.	Parameter	Standard Gauge 3.2 m wide stock
1	**Gauge (Nominal)**	1435mm Standard Gauge
2	**Traction system**	
2.1	Voltage	25 KV AC
2.2	Method of current collection	Overhead Current Collection System
3	**Train composition**	
3.1	6 car train	DM+T+M+M+T+DM Or DT+M+M+M+M+DT
4	**Coach Body**	Stainless Steel/Aluminium
5	**Coach Dimensions**	
5.1	Height	3.9 m
5.2	Width	3.2 m
5.3	Length over body (approx)	
	- Driving Trailer Car (DTC)	21.84m
	- Driving Motor Car (DMC)	21.84 m
	- Trailer Car (TC)	21.74 m
	- Motor Car (MC)	21.74 m
	Maximum length of coach over couplers/buffers:	*22 to 22.6 m (depending upon Kinematic Envelop)*
5.4	Locked down Panto height	4048 mm
5.5	Floor height	1100mm
6	**Designed - Passenger Loading**	
6.1	Design of Propulsion equipment	8 Passenger/ m2
6.2	Design of Mechanical systems	10 Passenger/ m2
7	**Carrying capacity- @ 6 standees/sqm**	
7.1	Coach carrying capacity	
	DMC	282 (seating -42 ; standing - 240)
	TC	298 (seating - 50 ; standing - 248)
	MC	298 (seating - 50 ; standing - 248)
7.2	Train Carrying capacity	

S. No.	Parameter	Standard Gauge 3.2 m wide stock
	6 car train	1756 (seating - 284 ; standing - 1472)
8	**Weight (Tonnes)**	
8.1	Tare weight (maximum)	
	DMC	42
	TC	41.5
	MC	42
8.2	Passenger Weight in tons	@ 0.065 T per passenger
	DMC	18
	TC	19
	MC	19
8.3	Gross weight in tons	
	DMC	60
	TC	60.5
	MC	61
9	**Axle load(T)(@ 8 persons per sqm of standee area)**	**17**
		System should be designed for 17T axle load
10	**Maximum Train Length (approx.)**	136 m(6-car Train length) 181 m(8-car train length)
11	**Speed**	
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
12	**Wheel Profile**	IRS
13	**Traction Motors Ventilation**	Self
14	**Acceleration on level tangent track**	1.0 m/sec^2 @ AW3 1.2 m/sec^2 @ AW2
15	**Deacceleration on level tangent track**	1.0 m/sec^2 @ AW3 1.1 m/sec^2 @ AW2 (>1.3 m/sec2 during emergency)
16	**Type of Bogie**	Fabricated
17	**Secondary Suspension springs**	Air

S. No.	Parameter	Standard Gauge 3.2 m wide stock
18	**Brakes**	- An electro-pneumatic (EP) service friction brake - An electric regenerative service brake - Provision of smooth and continuous blending of EP and regenerative braking - A fail safe, pneumatic friction emergency brake - A spring applied air-release parking brake - Tread brakes
19	**Coupler**	
	Outer end Unit (except driving cab ends)	Automatic coupler with mechanical, electrical & pneumatic coupling (between units)
	Between cars of same Unit	Semi-permanent couplers
	Driving Cab end of cars (DTC/DMC)	Automatic coupler with mechanical & pneumatic coupling but without electrical coupling head
20	**Detrainment Door**	Front
21	**Type of Doors**	Sliding
22	**Lighting**	LED
23	**Cooling**	
23.1	Transformer	Forced
23.2	CI & SIV	Self/Forced
23.3	TM	Self ventilated
24	**Control System**	• Train based Monitor & Control System (TCMS/TIMS)
25	**Traction Motors**	3 phase VVVF controlled
26	**Temperature Rise Limits**	
26.1	Traction Motor	Temperature Index minus 70 deg C
26.2	CI & SIV	10 deg C temperature margin for Junction temperature
26.3	Transformer	IEC specified limit minus 20 deg C
27	**HVAC**	-Cooling & Heating -Automatic controlling of interior temperature throughout the passenger area at 25°C all the times under varying ambient conditions up to full load.
28	**PA/PIS**	Required
29	**Passenger Surviellance (CCTV)**	Required
30	**Battery**	Ni-Cd

Chapter - 4

CIVIL ENGINEERING

4.1 GEOMETRIC DESIGN NORMS

4.1.1 General

The proposed corridors will be implemented with track on Standard Gauge (SG) 1435mm.

The geometrical design norms are based on international practices adopted for similar metro systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 80kmph. Planning for any higher speed is not desirable as the average inter-station distance is kept close to one km and trains will not be able to achieve higher speed.

The elevated tracks will be carried on twin-U girders supported on single circular piers, generally spaced at 28-m centres and located on the median or on the space available between main carriageway and service road to the extent possible. The horizontal alignment and vertical alignment are, therefore, dictated to a large extent by the geometry of the road and ground levels followed by the alignment.

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.

As regards the type of alignment i.e. At-grade, Elevated and Underground depends upon the ROW. If ROW is 20 m or more, Elevated alignment is preferred over Underground as the cost of Underground alignment is 2 to 2½ times of Elevated alignment. The Merits and demerits of Elevated and Underground alignments are detailed at Annexure- 4.1

4.1.2 Horizontal Alignment

As far as possible, the alignment follows the existing roads. This leads to introduction of horizontal curves. On consideration of desirable maximum cant of 110 mm and cant deficiency of 85 mm on Metro tracks, the safe speed on curves of radii of 300 m or more is 80 km/h. Minimum radius of 125m has been used at four locations having speed potential upto40 km/h.

Horizontal Curves:

Table 4.1- Horizontal Curves

Description	Elevated Section
Desirable Minimum radius	200m
Absolute minimum radius	120m*
Minimum curve radius at stations	1000m
Maximum permissible cant (C_a)	125 mm
Maximum desirable cant	110mm
Maximum cant deficiency (C_d)	85mm

* not used in this corridor.

Transition Curves

It is necessary to provide transition curves at both ends of the circular curves for smooth riding on the curves and to counter act centrifugal force. It is necessary to provide frequent vertical curves along the alignment due to change in gradients at various locations in the corridor. In case of ballast less 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 at certain locations. The transition curves have certain minimum parameters:

- Length of transitions of horizontal curves (m)
  - Minimum :0.44 times actual cant or cant deficiency (in mm), whichever is higher.
  - Desirable :0.72 times actual cant or cant deficiency (in mm), whichever is higher.
- Overlap between transition curves and vertical curves not allowed.
- Minimum straight between two Transition curves (in case of reverse curves): either 25 m or Nil.
- Minimum straight between two Transition curves (in case of same flexure curves): either 25 m or both curves should be converted in to the compound curve by introducing single transition between the two circulars.
- Minimum curve length between two transition curves: 25 m

4.1.3 Vertical Alignment and Track Centre

(a) Elevated Sections

The viaducts carrying the tracks will have a vertical clearance of minimum 5.5 m above road level as mandatory requirement of Indian Road Congress (IRC). For meeting this requirement with the ‘U’ shaped pre-stressed concrete girders, the rail level will be about 9.8 m above the road level. However, at stations which are located above central median, the rail level will be 13.5 m above the road level with concourse at mezzanine. These levels will, however, vary marginally depending upon where the stations are located.

The track centre on the elevated section is kept as 5.03 m uniform throughout the corridor to standardize the superstructure.

(b) Gradients

Normally the stations shall be on level stretch. In exceptional 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% or for Switch Over Ramps gradient up to 4% (compensated) can be provided in short stretches on the main line.

(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.

(d) Radius of vertical curves:

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

4.1.4 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 4.2 - Cant, Maximum Speed & Minimum track centre for Curves

RADIUS	CANT	MAXIMUM PERMISSIBLE SPEED	MINIMUM TRACK CENTRE (ELEVATED & AT-GRADE)
m	mm	kmph	mm
3000	15	80	3650
2800	15	80	3650
2400	20	80	3650
2000	20	80	3650
1600	25	80	3650
1500	30	80	3650
1200	35	80	3650
1000	45	80	3700
800	55	80	3700
600	70	80	3750
500	85	80	3750
450	95	80	3800
400	105	80	3800
350	110	75	3800

RADIUS	CANT	MAXIMUM PERMISSIBLE SPEED	MINIMUM TRACK CENTRE (ELEVATED & AT-GRADE)
m	mm	kmph	mm
300	110	70	3850
200	110	55	3950
150	110	45	4050
150*	0	30	4050
120	110	40	4150
120*	0	25	4150

*The curves of 120 and 150 meters radii are used without transitions.

Notes: (a)The track spacing is without any column/structure between two tracks and is with equal cant for both outer and inner tracks.

(b) Track spacing shown is not applicable to stations which should be calculated depending on specific requirement.

(c) Figures for any intermediate radius of curvature may be obtained by interpolating between two adjacent radii. For higher radii, values may be extrapolated.

4.1.5 Codes and Standards

The codes, standards and specifications applicable for design of the components of the Rail System and for its operation and maintenance are:

i) NFPA 130 – 'Standard for Fixed Guide way Transit and Passenger Rail Systems'
ii) European Norms (EN):
iii) International Electro Technical Commission Standards (IEC):
iv) International Standards organization (ISO):
v) Japanese Industrial Standards (JIS):
vi) United States of America, AIS, AAR:
vii) British standards (BS):
viii) Indian Standards (IS)
ix) German Standards (DIN)
x) Indian Railway Standards (IRS):
xi) Indian Roads Congress (IRC): and
xii) Any other specified standards.

4.1.6 General technical requirements of the Rail System

The rail system shall be designed to:

i) Handle the user demand efficiently;
ii) Minimize noise pollution;
iii) Provide adequate interchange facilities including pedestrian facilities;

The design of the Rail System shall also conform to:

i) Local building bye-laws;
ii) Relevant published standards of UIC;
iii) All statutory requirements, guidelines and directives; and
iv) Stipulations of fire service department.

4.2 ALIGNMENT

4.2.1 Introduction

4.2.1.1 First station on this corridor is named as Swami Samarth Nagar and last station is Vikhroli (EEH).

4.2.1.2 Centre Line Chainage of Swami Samarth Nagar proposed station is taken as 0.0 for reference and dead end chainage of this station as (-) 822.5 m.

4.2.1.3 Total length of the corridor from dead end to dead end is 14.477 km. The entire corridor proposed is elevated.

4.2.1.4 Thirteen stations have been proposed on the corridor. Names of stations are Swami Samarth Nagar, Adarsh Nagar, Jogeshwari (W), JVLR, Shyam Nagar, Maha Kali Caves, SEEPZ Village, Saki Vihar Road, Rambaug, Powai Lake, IIT Powai, Kanjur Marg(W) and Vikhroli(EEH). Attempt has been made to locate stations at about a kilometer apart. However due to various considerations such as ridership, accessibility, availability of land, design considerations etc; a few stations could not be located at one km distance apart. The maximum and minimum inter station distances are 1658 m and 728.8 m respectively. Depot for this corridor has been planned at Kanjur Marg (W) by the side of Eastern Express Highway after last station Vikhroli(EEH).

4.2.1.5 This corridor runs in West to East direction. It connects eastern suburbs, market places, Kanjur Marg Railway Station, etc. This Corridor also provides connectivity with other metro corridors viz with line No. 2, 7, 3 and 4 at Adarsh Nagar, JVLR, SEEPZ Village and Kanjur Marg.

4.2.2 Archeological protected monuments

The Mahakali Caves (also known as the Kondivite Caves) are a group of 19 rock-cut monuments built between 1st century BCE and 6th century. This Buddhist monastery is located in the eastern suburb of Andheri in the city of Mumbai. Monument consists of two groups of rock-cut caves - 4 caves more to the north-west and 15 caves more to the south-east. Most caves are viharas and cells for monks, but Cave 9 of south-eastern group is chaitya. Caves in north-west have been created mainly in 4th - 5th century, while south-eastern group is older. Monument contains also rock-cut cisterns and remnants of other structures. Caves are carved out of a solid black basalt rock. The largest cave at Mahakali (Cave 9) has seven depictions of the Buddha and figures from Buddhist mythology but all are mutilated. It is located near the junction between the Jogeshwari - Vikhroli Link Road and SEEPZ. The road that connects these monuments to Andheri Kurla Road is named Mahakali Caves Road after it. The caves are located on a hill that overlooks the Jogeshwari-Vikhroli Link Road and the SEEPZ.

Alignment passes along the Jogeshwari-Vikhroli Link Road, these caves are about 120m to 150m away from the alignment. Proposed Mahakali Caves metro station has been named after these caves. Necessary approval from the Archeological Survey of India may please be obtained by the MMRDA in this regard.

4.2.3 Station Locations

4.2.3.1 Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport such as Railway Stations, Bus Terminals, etc. 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 close to one km.

4.2.2.2 All stations except Jogeshwari (W) and Shyam Nagar, will be two level stations. Jogeshwari (W) station is partly projected over the flyover and Shyam Nagar station is above proposed flyover. Concourse of these two stations will be on ground level. For all other stations, the concourse comprising of passenger facilities and station facilities will be at lower level and the platforms on the higher level. Stations on the road have been planned cantilever leaving 10.5m road width either side of the median.

4.2.4 Terminals

4.2.4.1 Swami Samarth Nagar Terminal

This Station is proposed on the road. Since the road alignment on both sides of the station is kinky, hence there is no space on front end of the station to provide crossover. On rear end of the station, alignment has been extended about 0.8 km to provide scissors crossover for train reversal.

4.2.4.2 Vikhroli (EEH) Terminal

This Station is proposed on median of the road just before depot location. Scissors cross overs are proposed at the rear end of station and depot entry also has been planned at rear end of the station.

4.2.5 Scissors Crossovers

Scissors Crossovers will be provided at both the terminal stations viz. Swami Samarth Nagar and Vikhroli (EEH).

4.2.6 Depot

It is proposed to provide depot at Vikhroli, in the Government land identified by MMRDA. The total land for depot will be 15 Ha.

4.2.7 Description of Alignment

4.2.7.1 Horizontal Alignment

The proposed alignment starts from CH: -822.541 m and Station No. 1 named as Swami Samarth Nagar is located at CH:0.0 m.

The alignment originates from median of Back Road in Lokhandwala Area and runs along it up (-) 0.400 km. Hereafter it turns left crosses Lokhandwala Circle/Swami Samarth Chowk at about -185m chainage runs along P Tandon Marg. First station on this corridor is Swami Samarth Nagar at chainage 0.0m. Soon after this station, the alignment turns right along with the road with 125m curve. This turn is followed by a proposed flyover from approximate chainage 300 m to 1770 m. Starting portion of the flyover is proposed to have split design and second station on this corridor i.e. Adarsh Nagar will be in between the split portion. This station is proposed after Santh Nirankari Baba Chowk, from where another metro corridor i.e. Dahisar (E) to

Mandala (Line-2) is also crossing. Chainage of this station is 728.8m. Soon after this station, metro corridor and this proposed flyover will be integrated, same piers will be there for Metro as well as for flyover and corridor will run above the flyover. Next station on this corridor is Jogeshwari (W) at 1717.9m which is partly on straight and partly on curved section. This station is partly projected over the flyover. This station is followed a reverse curve of 125m and alignment runs on the right side of the flyover then it crosses over Balasaheb Thakre Flyover from chainage 1978m to 2070m and comes onto its left side. The alignment is off the road and it continues to the left side of the flyover. From chainage 2327.766m, it turns slight left with a curve of 450 m and pass over western railway lines. This curve is followed by a straight length of 50.834 m which is then followed by a curve of 1010m. Next station is on this curved section at chainage 2877.7m and is named as JVLR. This station is proposed near Balasaheb Thakre Hospital. After this station, it crosses Western Express Highway.

Here onwards the alignment runs mostly over the footpath (on the left side of the road). From chainage 3600m, it aligns along the road median. The next station on the corridor is Shyam Nagar at chainage 3839.6m. This station is above proposed flyover. Hereafter also the alignment mostly follows road median till 5500m, thereafter it deviates from the road median. The next station is Maha Kali Cave sat chainage 5387.4m. This station is on the road median. It is proposed just before Mahakali road crossing and is close to Kamal Amrohi Studio for this stations other option of making it underground and taking alignment beyond this station to Kanjur Marg by the right side of the flyover was also examined. In fact even keeping this station elevated, and taking metro alignment on right side of the flyover could be much easier option from constructability and integration point of view with line 3 station. However, MMRDA was of the view that the alignment be taken on left side of the flyover and on footbath and thereafter on the boundary wall of hutment Colony. Hence, just after this station, the alignment has been off the road and runs on the left side of road. It comes on footpath of the road for small section in between. Next station is SEEPZ Village at chainage 6510.3 m this station is mostly on curved alignment. Thereafter the alignment runs along the footpath and crosses a bridge from chainage 6820 to 6850m. The alignment turns right from 6929.56m with a curve of 220m and remains mainly on footpath. Next station is Saki Vihar Road at chainage 7646.6m at Adi Shankaracharya Marg before Saki Vihar Rd. crossing. This station is on straight alignment. Except at some locations, the alignment continues along the footpath on the left side of the flyover and it turns right with a curve of 340m. Next station on this corridor is Rambaug at chainage 8658.9 m. It is adjacent to Powai Lake. This station is followed by left hand curve of 150m. Alignment runs on left side of the flyover on JVLR and from chainage 9320m it comes along the road median. Next station is Powai Lake at 9508.2m, on curved alignment. This station is also adjacent to Powai Lake and is on road median. Hereafter also the alignment continues along the median of Jogeshwari - Vikhroli link road. From chainage 9950.619m, alignment turns right with a curve of 130m. Next station is I.I.T, Powai at chainage10572.6 m. This station is on straight length. Till chainage 11385m, the alignment runs nearly along the road median. Thereafter it goes away from road median and finally goes off the road. At this location, other option of making IIT, Powai Station underground was examined with further alignment underground and coming out near National Marble Shop. Thereafter crossing the main JVLR – Kanjur Marg Road elevated and subsequently following the road by the side of Kendriya Vidyalaya of Defence. This option could be technically better but it was felt to cause more inconvenience during construction. Therefore, preferred alignment was only elevated. The alignment crosses Lal Bahadur Shastri Marg. This is followed by Kanjur Marg (W) Station at chainage 12230.6 m. This station is proposed off the road. After this station, alignment crosses railway track/lines and then it aligns with road median with help of one right hand curve and one left hand curve of radius 210m each, separated by straight length of 110.782m.Next station is the last station i.e. Vikhroli (EEH) at chainage13204.2 m. Dead end of the corridor is at 13654.2 m. Depot is located in Vikhroli after this station.

Train reversal facility has been provided on both terminal station i.e. Swami Samarth Nagar and Vikhroli (EEH). Emergency crossovers are provided at JVLR and SEEPZ Village station. Alignment plan may be referred in this regard.

Construction across the railway line will be done by Continuous Balanced Cantilever method without constructing any pier between the railway lines.

4.2.7.2 Vertical Alignment

Vertical alignment has been designed with consideration of 5.5 m clear head room on the road. Minimum height difference from existing road level and proposed rail levels is about13.5 m at station locations and 8.5m other than station locations. Efforts have been made to maintain minimum radius of vertical curves of 2500 m. However it is not possible to maintain this at certain locations due to space constraints or overlapping with the transition length of Horizontal curves. At such locations minimum vertical curve radius is 1500m. Length of vertical curve provided is more than 20m. Overlap between transition curves and vertical curves are strictly avoided. All proposed stations are kept on level gradient. The maximum gradient used is not steeper than 3.5% and has been used at three locations.

Ground along this corridor is very much undulated. The fall or rise of the ground is very steep more than the permissible gradient for metro line. Hence height of piers in certain the section of the corridor is more than 30m. in general height of piers on this corridor is in the rage of 16 to 22 metre as alignment passes along/cross the a number of the flyovers.

The proposed rail levels are given in **Table 4.3** and abstracts of gradients are given in **Table 4.4.**

Table 4.3: Proposed Gradients

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
1	-822.541	-260.000	562.541	15.900	20.000	0.729%	RISE
2	-260.000	300.000	560.000	20.000	20.000	0.000%	LEVEL
3	300.000	460.000	160.000	20.000	25.600	3.500%	RISE
4	460.000	884.500	424.500	25.600	25.600	0.000%	LEVEL

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
5	884.500	1420.000	535.500	25.600	33.500	1.475%	RISE
6	1420.000	1880.000	460.000	33.500	33.500	0.000%	LEVEL
7	1880.000	2180.240	300.240	33.500	27.300	2.065%	FALL
8	2180.240	2420.000	239.760	27.300	27.400	0.042%	RISE
9	2420.000	2740.000	320.000	27.400	33.400	1.875%	RISE
10	2740.000	3080.240	340.240	33.400	33.400	0.000%	LEVEL
11	3080.240	3500.240	420.000	33.400	44.800	2.714%	RISE
12	3500.240	3667.600	167.360	44.800	44.400	0.239%	FALL
13	3667.600	4100.240	432.640	44.400	44.400	0.000%	LEVEL
14	4100.240	4400.000	299.760	44.400	45.200	0.267%	RISE
15	4400.000	5215.500	815.500	45.200	73.743	3.500%	RISE
16	5215.500	5620.000	404.500	73.743	73.743	0.000%	LEVEL
17	5620.000	6365.600	745.600	73.743	47.647	3.500%	FALL
18	6365.600	6665.600	300.000	47.647	47.647	0.000%	LEVEL
19	6665.600	6853.278	187.678	47.647	42.016	3.000%	FALL
20	6853.278	7025.000	171.722	42.016	41.500	0.301%	FALL
21	7025.000	7483.518	458.518	41.500	42.950	0.316%	RISE
22	7483.518	7833.518	350.000	42.950	42.950	0.000%	LEVEL
23	7833.518	8473.518	640.000	42.950	51.500	1.336%	RISE
24	8473.518	8833.518	360.000	51.500	51.500	0.000%	LEVEL
25	8833.518	9089.923	256.405	51.500	49.582	0.748%	FALL
26	9089.923	9390.108	300.185	49.582	51.400	0.606%	RISE
27	9390.108	9634.518	244.410	51.400	51.400	0.000%	LEVEL
28	9634.518	10073.278	438.760	51.400	47.400	0.912%	FALL
29	10073.278	10383.518	310.240	47.400	53.400	1.934%	RISE
30	10383.518	10713.518	330.000	53.400	53.400	0.000%	LEVEL
31	10713.518	11093.518	380.000	53.400	55.000	0.421%	RISE
32	11093.518	11433.518	340.000	55.000	55.800	0.235%	RISE
33	11433.518	12023.811	590.293	55.800	38.091	3.000%	FALL
34	12023.811	12392.149	368.338	38.091	38.091	0.000%	LEVEL
35	12392.149	13018.751	626.602	38.091	20.000	2.887%	FALL
36	13018.751	14424.727	1405.976	20.000	20.000	0.000%	LEVEL

Table 4.4: Abstract of Gradients

S. N.	Description	Nos. Occurrences	Length (m)	% w. r. t. total Alignment length
1	Level	13	5980.604	39.22%
2	> 0% to = 1%	11	3615.011	23.71%
3	> 1% to = 2%	4	1805.740	11.84%
4	> 2% to = 3%	5	2124.813	13.94%
5	> 3% to = 4%	3	1721.100	11.29%
	Total	**36**	**15247.268**	100.00%

4.2.8 Curvature

There are many sharp turns and curves along the road. This necessitates provision of curves for metro alignment also. The radius of curves is kept as low as 125 m to reduce the property acquisition. Total 50 curves have been provided in the entire length of Swami Samarth Nagar to Vikhroli (EEH) Corridor. The details of curves and abstracts of horizontal curves are indicated in Table 4.5 and 4.6 respectively.

Table 4.5 Details of Horizontal Curves

Curve No.	Hand of Arc	Radius (m)	Arc Length (m)	Transition Length (m)		Included Angle	Tangent (m)	Straight Length (m)
				L1	L2	D M S		339.196
1	Left	125	86.869	55	55	39 49 03	45.271	49.469
2	Left	260	28.581	55	55	06 17 53	14.305	49.728
3	Left	1010	104.611	30	30	05 56 03	52.352	3.841
4	Right	125	30.471	55	55	13 58 00	15.311	237.69
5	Right	510	30.971	50	50	03 28 45	15.49	0
6	Left	2510	33.492	25	25	00 45 52	16.746	120.111
7	Left	1010	53.634	25	25	03 02 33	26.823	0
8	Right	340	98.029	55	55	16 31 10	49.357	28.539
9	Left	510	32.882	45	45	03 41 38	16.447	52.84
10	Left	350	35.99	55	55	05 53 30	18.011	0
11	Right	175	17.503	55	55	05 43 49	8.759	94.151
12	Left	1020	65.464	30	42.512	03 40 38	32.743	0
13	Left	125	68.939	42.512	55	31 35 57	35.371	0
14	Right	125	36.424	55	55	16 41 43	18.342	203.371
15	Left	450	183.154	50	50	23 19 11	92.862	50.834
16	Right	1010	157.502	30	30	08 56 05	78.911	302.83
17	Right	300	166.909	55	55	31 52 38	85.676	136.496
18	Left	250	34.269	55	55	07 51 13	17.161	50.706
19	Right	2010	25.284	25	25	00 43 14	12.642	66.65
20	Left	230	32.784	50	50	08 10 00	16.42	60.177
21	Left	410	36.305	50	50	05 04 24	18.164	52.816
22	Right	425	124.508	50	35	16 47 07	62.703	0
23	Right	600	123.804	35	40	11 49 20	62.122	40.351
24	Right	300	31.906	55	55	06 05 37	15.968	28.187
25	Right	425	116.695	45	45	15 43 55	58.717	30.148
26	Right	800	82.461	35	35	05 54 21	41.267	53.513
27	Right	1020	303.325	30	30	17 02 18	152.79	0
28	Left	175	83.453	55	60	27 19 22	42.536	0
29	Left	450	163.178	60	45	20 46 35	82.495	322.105
30	Left	1010	117.709	30	30	06 40 38	58.921	318.737
31	Right	220	87.729	55	55	22 50 51	44.455	289.998
32	Left	540	37.706	45	45	04 00 02	18.861	198.426
33	Left	700	309.502	40	40	25 19 58	157.322	0
34	Right	340	331.604	50	50	55 52 51	180.328	187.6
35	Left	150	79.26	55	55	30 16 29	79.26	93.438
36	Right	610	30.203	40	40	02 50 12	15.104	26.165
37	Left	220	93.997	55	55	24 28 48	47.727	29.843
38	Left	1010	156.458	25	25	08 52 32	78.386	38.216
39	Left	210	134.567	55	55	36 42 53	69.685	56.348
40	Right	130	146.098	55	55	64 23 26	81.851	99.036

Curve No.	Hand of Arc	Radius (m)	Arc Length (m)	Transition Length (m)		Included Angle	Tangent (m)	Straight Length (m)
41	Left	225	39.744	55	55	10 07 14	19.924	357.854
42	Left	210	72.463	55	55	19 46 14	36.595	336.677
43	Right	140	207.641	55	55	84 58 42	128.238	43.53
44	Left	210	119.843	55	55	32 41 51	61.602	25.348
45	Left	390	49.914	50	50	07 19 58	24.991	230.115
46	Right	610	46.532	40	40	04 22 14	23.277	64.887
47	Right	210	61.267	55	55	16 42 57	30.853	110.782
48	Left	210	57.539	55	55	15 41 55	28.951	383.946
49	Left	210	212.492	55	55	57 58 32	116.346	132.083
50	Right	510	28.789	40	40	03 14 03	14.398	507.526

Table 4.6 Abstract of Horizontal Curves

S. No.	Radius (m)	Nos. Occurrences	Curved Length With TL (m)	% w. r. t. total curved length
1	>125m - 500m	32	3070.125	63.82%
2	>500m - 1020m	16	1681.553	34.96%
3	>1020m - 1500m	0	0	0.00%
4	>1500m - 2500m	1	25.284	0.53%
5	>2500m - 5000m	1	33.492	0.70%
6	>5000m	0	0	0.00%
	Total	**50**	**4810.454**	**100.00%**

4.3 CIVIL STRUCTURE AND CONSTRUCTION METHODOLOGY

4.3.1 Viaduct – Elevated Structure

4.3.1.1 Choice of Superstructure

The choice of superstructure has been made keeping in view of the factors like ease in construction, standardization of formwork, Optimum utilization of form work for wide spans etc.

Generally four types of Superstructure are used for construction of elevated section of Metro Corridor, i.e. (i) Segmental Box Girder, (ii) Segmental U Girder, (iii) I Girder and (iv) Double U Girder, depending upon characteristic of the corridor such as traffic congestion on roads, available working space, etc.

In case of this corridor of Mumbai Metro, it is suggested to use Double U-Girder in the superstructure upto radius 300m because of the following merits:

- It is an efficient and economical method.
- Its construction permits a reduction of construction time as it may be manufactured while substructure work proceeds and assembled rapidly thereafter.
- This method of 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 at site.

- Girders are easy to stack in the casting yard/stacking yard in more than one layer, thereby saving in requirement of space.
- Interference to the traffic during construction is significantly reduced.
- It contributes towards 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.

For Radius less than 300 m and at locations where point and crossing are to be provided, it is suggested to use I-Girder.

4.3.2 Pre-Cast Construction

4.3.2.1 Casting of U-Girder

It requires a casting yard for pre-casting Double U-Girders for viaducts. 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 2.0 ha to 2.5 ha is required for each construction depot.

The girders are cast in casting moulds with pre-tensioning. The girders are water cured for a period of 14 days from the date of casting.

4.3.2.2 Erection of U-Girder

The U-girders are transported from stacking yard to erection point with the means of Hydraulic Multi Axle trailers.

The erection of precast U-Girder is done by means of two mobile cranes of capacity not less than 300 MT each. After erection of U-Girder, bearing pedestal will be concreted for placement of bearing.

4.3.3 Structural System of Viaduct

4.3.3.1Superstructure

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. These details will be worked out at detailed design stage.

Normally two U-Girders having a soffit width of about 3.8 m (approx) each, accommodates two tracks situated at 5.03 m center to center (c/c). The U-Girder superstructure for almost all the simply supported standard spans will be constructed by precast pre-stressed construction.

The standard length (c/c of piers) of simply supported spans, constructed by precast construction technique, has been proposed as 28.0m. The standard length of U-Girder will be around 28m and usually up-to 35m length can be managed with the help of extended pier cap. For shorter span or at sharper curves (less than 300m), I-Girders will be used.

For major crossings having span greater than 35 m, special continuous 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.

4.3.3.2 Substructure

The superstructure of the viaduct 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 soffit of the girder. At the preliminary design stage, the size of pier is found to be limited to 1.8m to 2.0 m 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 1.0 m height above existing road level has been provided all around the pier. A gap of 25 mm has also been 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 5.5 m 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 about 8.4 m.

The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.8 m. 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 about 3.2 m (however its exact dimension to be decided by the DDC).

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. Since the vertical and horizontal loads will vary from pier to pier, this will be catered to by selecting the appropriate structural dimensions.

4.3.4 Construction of Stations

At almost all locations, it is proposed to construct ‘the elevated stations’ with elevated concourse over the road to minimize the land acquisition. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus, a separate structural configuration is required to be proposed, although this may necessitate a break in the launching operations at each station location.

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

4.3.5 Grade of Concrete

It is proposed to carry out construction work with 'Design mix concrete' through computerized automatic Batching Plants with following grades of concrete for various members considering the design requirements and durability.

i)	Piles	-	M -35
ii)	Pile cap and open foundation	-	M -35
iii)	Piers	-	M -40
iv)	All precast element for viaduct and station	-	M -45
v)	Cantilever piers and portals	-	M -45/M -60
vi)	Other miscellaneous structure	-	M -30

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

4.3.6 Reinforcement and pre-stressed Steel

It is proposed to use HYSD 500 or TMT steel as reinforcement bars. For pre-stressing work, low relaxation high tensile steel strands with the configuration 12 K 15 and or 19 K 15 is recommended (confirming to IS:14268).

4.3.7 Road width required during construction

As most of the construction is to be carried out in 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 side 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 thereof.
ii) Reservation of land along the corridor, identification and survey for acquisition.

4.4 GEOTECHNICAL INVESTIGATIONS

No fresh Geotechnical Investigation has been carried out by DMRC. The data available in the DPR prepared by M/s RITES for Mahim to Kanjur Marg corridor has been used for SEEPZ to Kanjur Marg section of the corridor, as the alignment beyond SEEPZ village is more or less same as it was proposed by RITES and ground profile does not changes for smaller deviation in this section of corridor. MCGM is constructing the flyover along JVLR, geotechnical data of the same may be referred for that section.

4.4.1 General Geology & Related Characteristics:

a) **Physiography and Climate-** 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.

b) **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

4.4.2 Seismicity-Mumbai lies in seismic zone III and also adjacent to 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.1893-2002 which is revised after the occurrence of Gujarat Earthquake in January' 2001.

4.4.3 Field Investigations - SEEPZ to Kanjur Marg section

4.4.3.1 Bore Hole Locations

The details of boreholes along SEEPZ to Kanjur Marg section of the corridor are shown in Table 4.7.

TABLE 4.7: DETAILS OF BOREHOLES

S. No.	Borehole number	Chainage (m)	Ground level (m)	Ground water table depth (m)	Depth of investigation (in m)		
					In soil	In rock (soft/ hard)	Total
1	BH 2	16525	26.602	1.70	4.05	10.45	14.50
2	BH 3	17775	37.886	1.30	3.00	9.50	12.50
3	BH 4	18750	37.058	1.60	4.00	8.80	12.80
4	BH 5	19690	40.500	2.00	5.95	5.55	11.50
5	BH 6	20900	32.671	1.20	2.55	7.45	10.00
6	BH 7	22100	4.189	1.50	5.15	6.72	11.87

4.4.3.2 Field Investigations

Standard Penetration Tests

This test was carried out using a Terzaghi spoon sampler driven by a 63.50 kg. Hammer weight falling freely through a height 750 mm. The refusal of the test has been considered when the penetration is not possible with no. of blows. The actual values of SPT such as (N2 + N3) have been reported. Refusals have been indicated in boreholes by mentioning 'R' in the SPT Value column. The SPT values help in assessing the stratum strength in general.

The field tests conducted covers the Standard Penetration Tests. The results of the same are summarized in **table 4.8.**

TABLE 4.8: STANDARD PENETRATION TEST RESULTS

BH No.	Sr. No.	Depth of test (m)	N' Value (No. of blows per 30 cm)	Remarks
1	1	3.45 - 4.05	11-16-30-32	46 Residual Gravelly Soil
2	1	3.00 - 3.30	15-29 (10 cm)	R Refusal Rock
	2	4.50 - 4.80	18-35 (10 cm)	R Refusal Rock
3	1	1.65 - 2.10	02-03-04-05	07 Fill Materials
	2	3.00 - 3.60	08-10-14-21	24 Residual Soils
4	1	2.00 - 2.60	08-07-09-10	16 Brackish Grey Soils
	2	5.50 - 5.95	14-18-22-27	40 Brackish Grey Soils
	3	6.00 - 6.05	23 (5 cm)	R Refusal Rock
5	1	2.50 - 2.55	26 (5 cm)	R Refusal Rock
6	1	2.20 - 2.80	02-03-04	07 Soft Marine Clay
	2	3.45 - 4.05	03-04-06-08	10 Stiff Marine Clay
	3	5.15 - 5.25	28 (10 cm)	R Refusal Rock

4.4.3.3 Construction Methodology

Type of Foundation -Considering the insitu conditions (sample disturbance), confinement aspect do play a major role in transfer of loads to the bearing stratum. In the light of recovery pattern, the visual inspection of samples covering the texture, fracture and weathering aspect we recommend that the foundations may be laid based on chiseling criteria. IS: 2911 (Part-I/Sec2)-1999 provide design approach in weathered rock stratum for bored cast in-situ piles.

Type of Piles -In the present case bored cast in situ Concrete or precast piles can be adopted. From quality control considerations pre bored and precast piles, may be preferred. If one considers bored cast insitu and precast piles, the technical parameters connected with both the methods are almost similar. Pile soil interaction, Pile chipping head, loose materials at tip etc. are governing in a similar pattern.

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 8 m to 10 m as the piles are to be socketed in rock.

Pile Foundation-For the prevailing soil conditions and type of structures, bored cast-in-situ piles of 1000 mm, 1200 mm or 1500 mm diameter are proposed to be adopted. Actual socket length in completely weathered rock will be 3 times the pile diameter. However for design purpose only 0.5 times diameter length is considered. Piles transmit foundation loads through soil strata of low bearing capacity to deeper rock stratum having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance. The minimum diameter of pile should be 1000 mm.

Recommended safe vertical load carrying capacity of piles of different lengths below the ground level are as shown in **Table 4.9**.

TABLE 4.9: PILE CAPACITY (IN T)

For 1.00m dia pile	For 1.20m dia pile	For 1.50m dia pile
350 T	508 T	795 T

TABLE 4.10: BOREHOLE WISE PILE LENGTHS B.G.L

Sr. No.	BH No.	Minimum Pile Lenth	Pile termination depth BGL (in m)		
			For 1m dia	For 1.20m dia	For 1.50m dia
1	1	6.00 + 3.D	9.00	9.60	10.50
2	3	6.00 + 3.D	9.00	9.60	10.45
3	4	7.50 + 3.D	10.50	11.10	12.00
4	6	6.85 + 3.D	9.85	10.45	11.35

In almost all cases rock stratum is of completely highly weathered type. Hence determination of termination depth of pile is based on chiselling criteria only. Accordingly, there is possibility that actual socketing may be more than specified. However for design purpose only specified thickness of socket will be considered for pile strength.

4.5 UTILITY IDENTIFICATION

4.5.1 Introduction

Besides the details of various aspects e.g. transport demand analysis, route alignment, station locations, system design, viaduct structure, geo-technical investigations etc., there are a number of other engineering issues, which are required to be considered in sufficient details before really deciding on taking up any infrastructure project of such magnitude. Accordingly, Existing utilities along/across the alignment have been described here.

Large number of sub-surface, surface and overhead 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. Meticulous planning therefore will have to be taken in tackling the issue of protection/diversion of these utility services. Accordingly, the following engineering items have been studied and described below:

4.5.2 Utilities owning Organizations/Departments agencies along the corridors

Organizations/Departments with concerned utility services in Mumbai are mentioned in **Table 4.11.**

Table 4.11: UTILITY RESPONSIBILITY DEPARTMENTS

S. No.	Name of Utility	Organizations/Departments
1	WATER SUPPLY	Officer of the Hydraulic Engineer, GCMC
2	SEWERAGE	Office of Sewer Operations, Eastern and western Suburb, GCMC
3	STORM WATER DRAINAGE	Office of storm water drainage planning section
4	MTNL	Office of DGM, Planning
5	ELECTRIC CABLES AND LINE	Reliance Energy, MSEB, MSEDCL (Maharashtra State Electricity Distribution Company Limited), MSETCL (Maharashtra State Electricity Transmission Company Limited), Tata underground distribution Tata overhead high tension transmission lines. Tata raw power supply for metro operation (traction & auxiliary load)
6	GAS PIPELINES	Mahanagar Gas Limited
7	MOBILE PHONE	Vodafone TTML TATA Communications Airtel Bharti Sanchar Nigam Limited Reliance Telecom

4.5.3 Details of Above Ground Utilities

Affected above ground utilities have been identified based on topographical survey maps. The details have been placed in the following tables;

Table No. 4.12: Details of the HT Lines

S. No	Location Chainage(m)	Position w.r.t alignment	Remarks
1	545	Across	-
2	7390	Across	22kV
3	7406	Across	110kV
4	7726	Across	66kV
5	12832	Across	220kV
6	12965	Across	110kV
7	13453	Across	22kV

Table No. 4.13: Other Affected Services

S. No	Description	Number
1.	Lamp Post	167
2.	Manhole	107
3.	Signal Pole	25
4.	High Tension Line	7

4.5.4 Details of Underground Utilities

While planning for diversion of underground utility services viz. sewer lines, water pipelines, cables etc., during construction of Metro Rail 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.

Sewer lines and water supply lines are mainly affected in underground cut and cover construction. These services are proposed to be maintained by temporarily replacing them with CI/Steel pipelines and supporting them during construction, these will be encased in reinforced cement after completion of construction and retained as permanent lines.

Where permanent diversion of the affected utility is not found feasible, especially at the station locations, temporary diversion with CI/Steel pipes without manholes is proposed during construction. After completion of construction, these will be replaced with conventional pipes and manholes. During execution, trail pits shall be taken, number & type of exact utilities shall be ascertained. Protection could be taken by having structural piles away from the paver block area (containing all the utilities) & construction done not simultaneously, but in phases for viaduct & station locations respectively.

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. Also portal way of designing could be also proposed as an alternative option.

Sewer Lines, Strom Water Drains and Water Lines: 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. The 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 services lines.

Details of major underground utilities requiring relocation are given below (These details are notional and are provided by concerned departments):

Table 4.14: Details of Sewer Lines

S. No.	Chainage	Affected length (m)	Dia. (mm)	Position wrt alignment	Diversion proposal 'A' or 'B'
1	(-)286.5 – (-)190	96.5	300	Along	A
2	(-)190 - (-)117	73	600	Along	A
3	845		--	Across	B
4	845 - 970	125	---	Along	A
5	1090		230	Across	B
6	1832 - 1912	80	600	Along	A
7	1912		600/ 350	Across	B
8	2200		900	Across	B
9	3263.5		230	Across	B
10	4740 - 5059	319	350	Along	A

*Note: 1. the depth of sewer lines are approx. at 2.50m below ground level.
2. "A" – to be shifted away from median pier locations or to be bridged.
3. "B" – Suitably locate the pier/change the pile layout to avoid diversion.

Table 4.15: Details of Box Drains

S. No.	Chainage	Affected length (m)	Dimension	Position wrt alignment	Diversion proposal
1	9894 - 10050	156	2m X 2 m	Along	A
2	10050 - 10206	156	5 m X 2 m	Along	A
3	10440 - 10670	230	3 m X 2 m	Along	A
4	11140 - 11388	248	2 m X 2 m	Along	A
5	12410 - 12570	160	6.6 m wide	Along	A
6	13550		6.6 m wide	Diagonally Across	B

*Note: 1. "A" – to be shifted away from median pier locations.
2. "B" – Suitably locate the pier.

Table 4.16: Details of MGL Lines

S. No.	Chainage	Affected length (m)	Description	Position Wrt Alignment	Diversion proposal
1	7650 - 7900	250	MGL MP Pipe (125)	Along	A
2	7880	-	MGL MP Pipe (125)	Across	B
3	7900	-	MGL MP Pipe (125)	Across	B
4	8135 - 9320	1185	MGL MP Pipe (125)	Along	A
5	10600 - 11200	600	MGL MP Pipe (125) & MGL Steel Pipe	Along	A
6	11300 - 11400	100	MGL MP Pipe (125) & MGL Steel Pipe	Along	A
7	11800	-	MGL MP Pipe (125) & MGL Steel Pipe	Across	B

*Note: 1. the depth of affected water lines are approx. at 1.20m – 1.50m below ground level.
2. "A" – to be shifted away from median pier locations or to be bridged.
3. "B" – Suitably locate the pier.

Table 4.17: Details of 220 KV Reliance Infrastructure Ltd. EHV Cable

S. No.	Chainage	Affected length (m)	Description	Position Wrt Alignment	Diversion proposal
1	6524.823	-	EHV Cables	Across	B

*Note: 1. the depth of affected water lines are approx. at 1.20m – 1.50m below ground level.
2. "A" – to be shifted away from median pier locations or to be bridged.
3. "B" – Suitably locate the pier.

4.6 LAND ACQUISITION

4.6.1 Land

In order to minimise land acquisitions and to provide good accessibility form either directions, the metro alignments are located mostly along the road, which lie on the corridor. But, at some locations the geometrics of the roads especially at road turnings may not match with geometric parameters required for metro rail systems. In such cases, either the alignment will be off the road or some properties abutting the road would get affected. Further, some land is required for various purposes as detailed below.

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.
- Staff quarters, office complex and operation control centre (OCC)

4.6.2 Land Requirement for Elevated Stretches

For elevated section, single pier as well as portal structure supporting the viaduct will be located on road. Accordingly, necessary permission for using such right-of-way will have to be obtained from the concerned authorities. Elevated station is generally proposed with elevated concourse so that land is required only for locating the entry/exit structures. Traffic integration facilities are provided wherever the same are required and, but no land is proposed for acquisition.

The normal viaduct structure of elevated Metro with double U-girder is about 9.9 m (edge to edge) wide. However, for reasons of safety a clean marginal distance/set back of about 5 m is necessary from either edge of the viaduct (or 10 m on both sides of the centre line) wherein no structures are to be located. This is necessary as the traction system as proposed is overhead 25 KV AC system with masts fixed on the parapets. Also, it ensures road access and working space all along the viaduct for working of emergency equipment and fire brigade. In stretches, where the elevated alignment has to be located away from road, a strip of 20-m width is proposed for acquisition.

In view of the constraints on space on ground, it is proposed to provide the concourse area on the mezzanine level. All the stations in elevated stretch including terminal station are planned with single side discharge platforms. Normally, the width required for stations is 21 m. The staircases giving access to concourse area from ground have been proposed as per site conditions and constraints. Nevertheless it is not possible to find open space at all the locations therefore acquisition of certain private structures is inevitable.

4.6.3 Land for Traffic Integration

As indicated no land acquisition is proposed for traffic integration purpose. It is expected that the public parking policy of MCGM will be taking care of parking generated near metro stations.

4.6.4 Land for Depot

Depot for this Corridor has been proposed in land identified by MMRDA at Vikhroli. Hence an area of 15 ha govt. land has been earmarked.

4.6.5 Land for Traction and Receiving Substation and Radio Towers

Two RSS near JVLR Station and Depot are proposed to be located for this Corridor. Hence, an area of 11,200m^2 (Government) has been earmarked. Exact location will be decided at the time of implementation of the project. No additional land proposed for locating radio towers. These will be accommodated in the land already acquired.

4.6.6 Land Requirement for Stations & Running section

As indicated earlier, the ROW of the roads along which the alignment is planned is sufficiently wide and hence no land is required for acquisition as long as the alignment is straight and in the centre/footpath of the road. However, at curved portions, the alignment could not be kept in the centre of the road and land acquisition at such locations is inevitable in spite of introduction of sharper curves.

To the extent possible the Entry and Exit points of stations were planned out of ROW of Road. Details of land permanently required for stations and running sections are indicated in Table 4.18 and 4.19.

Table 4.18 RUNNING SECTION

S. No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
1	RS-1	1046	Pvt.
2	RS-2	2652	Pvt.
3	RS-3	481	Pvt.
4	RS-4	3597	Pvt.
5	RS-5	2170	Govt.
6	RS-6	1124	Govt.
7	RS-7	1807	Pvt.
8	RS-8	1750	Pvt.
9	RS-9	420	Pvt.
10	RS-10	2021	Pvt.
11	RS-11	361	Pvt.
12	RS-12	8253	Pvt.
13	RS-13	460	Pvt.
14	RS-14	3887	Pvt.
15	RS-15	275	Pvt.
16	RS-16	5014	Pvt.
17	RS-17	2068	Govt.
***TOTAL = 37386*m^2**			
***GOVT. =5362*m^2**			
***PVT. =32024*m^2**			

Table 4.19 LAND REQUIRED FOR STATIONS

S. No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
1	LC	1465	Pvt.
2	AN	1200	Pvt.
3	MN	1200	Pvt.
4	SN	2552	Pvt.
5	MKC	1481	Govt.
6	SV	1481	Govt.
7	SVR	1099	Govt.
8	R	1273	Govt.

S. No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
9	PL	2000	Govt.
10	IIT,P	2361	Govt.
11	V(EEH)	1637	Govt.
Total Land Area = 17749 m^2			
Govt. Land Area = 11332 m^2			
Pvt. Land Area= 6417 m^2			

4.6.7 Land for Staff Quarters, office complex and operation control centre (OCC)

A large number of officers and staff will be required to be deployed permanently to take care of project implementation and post construction operational activities. Moreover Metro Office Complex and Metro Operation Control Centre (OCC) will also be required. Metro Office Complex will be same for all the proposed metro lines, therefore no separate office complex is proposed for this corridor. It is proposed to keep the provision of **0.5 ha** and **0.5 ha** of government land for staff quarters and OCC respectively. Exact location of land has not been identified at this stage. It may be decided at the time of project implementation.

4.6.8 Temporary office accommodation

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. The areas may be identified based on availability as vacant on date nearer to the corridors. At the time of construction, depending up-on the need, the location and size can be reassessed and temporary land acquisitions can be made accordingly.

Since the area of land being acquired permanently at most of the stations is bare minimum, the land required for construction depots purpose has been considered throughout the corridor @ 2000 m^2 at every 5 km. 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.

Table 4.20 Details of Temporary Land office accommodation

S. No.	Corridor	AREA (m^2)	OWNER-SHIP
1	Swami Samarth Nagar to Vikhroli (EEH)	6000	Government
	Total	**6000**	

4.6.9 Casting Yard

Pre-cast girders 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 three casting yards for the proposed corridor. Accordingly a provision of **6ha** land has been proposed on temporary basis considering 2.0 ha of land for each casting yard for a period of four years.

4.6.10 Summary of Land Requirements

Abstract of land requirements for different components of this corridor is given in **Table 4.21**.

Table 4.21 Summary of Permanent Land Requirement (All figures in Sq. m)

S. No.	Description	Govt.	Pvt.
1	Stations	11332	6417
2	Running Section	5362	32024
3	Depot	150000	0
4	Staff Quarter	5000	0
5	OCC	5000	0
6	RSS	11200	0
	Total (Area in sq m)	**187894**	**38441**

Total Permanent Land	**=**	**22.6335ha**
Permanent Land (Govt.)	**=**	**18.7894 ha**
Permanent Land (Pvt.)	**=**	**3.8441 ha**

Table 4.22 - Summary of Temporary Land Requirement

S. No.	Description	AREA (m^2)	OWNER-SHIP
1	Temporary Office/ Site Office	6000	Government
2	Segment Casting Yard	60000	Government
	Total	**66000**	

Total land required for temporary acquisition is **6.6ha,** which is assumed that it will be government land.

4.7 SAFETY & SECURITY SYSTEMS

4.7.1 General

4.7.1.1 This section lays down the standards and requirements for safety & security, arising out of fire and unauthorized entry into premises. The system will be designed and installed for safe transportation of passengers & premises safety in Metro Railway System.

4.7.1.2 Requirements

i. The System shall protect the passengers against the fire in train services and at the premises of Metro Railway.

ii. The system shall protect vulnerable premises from fire.

iii. The system shall be able to detect the unauthorized entry and exit at nominated places.

iv. The system shall include

- Fire alarm system.
- Fire Hydrant and Sprinkler System.
- Fire Extinguishers.
- Closed circuit television with video analytics.

- Security Gates – Metal Detector.
- Baggage Scanner.

4.7.2 Fire Alarm System

4.7.2.1 General

The Fire Alarm System is a fully integrated, Fire Detection & Alarm System. It includes alarm initiating devices, alarm notification appliances, control panels, auxiliary control devices, power supplies, and wiring. Its installation is restricted to designated areas. In Metro railway this system shall be provided at the following locations:

i. At Station Control Room (SCR).
ii. Station security services centre.
iii. At Operational Control Centre.
iv. At Depot, in depot controller room.
v. Escalator landing and inside elevators.
vi. Evacuation routes.
vii. Cash transfer routes on the station.
viii. Equipment room.
ix. Store room.
x. Any other place required.

4.7.2.2 Scope

The system comprises of Main Addressable Intelligent fire alarm panel, smoke sensors, and smoke laser sensors, smoke optical sensors, heat sensors, audio visual indicators, isolator modules, monitor control and relay modules connected by interconnecting with Fire Retardant Low Smoke (FRLS) copper armored cable.

The main panel shall be located in security / control room. All the sensors and devices shall be connected to main panel. The panel shall operate with UPS power, 210 AC and shall have its in-built battery backup with battery charger.

A smoke detector is a device that detects the presence of smoke. It will be provided in commercial, industrial, and residential complexes and also closed and limited open space areas. Provision of smoke detector at equipment / store room shall be mandatory.

4.7.2.3System Components

Fire Alarm Control Panel

The main Fire alarm control panel, forms the heart of the fire detection system which gives command to peripheral device like detectors & to sub-systems. It shall consist of microprocessor based Central Processing Unit (CPU).

The CPU communicates with control panel installed, for the system to function effectively. The system comprises of:

i. Addressable pull stations – Manual Call Point.
ii. Intelligent photo electric smoke, thermal detector.

iii. Addressable control model.
iv. Isolated modules.

4.7.2.4 Addressable Pull Stations (Manual Call Point):

Addressable pull station is an active fire protection device, usually wall-mounted. When activated, it initiates an alarm on a fire alarm system. In its simplest form, the user activates the alarm by pulling the handle down, which completes a circuit and locks the handle in the activated position, sending an alarm to the fire alarm control panel. After operation, fire alarm pull station must be restored to the ready position using a special tool or key in order to de-activate the alarm sequence and return the system to normal.

4.7.2.5 Intelligent Photo - Electric Smoke Detector:

This Smoke detector works on photoelectric (light-scattering) principal to measure smoke density and on command, from the control panel, sends data to the panel representing the analog level of smoke density. However the detectors do not respond to refrigerant gas.

4.7.2.6 Addressable Control Module:

Addressable control modules will be used to operate dry contacts for door holders, air handling unit, shut down or other similar functions. Optionally the module can be used to supervise wiring of the output load power supply. If the monitored voltage falls below threshold, then a fault condition shall be displayed.

4.7.2.7 Isolator Module:

The fault isolator module to be connected placed between groups of sensors on the loop wiring, to protect the loop, if a fault occurs in the event of short circuit. The two isolators located on either side of the short circuit fault, shall automatically sense the voltage drop, open their switches and remove the devices from the rest of the loop. If the line voltage rises above a fixed threshold, indicating that the short circuit fault is removed, then the isolator module shall automatically restore the power, to the isolated group of devices. The smooth functioning again shall be continued.

4.7.3 Fire Hydrant System:

4.7.3.1 General

Fire Hydrant System is a semi-automatic water based system. In this system a network of pipes is laid out, depending upon the risk, with hydrant valves placed at strategic places.

4.7.3.2 Scope

The entire pipeline shall be kept pressurized with water. When any of the hydrant valve opens, the pressure in the pipeline reduces drastically. Jockey pump set shall normally keep the complete system pressurized, and enables it to cope up with the system demand, which results in further fall in pressure. The fall in pressure is sensed by the designated pressure switch, which automatically starts the main fire pump set.

Depending upon the type and sensitivity of the risk, diesel-engine power pump set should be installed having 100% standby capacity.

Fire Hydrant System comprises of the following:

- Sufficiently large water reservoir
- Fire pump sets (Main and Standby)
- Jockey pump set
- Hydrant valves
- Fire fighting hoses
- Branch pipe with nozzles

Hydrant System is proposed to be installed at following Places

i. Building Stair Case area.
ii. Basement Area of Building.
iii. Restricted area of Yard / Car shed / Depot.

4.7.3.3 System Component

- Landing Valves
- Hoses
- Couplings
- Hose Reels
- Fire Brigade Connectors
- Branch Pipes & Nozzles

4.7.3.4 Landing Valve

It's a simple valve like water tap, whenever it is open, after connecting hose to that valve, water flow is targeted to extinguish fire.

4.7.3.5 Hoses

Hose is a flexible tube used to carry water

4.7.3.6 Hose Reel

A Hose Reel is a cylindrical spindle made of either metal, fiberglass, or plastic used for storing a hose. The most common style of hose reels are spring driven, hand crank, or motor driven. Hose reels are categorized by the diameter and length of the hose they hold, the pressure rating and the rewind method.

4.7.3.7 Coupling

Coupling is a short length of pipe or tube with a socket at both ends that allows two pipes or tubes to be connected together temporarily.

4.7.3.8 Fire Brigade Connector

Approved fire brigade connection, shall consist of 4 nos. of 63 mm instantaneous inlets, in a glass fronted wall box, at a suitable position on the street at convenient location to make inlets accessible. The size of the wall box shall be adequate to allow hose to connect to the inlets, after breaking glass cover if need be.

4.7.4 Sprinkler System

4.7.4.1 A fire sprinkler system is an active fire protection measure, consisting of a water supply system, with adequate pressure and flow rate to a water distribution piping system, onto which fire sprinklers are connected.

Each closed-head sprinkler is held by either a heat-sensitive glass bulb or a two-part metal link held together with fusible alloy. The glass bulb or link, applies pressure to a pipe cap which acts as a plug. This prevents water from flowing, until the ambient temperature around the sprinkler reaches the designed activation temperature of the individual sprinkler head. Each sprinkler activates independently, when the predetermined heat level is reached. The number of sprinklers that operate are limited to only those near the fire, thereby maximizing the available water pressure over the point of fire origin.

Sprinkler System is proposed to be installed at following places

i. Building Passages.
ii. Basement Area.
iii. OCC room.
iv. Equipment room.
v. Store room.

4.7.5 Fire Extinguishers

4.7.5.1 General

Fire extinguishers form a first aid action against small and incipient fire before it develops into a major hazard.

4.7.5.2 Scope

Types of Extinguishers:

i. Carbon-di-oxide of 4.5 kg.
ii. ABC Type 5Kg.
iii. Water Container 9 ltr. capacity.

These extinguishers shall be installed in the entire public, as well as service areas where the security is necessary. These appliances should be distributed, over the entire area, so that its users do not have to travel more than 15 m to reach the appliance. These appliances can be mounted or hanged on the wall at desired location.

4.7.5.3 Description

Carbon Di Oxide (CO2) Fire Extinguishers

The cylinder filled with carbon dioxide (CO_2), when operated extinguishes fire without any residue. Carbon-di-oxide Extinguishers are recommended, as these have inert gas with no residue, which is electrically non-conductive and ideal to be used over electronics and electric appliances.

4.7.5.4 ABC Dry Powder - Fire Extinguishers

ABC Extinguishers are proposed for Class ‘A’ fire. These extinguishers are portable & can be handled by anyone / common person. These when operated, protect against the fire to flammable material, such as wooden articles, curtains etc.

- Type ‘A’ extinguisher shall be used for ordinary combustible articles such as cloth, wood, paper.
- Type ‘B’ extinguisher shall be used for flammable liquid fires, such as oil, gasoline, paints, lacquers, grease, and solvents.
- Type ‘C’ extinguisher shall be used for electrical fires, such as wiring, fuse boxes, energized electrical equipments and other electrical sources.
- Type ‘D’ extinguisher shall be used for metal fires such as magnesium, titanium and sodium.

4.7.5.5 Water Type Fire Extinguishers

Water Type Fire Extinguishers are recommended for all Class “A” type of Fires where unskilled staff / personnel exist and can operate these without much difficulty.

4.7.5.6 Glow Signs

Different types of signs like Exit, Fire and Emergency shall be provided to ensure passengers guidance and safety. The signs can glow in the dark specially. Exit Fire and Emergency Signs help passengers to find exit and help fire fighters to locate emergency equipment.

4.7.6 Closed Circuit Television

4.7.6.1 General

The objective of CCTV System is to provide High degree of Electronic surveillance system to the entire premises. It is essential to have recorded images to be stored at least for 30 days of all critical area’s to facilitate investigations of reported cases. CCTV provision facilitates effective management.

Strategically placed video surveillance cameras help to enhance security by providing motion based / continuous monitoring of all corners / areas of premises.

CCTV monitoring shall cover the following areas:

i. Station Control Room (SCR)
ii. Station security services
iii. Platform Supervisor Booth
iv. Operational Control Centre and Traffic Controller (TC)
v. Depot controller (DC) in Depot.
vi. Escalator landing and inside elevators
vii. Evacuation routes
viii. Cash transfer routes at the station

4.7.6.2 Description:

CCTV comprises of the following components:

i. Integrated Port Camera (IP Cameras)

ii. Computer
iii. Software

4.7.6.3 Integrated Port Cameras:

For operation of IP Cameras, no external supply connection is needed. However, Power Over Ethernet (PoE) shall be attached to an Uninterruptible Power Supply (UPS) and sized to maintain camera operations. PoE technology, enables a system to pass electrical power, along with data, on Ethernet cabling. Standard version of PoE specify Category 5 cable or higher to be used for the system.

Two types of IP Cameras Shall be used:

*Fix Camera– Use of this camera is restricted to 20 m range.
*PTZ Camera– Pan/Tilt/Zoom Camera is used for range from 20 m to 100 m.

4.7.6.4 Computer

Images, when recorded by cameras, are transmitted to computer. When computer is on, images are displayed on its monitor instantly. These images are also stored in memory device.

Storing of images occurs automatically, even when computer is in off position.

4.7.6.5 Software

Software installed in computer enables coding & decoding of data for functioning of the system enforced.

4.7.6.6 Server Software

Software covers MS-SQL 2005, or better based Main Archive Server for audio and video, Main directory, Failover directory, Failover recording, Digital Virtual Matrix, Incident Reports, Alarm Management, Network Management System and Watchdog modules.

Server maintains a catalog of settings for all clients. It also encodes & decodes of stored information through I P cameras.

Software enables the client to dynamically create connections between Cameras and workstations and view live or recorded video on the digital monitors (Audio, video, serial ports and digital I/Os)

4.7.6.7 Client Software

Client software includes of Administrator Tool application, Monitoring application, Archive Player application, Sync archive player application, Map creation application etc. All the relevant software licenses work on concurrent basis and no restriction of its use for specific work station is classified.

Client software performs the following applications simultaneously without interfering with any of the Archive Server operations (Recording, Alarms, etc.):

- Live display of cameras and audio

- Live display of camera sequences, panoramic camera views.
- Playback of archived video
- Instant replays of Video and Audio
- Display and control of Maps
- Audio announcements
- Alarm management

Client application provides, management and control over the system, using a standard PC mouse, keyboard or CCTV keyboard. Standard scroll mouse moves the camera by merely clicking on the extremes of the picture, in all directions and zoom function by scroll button, to avoid the use of joystick keyboard while maintaining easiness of the control.

Client application is to control pan-tilt-zoom, iris, focus, presets and dome patterns of the PTZ camera for correct functioning of the system.

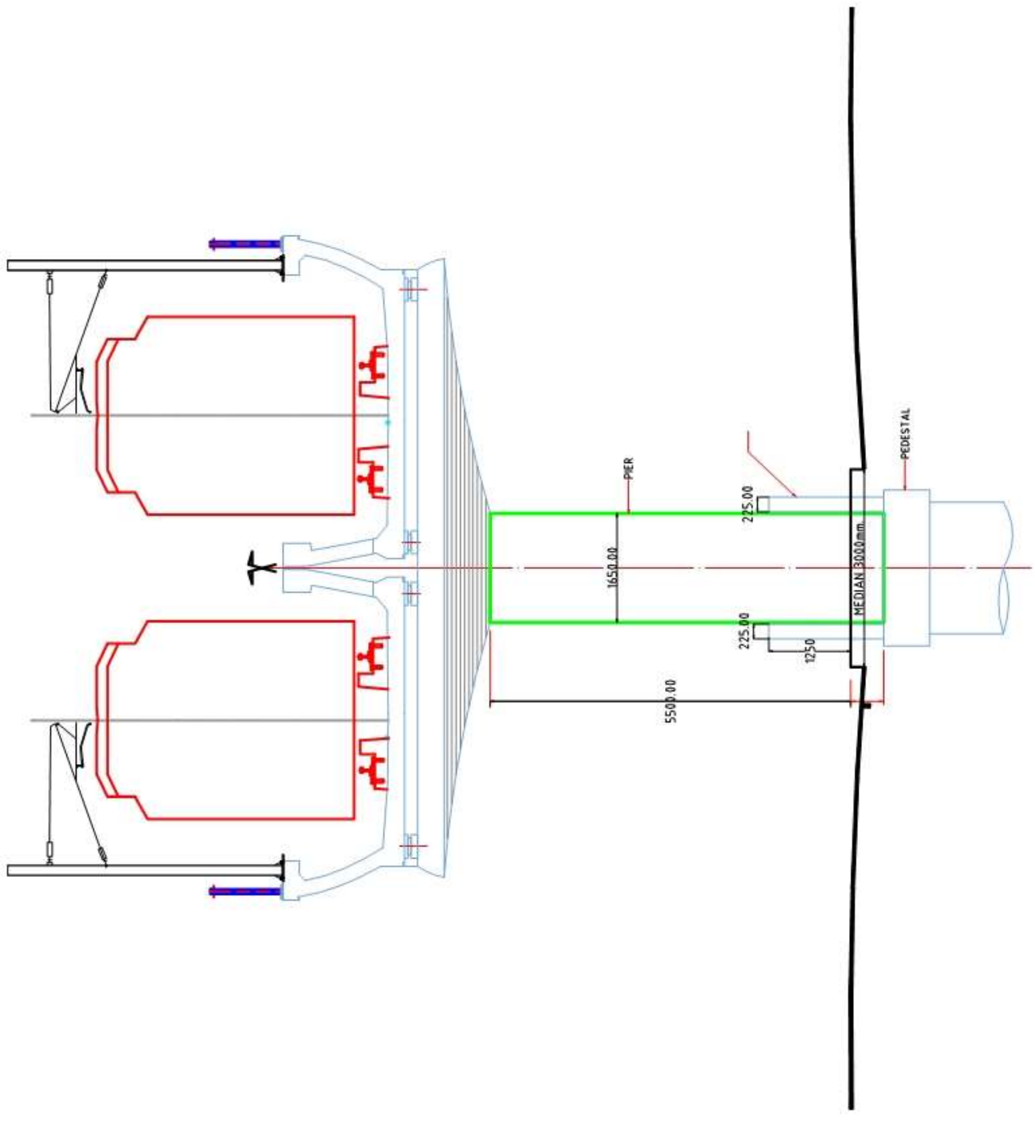
Software provides utility to play multiple exported clips simultaneously. It also provides the ability to play multiple clips in time sync with each other to understand the sequence of events occurred during an emergency.

4.7.6.8 Security in general has gained great importance during the last few years. It is a prime concern at the stations due to the large number of commuters who congregate there daily. Any short coming or lapse at the stations can cause a disaster. Security arrangement has been catered for at the stations and in the coaches. Cost of the same is included in the estimate.

The estimate for security may, however, need revision after level and quantum of security to be provided are known in greater detail.

Figure 4.1

TYPICAL CROSS SECTION OF THE VIADUCT WITH DOUBLE U GIRDER



SCALE- NTS

Figure 4.2(a): Erection of Girder using Crane

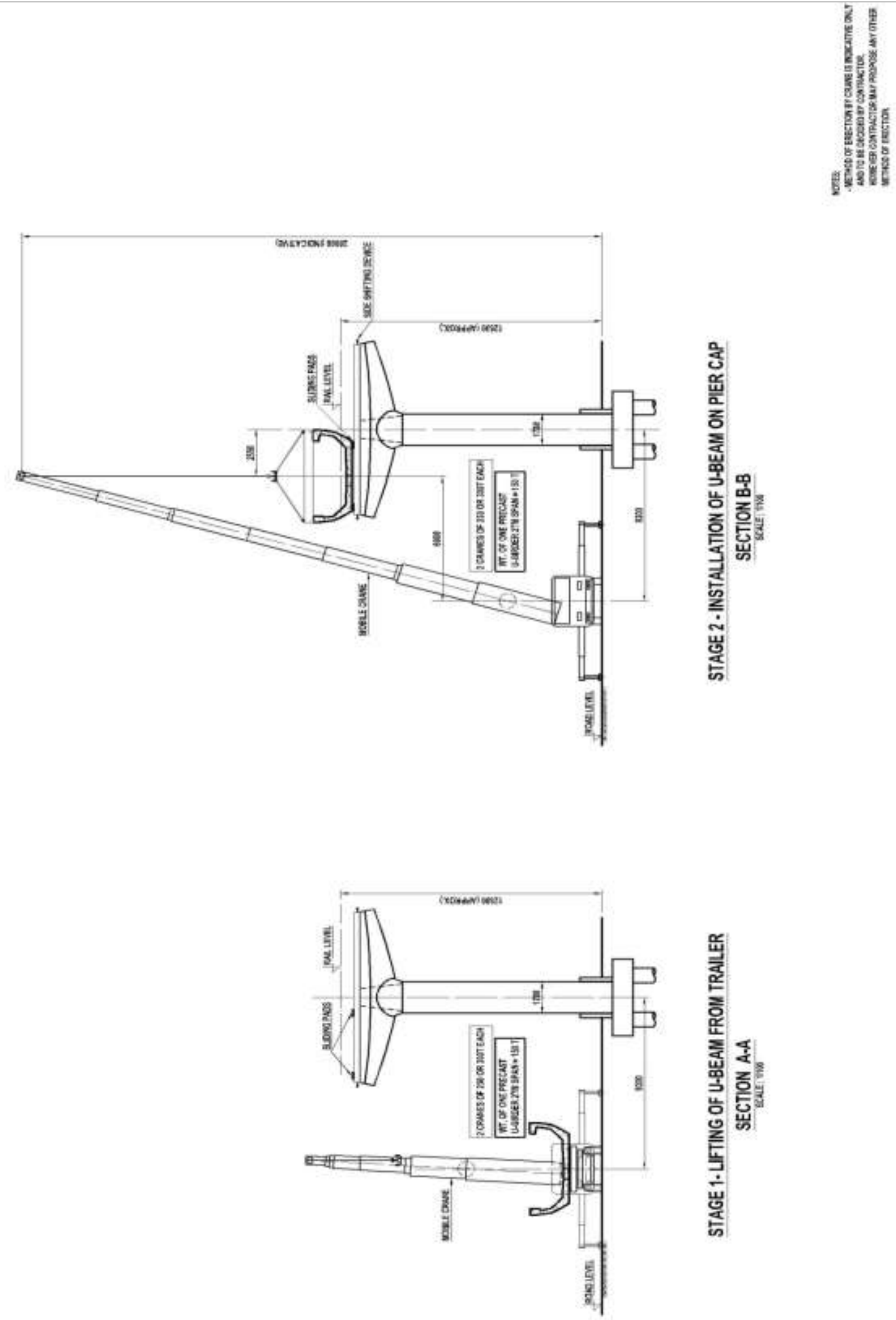
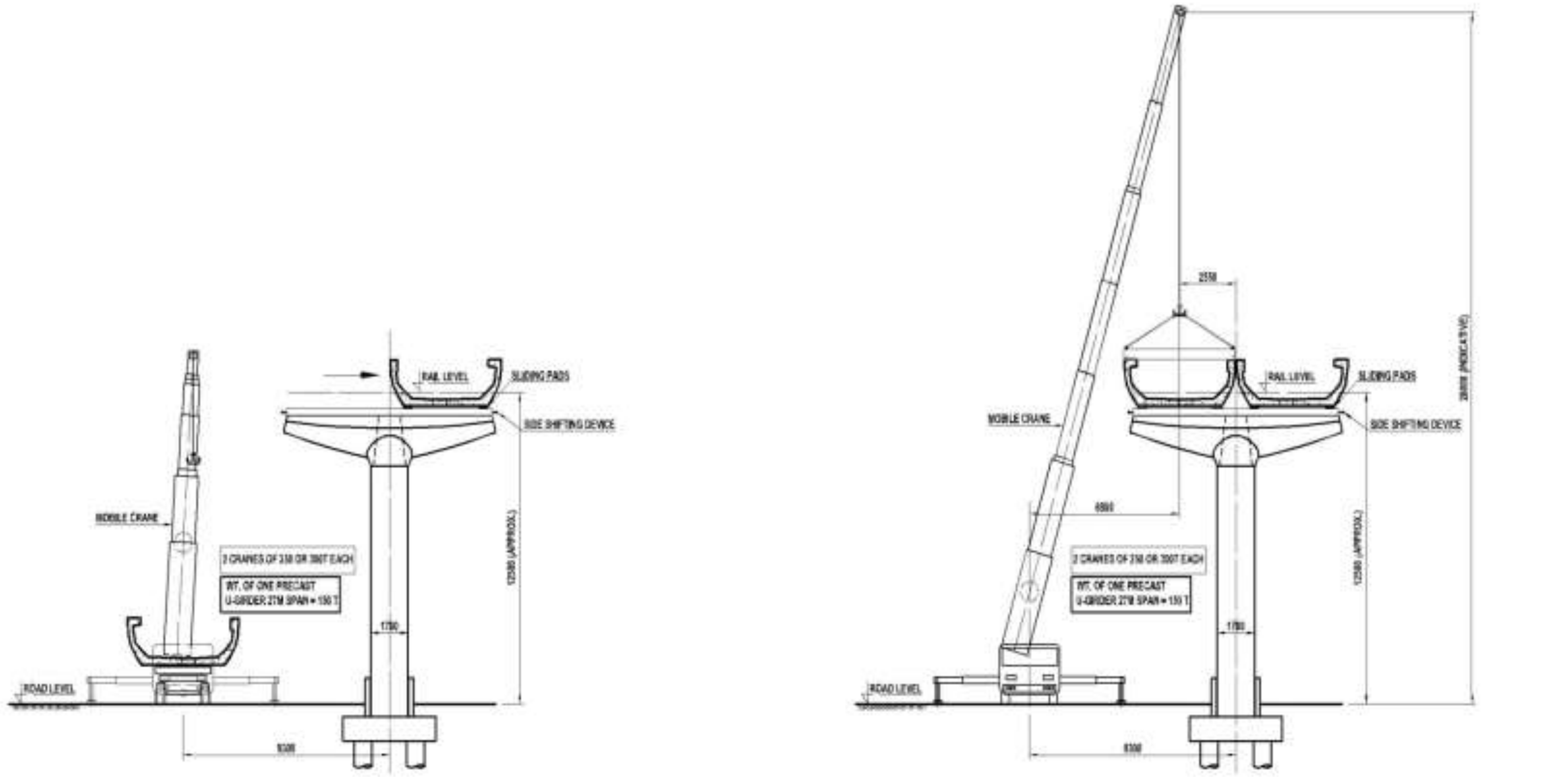


Figure 4.2(b): Erection of Girder using Crane



STAGE 3 - SIDE SHIFTING OF U-GIRDER

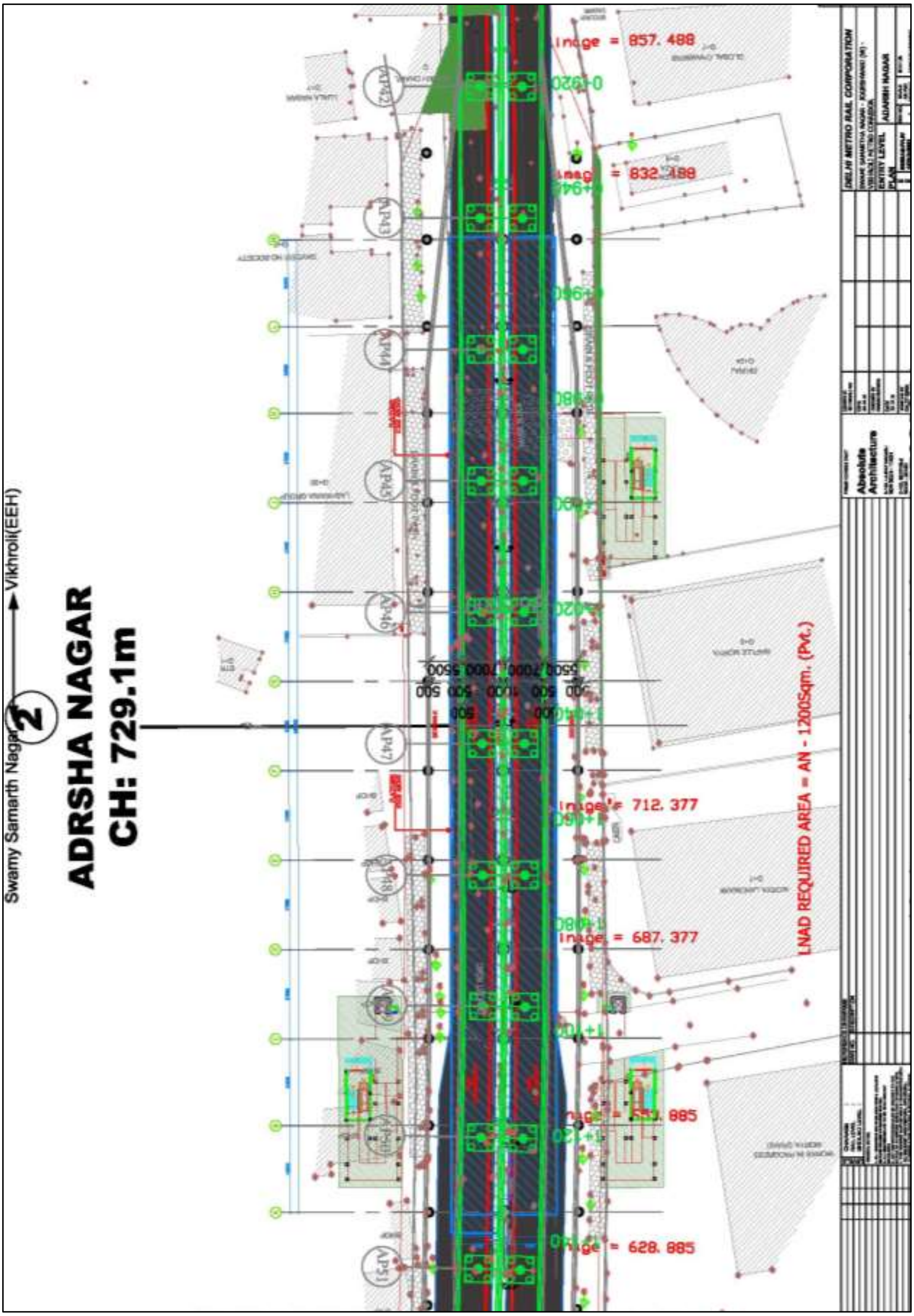
SECTION C-C

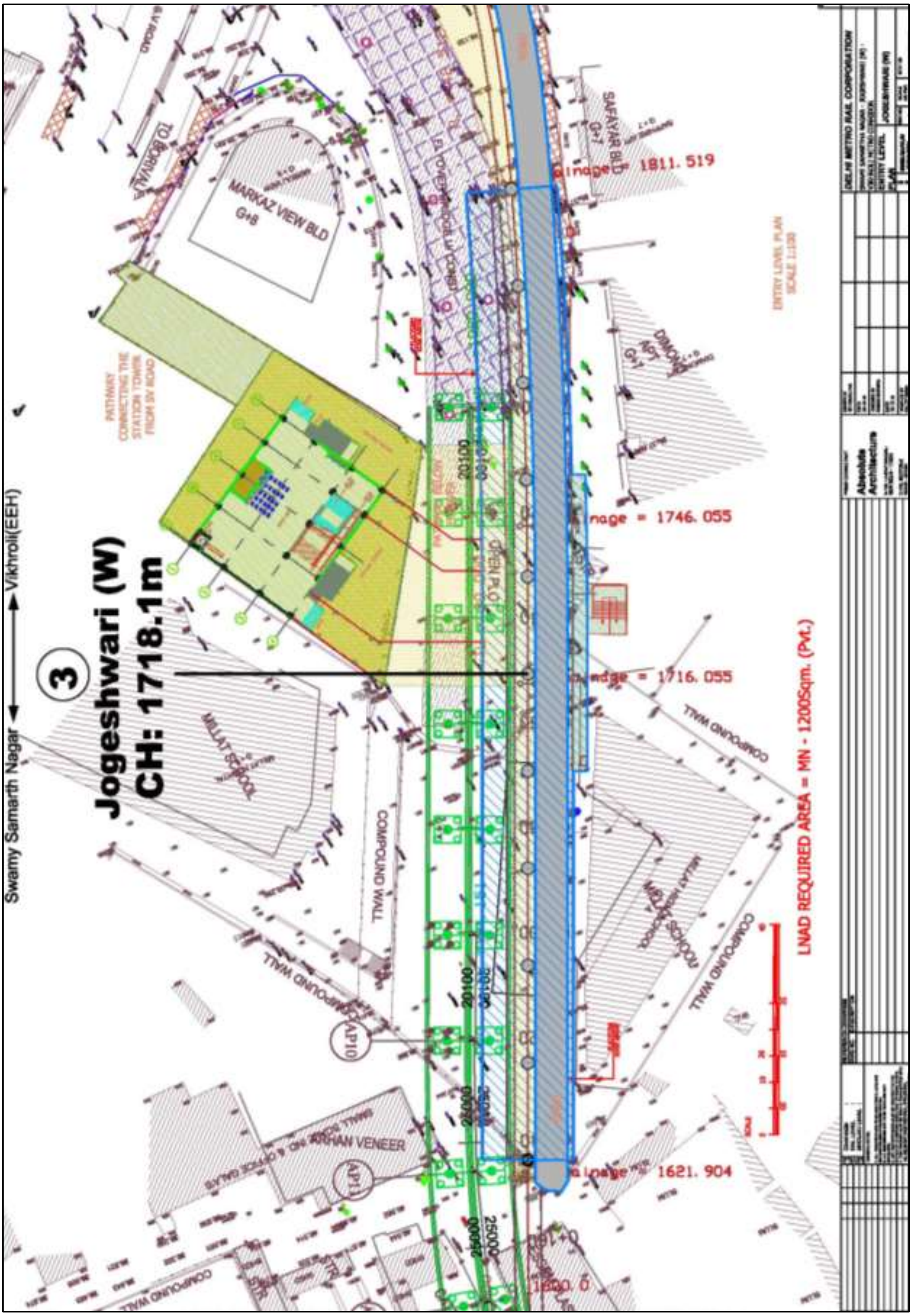
STAGE 4 - LIFTING AND INSTALLATION OF OTHER U-GIRDER

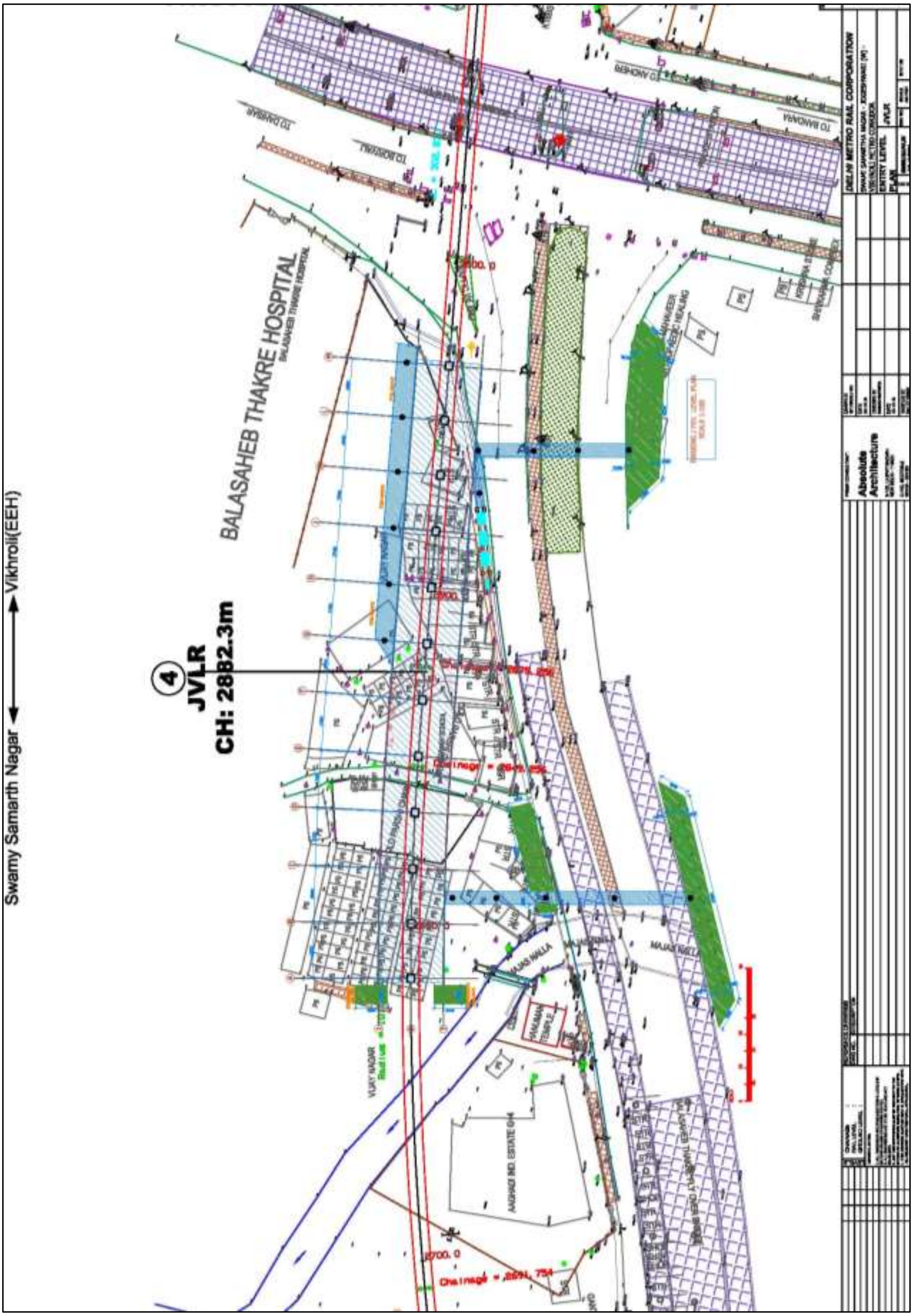
SECTION D-D

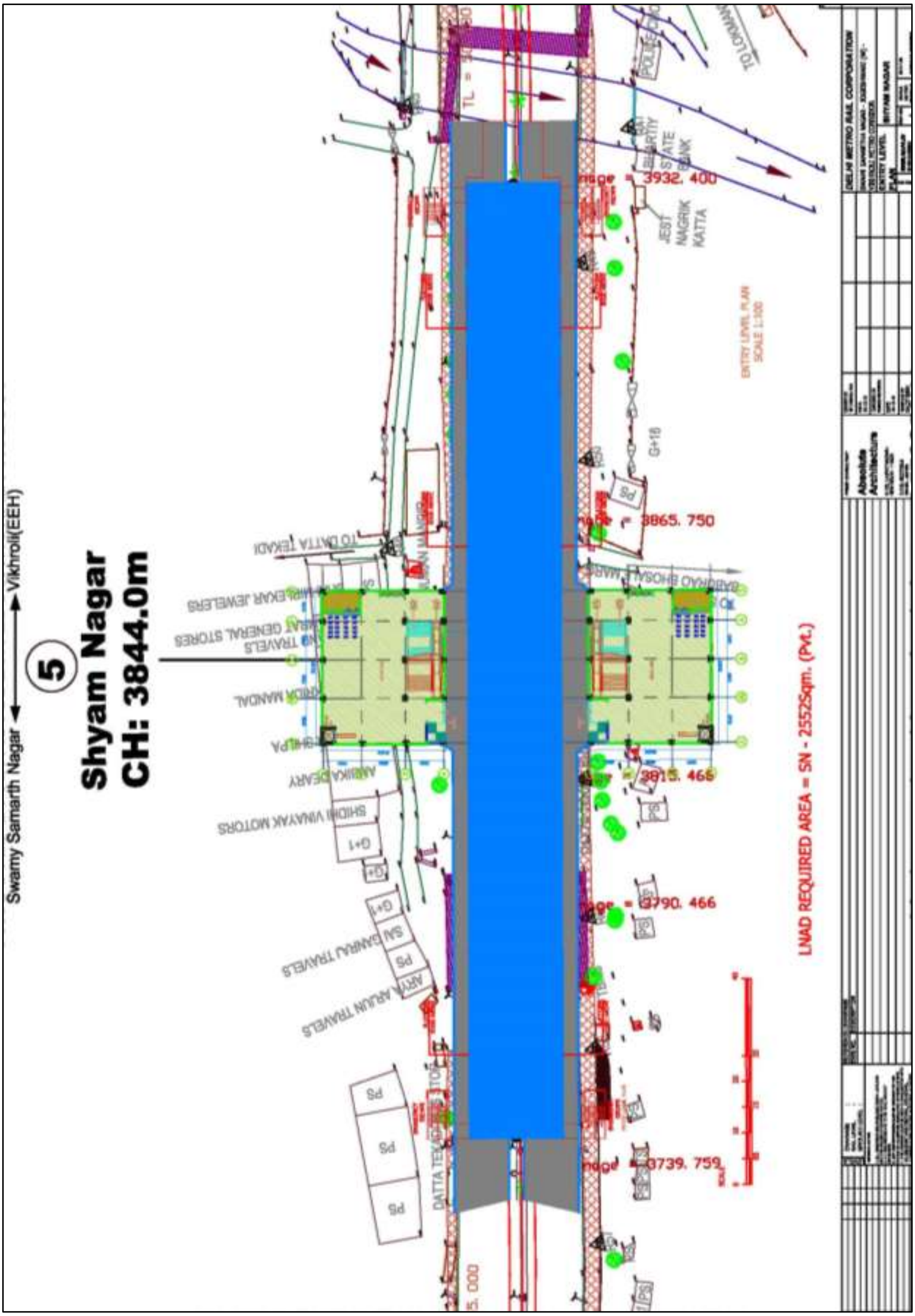
NOTES:
- METHOD OF ERECTION BY CRANE IS INDICATIVE ONLY AND TO BE DECIDED BY CONTRACTOR. HOWEVER CONTRACTOR MAY PROPOSE ANY OTHER METHOD OF ERECTION.


Vikhroli(EEH)
1
Swamy Samarth Nagar
CH:0.0m
LNAD REQUIRED AREA = LC - 14655Sqm. (Pvt.)


Swamy Samarth Nagar
Vikhroli(EEH)
2
ADRSHA NAGAR
CH: 729.1m
LNAD REQUIRED AREA = AN - 1200Sqm. (Pvt.)
DELHI METRO RAIL CORPORATION
ADARSH NAGAR
Absolute Architecture

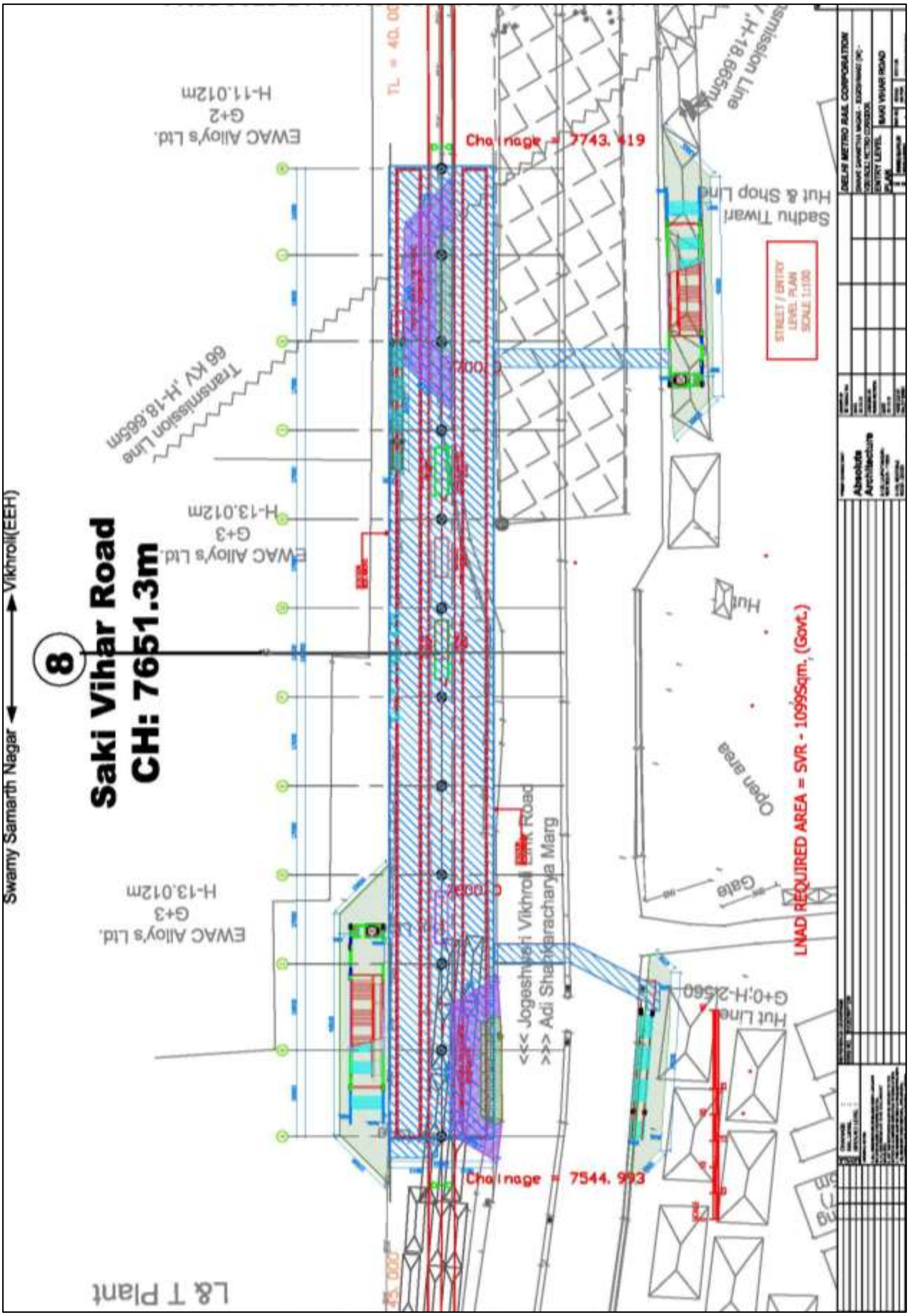

Swamy Samarth Nagar
Vikhroli(EEH)
3
Jogeshwari (W)
CH: 1718.1m
MARKAZ VIEW BLD
G+8
TO BORIVALI
SAFAYAR BLD
G+7
1811. 519
1746. 055
1716. 055
1621. 904
1800. 0
OPEN PLOT
COMPOUND WALL
MILLAT SCHOOL
AP10
AP11
ARHAN VENEER
LNAD REQUIRED AREA = MN - 1200Sqm. (Pvt.)
ENTRY LEVEL PLAN
DELHI METRO RAIL CORPORATION
Absolute Architecture


Swamy Samarth Nagar
Vikhroli(EEH)
4
JVLR
CH: 2882.3m
BALASAHEB THAKRE HOSPITAL
Absolute Architecture

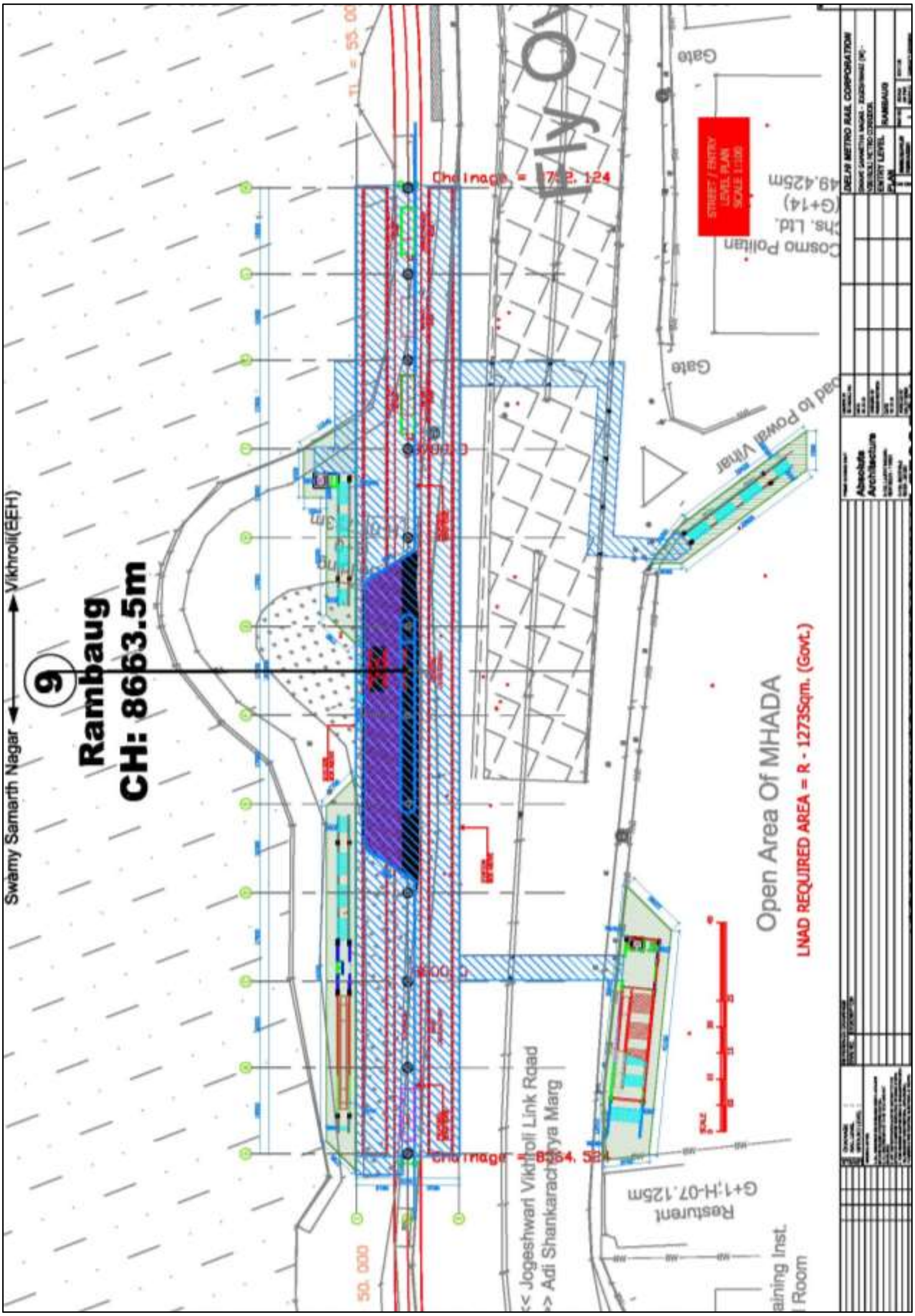

Swamy Samarth Nagar
Vikhroli(EEH)
5
Shyam Nagar
CH: 3844.0m
3932. 400
3865. 750
3815. 466
3790. 466
3739. 759
LNAD REQUIRED AREA = SN - 25525sqm. (Pvt.)
TO DATTA TEKADI
SHIDHI VINAYAK MOTORS
ARYA ARJUN TRAVELS
JESt NAGRIK KATTA
G+18
G+1
PS
DELHI METRO RAIL CORPORATION
Absolute Architecture

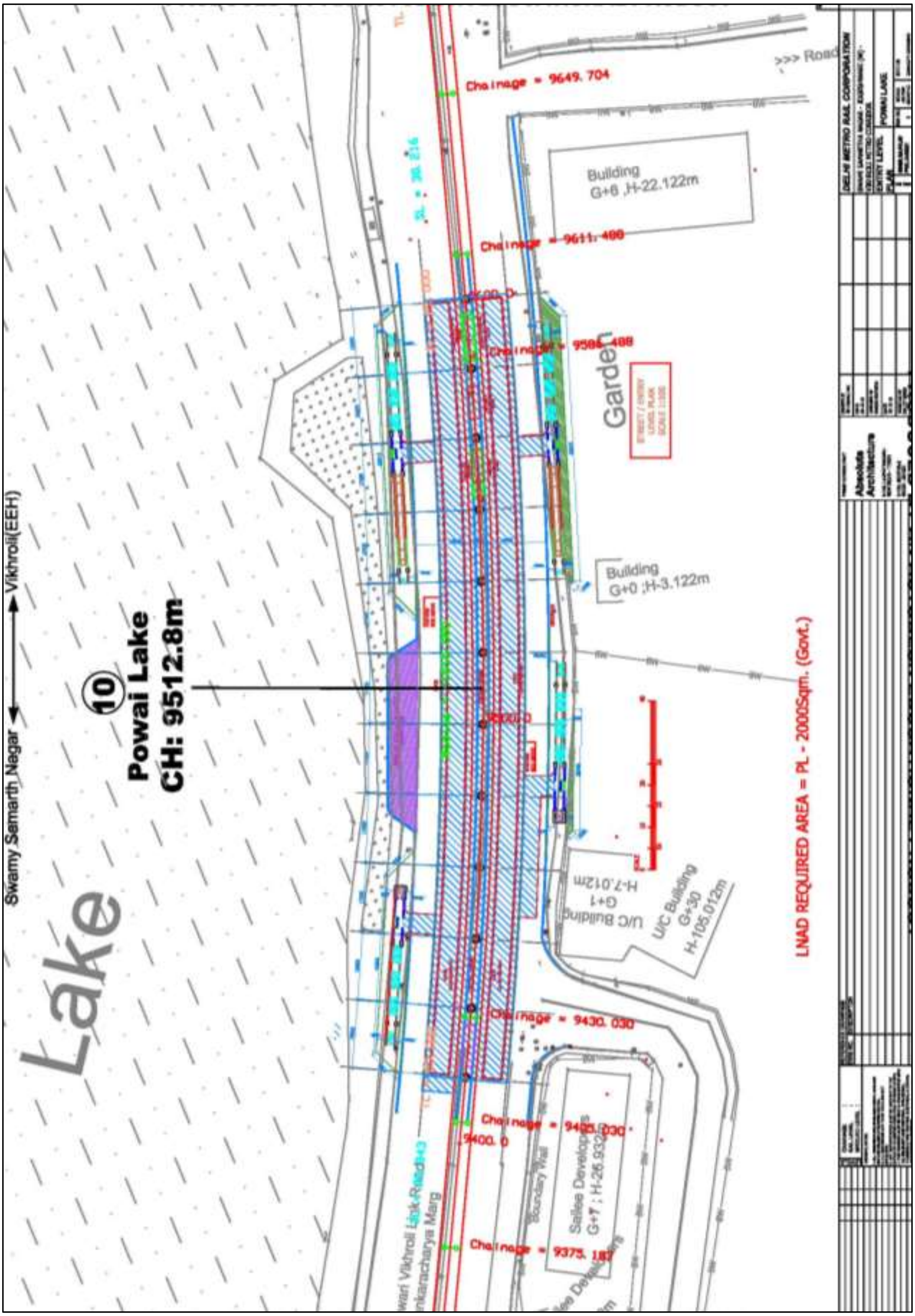

Swamy Samarth Nagar
Vikhroli(EEH)
6
Mahakali Caves
CH: 5392.2m
PRIVATE OPEN LAND
SAFFRON HOTEL
LNAD REQUIRED AREA = MKC - 1481Sqm. (Govt.)
TO MAHAKALI ROAD
KAMAL AMROHI STUDIO
OFFICE
DELHI METRO RAIL CORPORATION

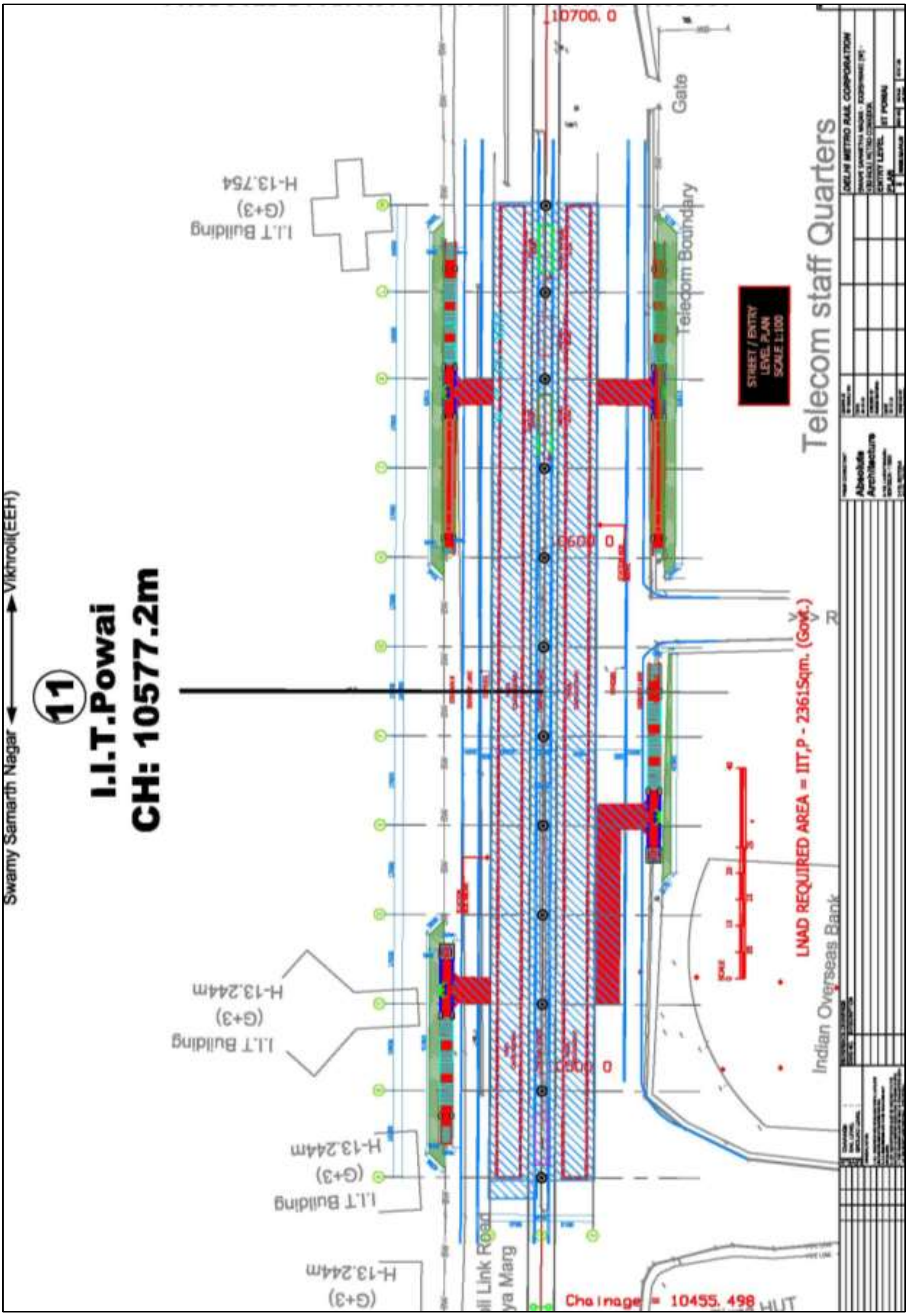

Swamy Samarth Nagar
Vikhroli(EEH)
7
SEEPZ Village
CH: 6515.0m
Reliance Energy
Training Center
(G+2)
H-11.021m
Gate
Bus Stop
Chainage = 6610.823
Chainage = 6463.114
Chainage = 6413.114
LNAD REQUIRED AREA = SV - 1481Sqm. (Govt.)
Bridge
>>> Road 1



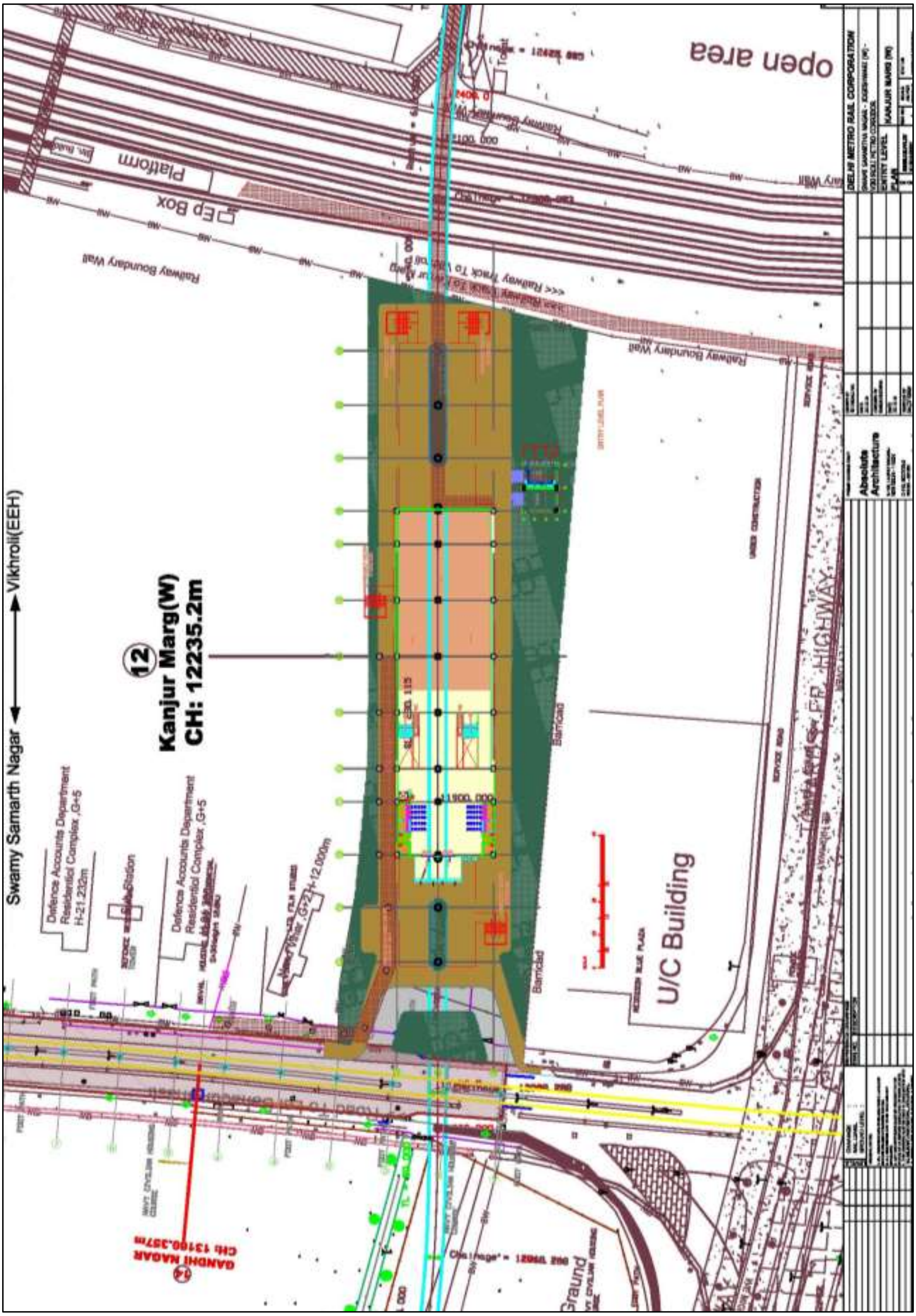
Swamy Samarth Nagar
Vikhroli(EEH)
8
Saki Vihar Road
CH: 7651.3m
EWAC Alloy's Ltd.
G+2
H-11.012m
EWAC Alloy's Ltd.
G+3
H-13.012m
66 KV 'H'-18.665m
Transmission Line
Chainage = 7743.419
Chainage = 7544.993
Hut & Shop Line
Sadhu Tiwari
Hut
Open area
Gate
LNAD REQUIRED AREA = SVR - 1099Sqm. (Govt.)
<<< Jogeshwari Vikhroli Link Road
>>> Adi Shankaracharya Marg
G+0;H-2.560
Hut Line
L& T Plant

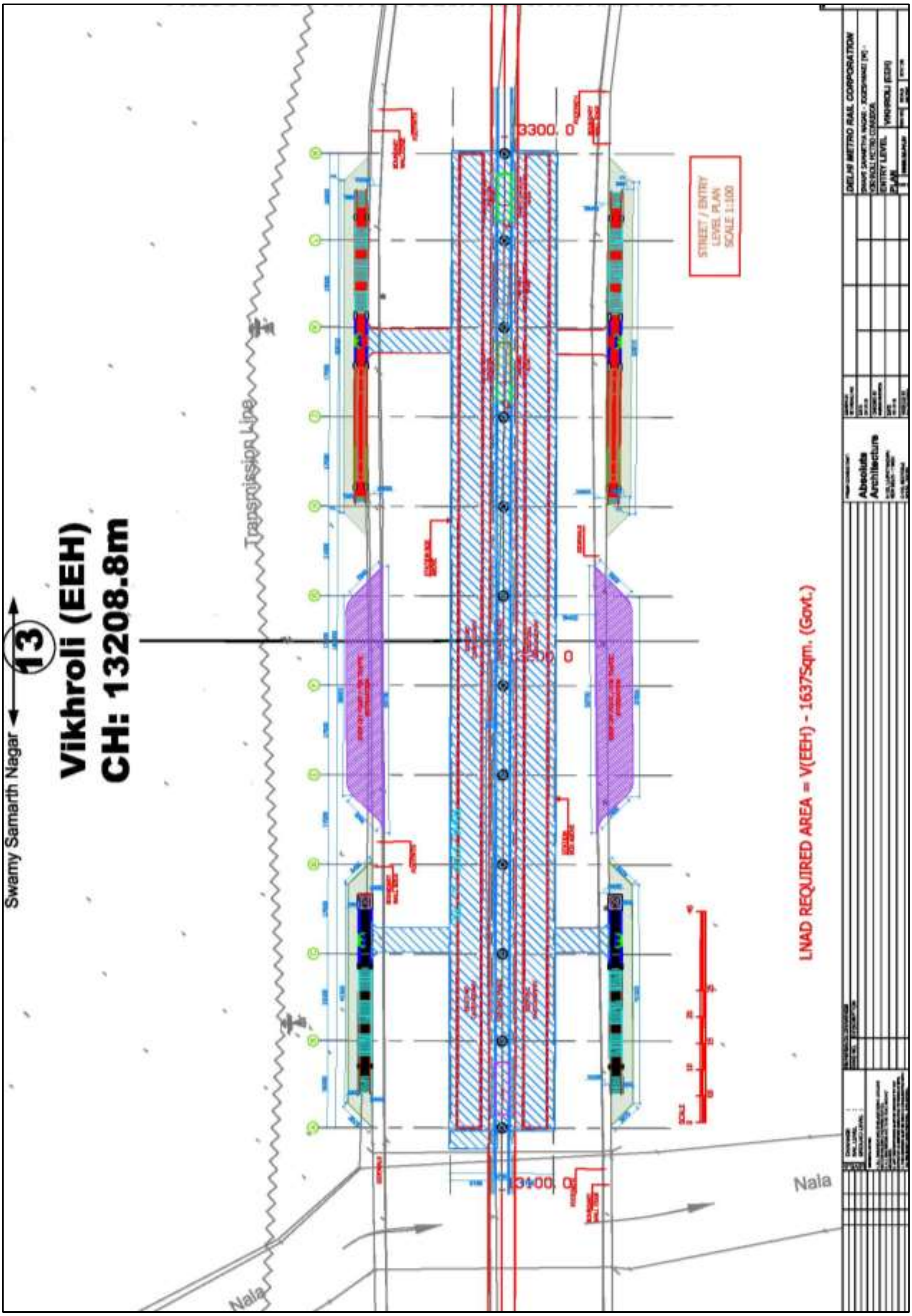

Swamy Samarth Nagar
Vikhroli(EEH)
9
Rambaug
CH: 8663.5m
Open Area Of MHADA
LNAD REQUIRED AREA = R - 12735Sqm. (Govt.)
Jogeshwari Vikhroli Link Road
Adi Shankaracharya Marg
Chainage = 8564. 524
Gate
Cosmo Politan
Restурent
G+1;H-07.125m
DELHI METRO RAIL CORPORATION


Swamy Samarth Nagar
Vikhroli(EEH)
10
Powai Lake
CH: 9512.8m
Lake
Garden
Building
G+6 ,H-22.122m
Building
G+0 ;H-3.122m
U/C Building
G+1
H-7.012m
U/C Building
G+30
H-105.012m
Chainage = 9649. 704
Chainage = 9611. 488
Chainage = 9430. 030
Chainage = 9375. 187
9400. 0
>>> Road
Boundary Wall
LNAD REQUIRED AREA = PL - 2000Sqm. (Govt.)
DELHI METRO RAIL CORPORATION
POWAI LAKE
Absolute Architecture



Swamy Samarth Nagar
Vikhroli(EEH)
11
I.I.T.Powai
CH: 10577.2m
I.I.T Building
(G+3)
H-13.754
H-13.244m
Telecom staff Quarters
Telecom Boundary
Gate
STREET / ENTRY LEVEL PLAN SCALE 1:100
LNAD REQUIRED AREA = IIT,P - 2361Sqm. (Govt.)
Indian Overseas Bank
10700. 0
Chainage = 10455. 498


Swamy Samarth Nagar
Vikhroli(EEH)
12
Kanjur Marg(W)
CH: 12235.2m
U/C Building
open area
Platform
Ep Box
Railway Boundary Wall
Defence Accounts Department Residential Complex ,G+5
GANDHI NAGAR
CH: 13160.357m
Barricad
DELHI METRO RAIL CORPORATION
Absolute Architecture



Swamy Samarth Nagar
13
Vikhroli (EEH)
CH: 13208.8m
Transmission Line
STREET / ENTRY LEVEL PLAN SCALE 1:100
LNAD REQUIRED AREA = V(EEH) - 1637Sqm. (Govt.)
Nala
Nala
DELHI METRO RAIL CORPORATION
Absolute Architecture

Annexure-4.1

SELECTION OF TYPE OF ALIGNMENT

The metro network may have the under-mentioned three types of alignments:

1. At-Grade
2. Elevated
3. Under-ground

1. At Grade - At-Grade type of alignment is technically feasible only in the areas where vacant land is available or a dedicated corridor of 14 meters width is provided in the mid of the road. However, the main limitation of providing At-Grade corridor is that city is divided in two parts and any crossing from one side to other side of At-Grade corridor has to be provided by grade separation i.e., either foot-over bridge or under passes. This alternative is the most economical. However, it should be noted that cost saving is only in Civil Engineering cost which is arrived if the land cost requirement for at grade alignment is taken into account and cost per km may come even more than elevated. Therefore, At-Grade type of alignment for metro systems in cities is normally ruled out.

2. Elevated – Elevated alignment is generally provided in the cities for metro network, but the pre-requisite is the right of way (ROW) of road should minimum be 20 meters. It will enable to provide a median of about 2.8 to 3.0 meters wide road, two lane each way (7 meters width) and foot-path 1.5 meter each way. The land requirement for elevated alignment is mainly for the exit and entries for the station. As the alignment pillars located on median of the roads, a rough estimate of land requirement is about 240 sq. meters on either side of the road, wherein even underground water tank and generator rooms can be accommodated under the staircase. Construction of elevated station is much easier, 8 meter wide strip for the platform length (say 185 meters) will be required temporarily for putting the pillars on the median. Small area of about 400 sq. meters is needed for execution of the work of exit and entries on either side of the road.

3. Under-ground – This type of alignment is adopted only in case when ROW is less than 20 meters and alignment has to necessarily pass through the area where no roads are available. In this case only station locations where metro stations can conveniently located are identified and these are joined by under-ground tunnels. However, under-ground station need much ground surface area than elevated station for the reasons that in case of under-ground station, there is a space requirement for chiller plants in addition to exit and entries, which may be almost same as required for elevated station. Normally, the construction of under-ground stations require the area with 240 meters length and 24 meters width which need to be cut open. Finding out such a big space for construction of under-ground station in a congested city and even on passenger roads is very difficult if not impossible. For construction of under-ground station, the traffic is

necessarily required to be diverted. Advantages and dis-advantages of these two types of alignments are given in the table below:

S. No.	Item name	Under-ground alignment	Elevated alignment
1.	Permanent land	More area required	Comparatively less area required
2.	Land requirement for construction	Much more area required. At least twice of what required for elevated station	Area requirement is much less than under-ground
3.	Construction time	At least 5 years	At least 3 and 1/2 years
4.	Cost of construction	2.25 to 2.50 times of elevated cost.	Much cheaper compared to underground
5.	Operation cost	1.25 to 1.5 times of elevated operation cost	Much cheaper compared to underground
6.	Security concern	Under-ground metro stations are more prone to terrorist attacks.	Less prone to terrorist attacks.
7.	Risk	More risk to the passengers during the disruption	Less risk compared to underground.
8.	Drainage Arrangement	Very exhaustive drainage arrangement needed	Very simple arrangement
9.	Ramp	In case of under-ground, when alignment is changes from under-ground to elevated, 11 meters width and 650 meters long land portion is needed for providing the ramp with physical barrier between 2 sides of the city.	There is no requirement of such ramp and land.

The rough estimate of under-ground and elevated alignments for 20 kms length has been made at the price level of March, 2015. The cost (without land and Taxes) of under-ground alignment comes to Rs. 412 crores and elevated Rs. 176 crores. It indicates that per kilometre of under-ground alignment replacing elevated alignment, the cost to the tune of 2.3 times has to be incurred.

In view of the above, the decision for opting a particular type of alignment has to be taken on techno-economic basis. For country like India, a balance has to be kept in two types of alignments for the reasons that we are already short of funds for our infrastructure projects. It is also recommended that underground alignment be opted only in the stretches where elevated alignment is not possible to provide.

To appreciate the magnitude of land requirement, Ground Level Plans of one Typical elevated station and underground station are put up at Figure-1 & Figure-2 to this appendix.

Figure -1 Typical Elevated Station Layout

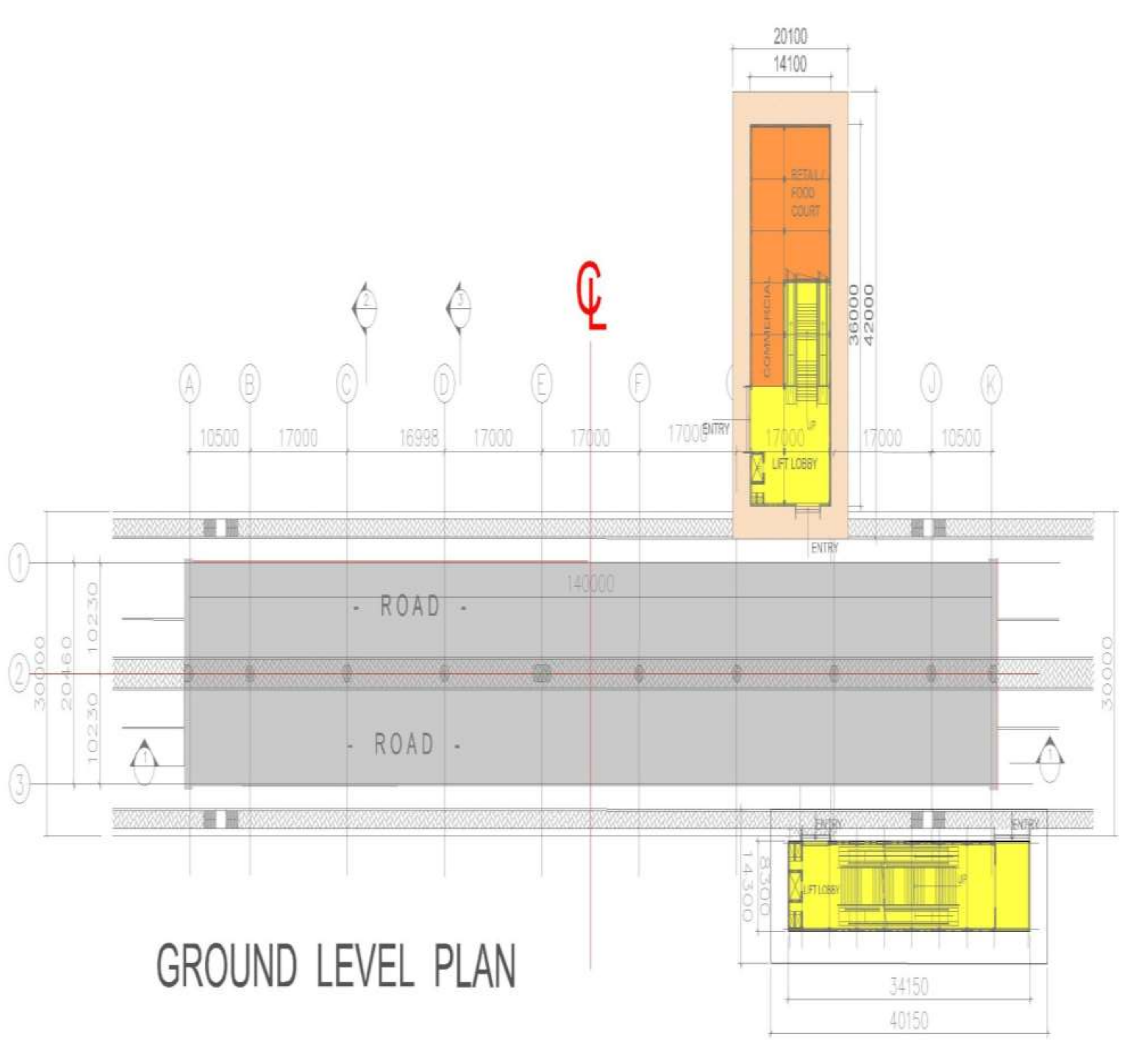
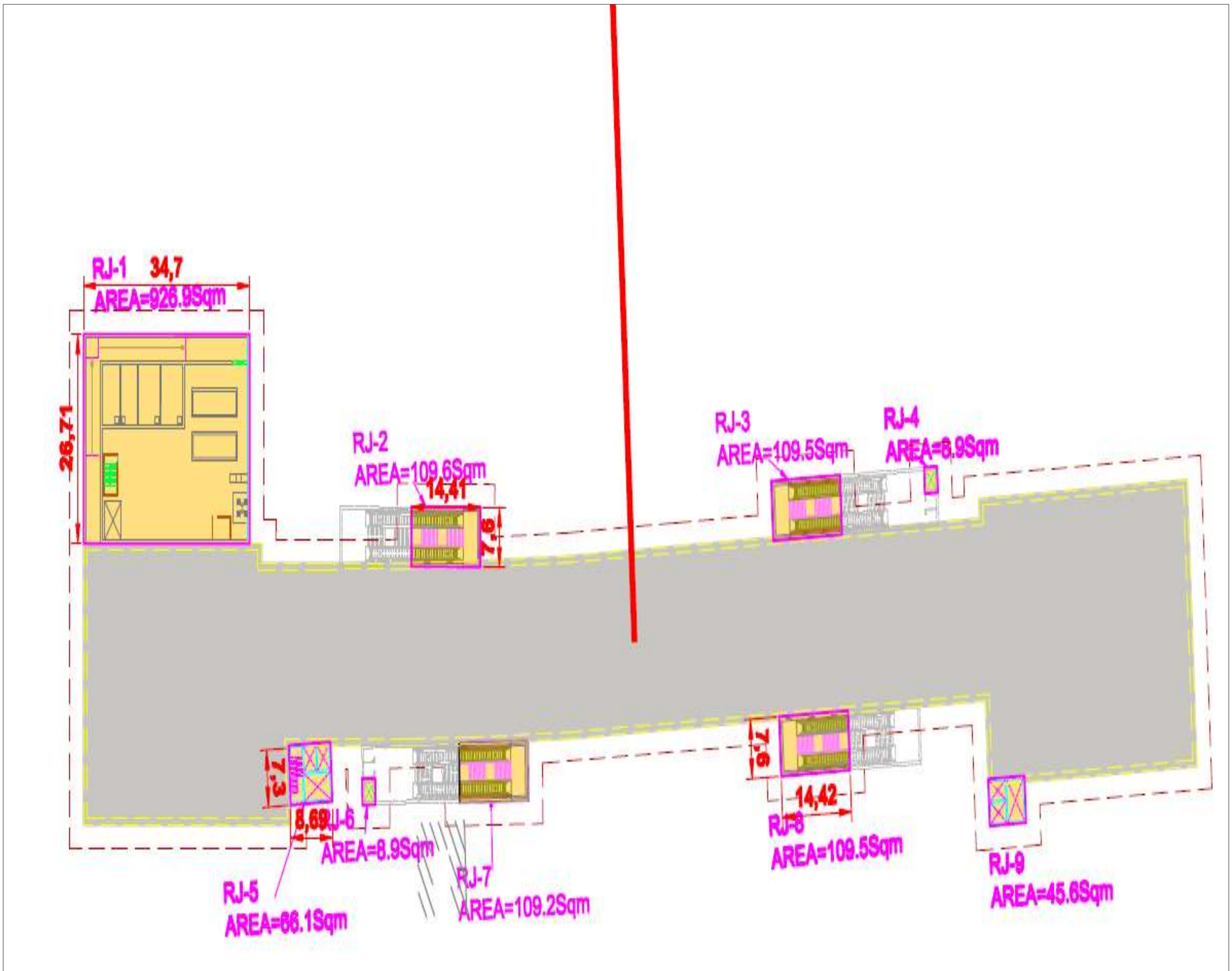


Figure-2 Typical Underground Station Layout

Ground Level Plan



Chapter – 5

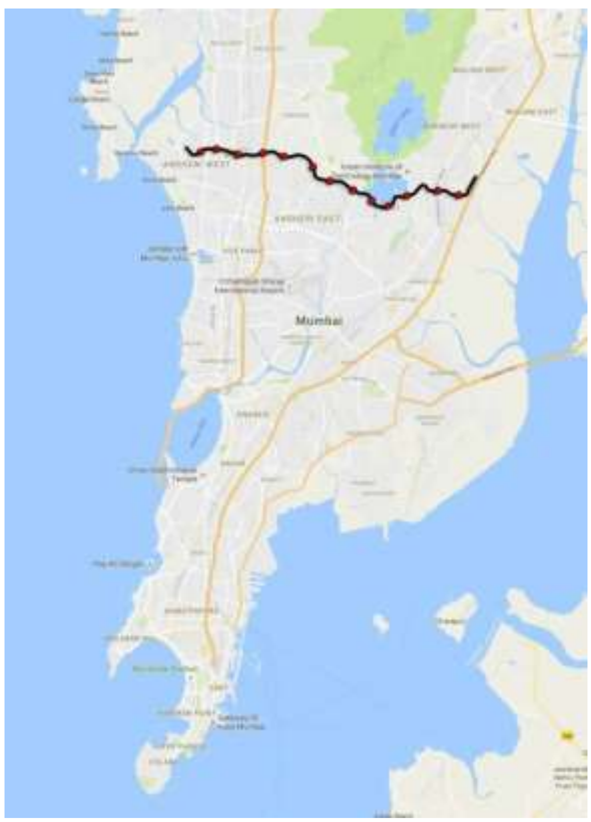
STATION PLANNING

5.1 STATION PLANNING

General

The proposed corridor for Mumbai Metro runs from Swami Samarth Nagar in the West to Vikhroli (EEH) in the East.

The length of the proposed corridor from Swami Samarth Nagar Complex Station in the West to Vikhroli (EEH) Station in the East is approximately 13km between the two terminal stations. Along this proposed corridor, 13 stations have been planned, off which all 13 are elevated. The locations of the stations have been identified taking into consideration the constraints in land acquisition and congestion issues. Stations are proposed in such a way so as to attract maximum demand from the traffic nodal points.



5.2 STATION TYPES

All thirteen stations planned in this section have side platforms. Care has been taken to locate stations on straight alignment only. However, in situations where other site constraints have become overpowering, a curve of minimum 1000m radius has been accepted within tolerance limits. Average inter-station distance is approximately 1019.65m varying from 729.1m to 1668.5m depending upon the site, operational and traffic constraints. The sequence of stations with their respective chainages and locational and platform characteristics is presented in **Table SP1**.

Table SP1

No.	Name of the Station	Chainage (m)	Interstation Distance (m)	Platform	Highest Ground Level	Rail Level	Rail Level Height from Ground	Platform Height from Ground
1	Swami Samarth Nagar	0	-	Side	4.705	18.000	13.295	14.385
2	Adarsh Nagar	729.1	729.1	Side	4.522	25.600	21.078	22.168
3	Jogeshwari (W)	1718.1	989.0	Side	14.429	33.500	19.071	20.161
4	JVLR	2882.3	1164.2	Side	16.009	33.400	17.391	18.481
5	Shyam Nagar	3844.0	961.7	Side	27.797	44.400	16.603	17.693
6	Mahakali Caves	5392.2	1548.2	Side	60.715	73.742	13.027	14.117
7	SEEPZ Village	6515.0	1122.8	Side	26.401	47.647	21.246	22.336
8	Saki Vihar Road	7651.3	1136.3	Side	29.83	42.950	13.120	14.210
9	Rambaug	8663.5	1012.2	Side	38.398	51.500	13.102	14.192
10	Powai Lake	9512.8	849.3	Side	38.296	51.400	13.104	14.194
11	IIT Powai	10577.2	1064.4	Side	40.299	53.400	13.101	14.191
12	Kanjur Marg (W)	12235.2	1658.0	Side	9.013	34.975	25.962	27.052
13	Vikhroli (EEH)	13208.8	973.6	Side	5.696	20.000	14.304	15.394

1. SWAMI SAMARTH NAGAR

Chainage	0.0m
Inter-station Distance	0.0m
Rail Level	13.295m
Platform Height from Ground	14.385m
Location	P Tandon Marg on road median
Entry / Exit Stairs	On four sides the entry exit structures are located flanking the station.
Catchment Area	Lokhandwala Complex, Shastri Nagar Phase - D, Sundervan Complex, SV Patel Nagar

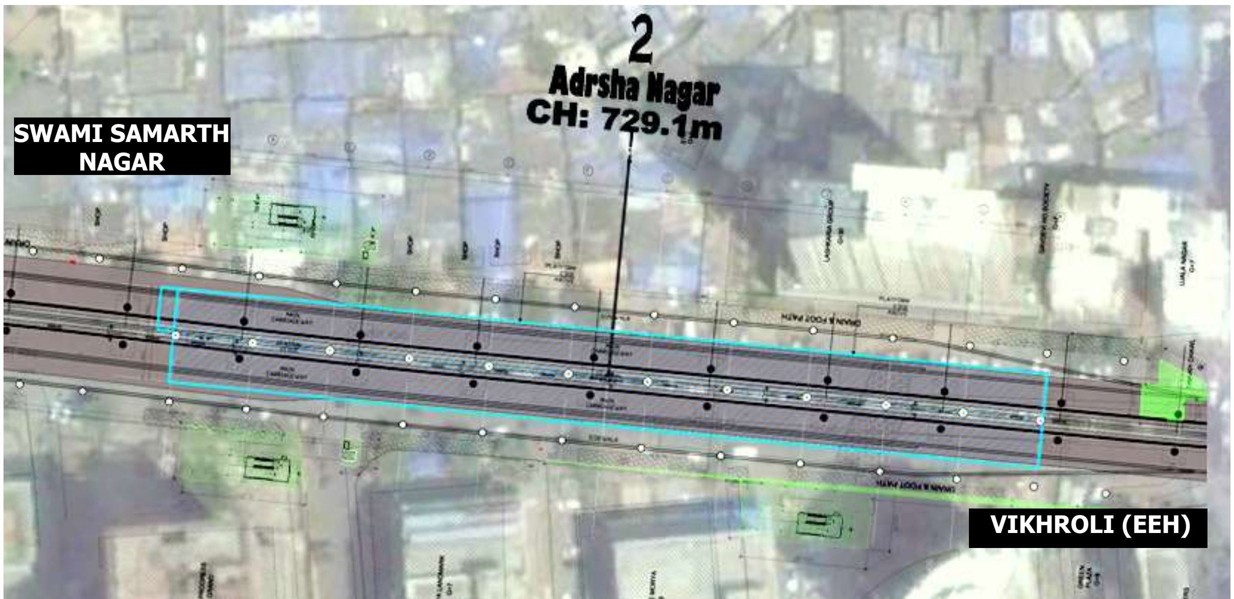
Existing Structures around station location

Existing Structures around station location

Existing Structures around station location

2. ADARSH NAGAR

Chainage	729.1m
Inter-station Distance	729.1m
Rail Level	21.078m
Platform Height from Ground	22.168m
Location	P Tandon Marg
Entry / Exit Stairs	On three sides the entry exit structures are located flanking the station.
Catchment Area	Kadam Nagar, Veer Desai Industrial Estate, Shastri Nagar, Jogeshwari West.




Main Road with existing buildings.


Sheds to the north of the alignment


Existing building structure, Maple and Morya Buildings.

3. JOGESHWARI (W)

Chainage	1718.1m
Inter-station Distance	989.0m
Rail Level	19.071m
Platform Height from Ground	20.161m
Location	To the south of proposed extension of Balasaheb Thakre Flyover
Entry / Exit Stairs	Tower type station. Tower on acquired land to the South of alignment.
Catchment Area	Momin Nagar, BR Nagar, Shastri Nagar, Jogeshwari Railway Station

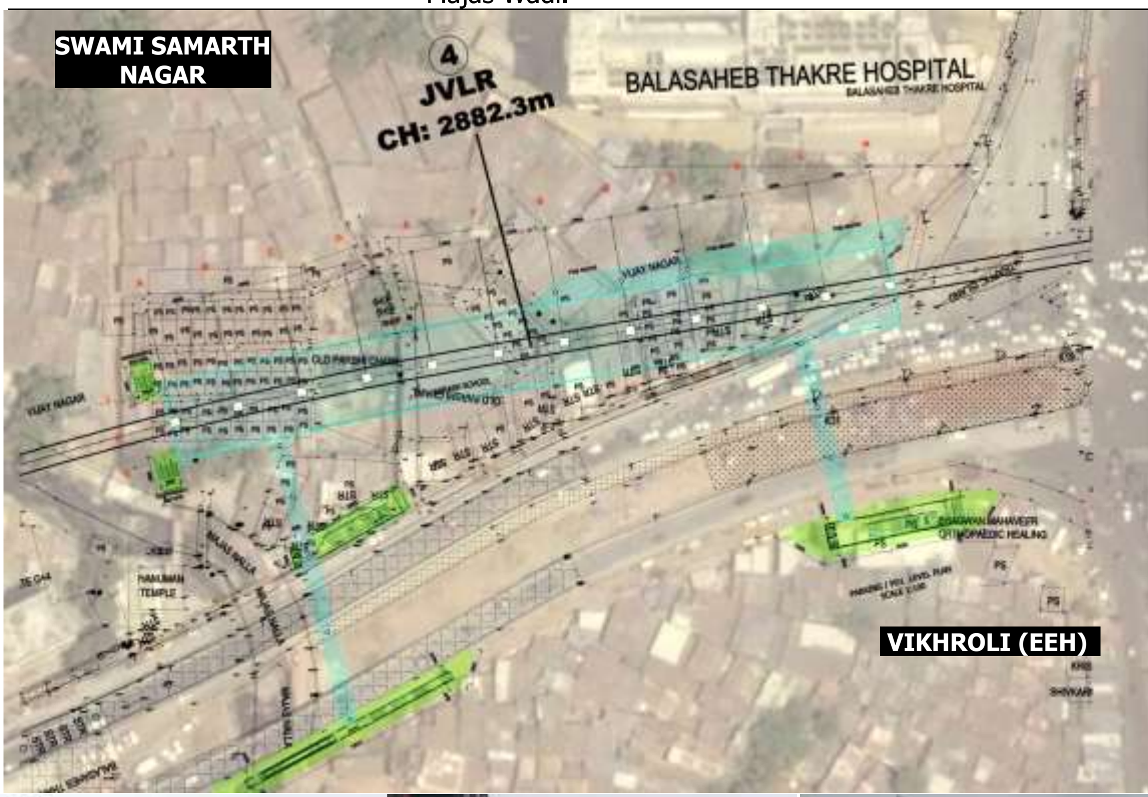

Site for tower block


School building adjacent to site


Flyover under construction

4. JVLR (INTERCHANGE WITH LINE 7)

Chainage	2882.3m
Inter-station Distance	1164.2m
Rail Level	17.391m
Platform Height from Ground	18.481m
Location	To the north of B Baug Road. Near intersection with Ai Yavar Jung Road.
Entry / Exit Stairs	Semi off road station, entry/exit on ground level itself as well as two structures on South side of B Baug Road
Catchment Area	Laxmi Nagar, Jogeshwari East, Jogeshwari Railway Station, Majas Wadi.



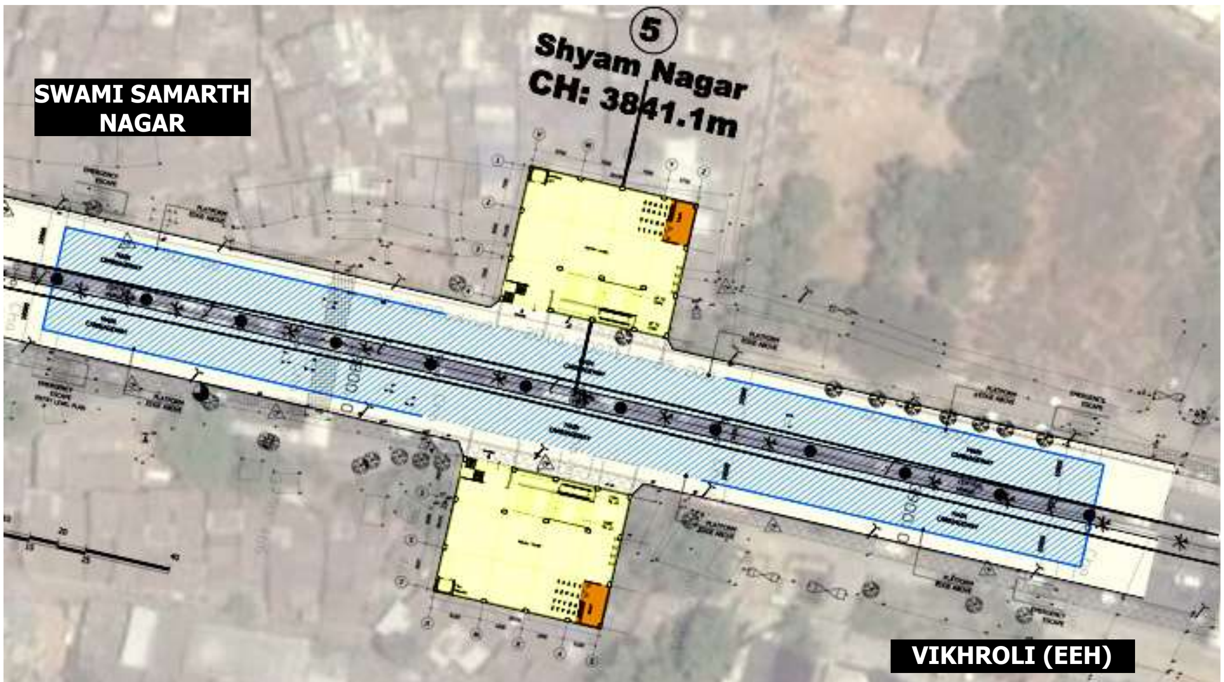

Existing Flyover.


Surroundings around Bala Saheb Thakre Hospital.


Existing Road along with site.

5. SHYAM NAGAR

Chainage	3844.0m
Inter-station Distance	961.7m
Rail Level	16.603m
Platform Height from Ground	17.693m
Location	JVLR road near Oberoi Splendor
Entry / Exit Stairs	Tower type station. Tower on acquired land on either side of the platform.
Catchment Area	Samarth Nagar, Anand Nagar, Squatters Colony, Majas Depot



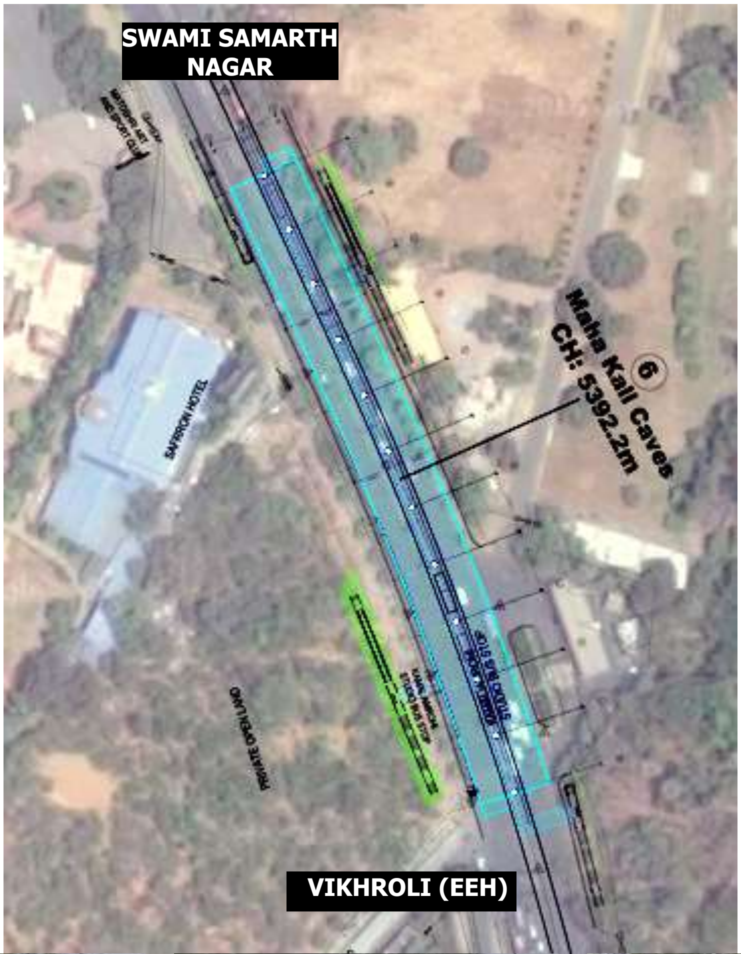

Existing foot over bridge


Station location to the north


Station location to the south

6. MAHAKALI CAVES

Chainage	5392.2m
Inter-station Distance	1548.2m
Rail Level	13.027m
Platform Height from Ground	14.117m
Location	On JVLR Road. Near Kamal Amrohi Studio.
Entry / Exit Stairs	Four structures, one at either corner of the station on the sidewalks.
Catchment Area	Kamal Amrohi Studio, Rup Nagar, Ganesh Nagar, Mahakali Caves




Existing footpath to the north


Existing footpath to the south


Road view from service lane

7. SEEPZ VILLAGE (INTERCHANGE WITH LINE 3)

Chainage	6515.0m
Inter-station Distance	1122.8m
Rail Level	21.246m
Platform Height from Ground	22.336m
Location	To the north of JVLR Road near SEEPZ Village
Entry / Exit Stairs	On the two northern ends the entry exit structures are located flanking the station.
Catchment Area	Rup Nagar, Ganesh Nagar, Customs Colony


Existing Buildings


Existing Road with Footpath


Existing Footpath

8. SAKI VIHAR ROAD

Chainage	7651.3m
Inter-station Distance	1136.3m
Rail Level	13.120m
Platform Height from Ground	14.210m
Location	To the north of JVLR Road
Entry / Exit Stairs	On four sides the entry exit structures are located flanking the station.
Catchment Area	L&T, Manohar Nagar, Savarkar Nagar, Raje Shivaji Nagar

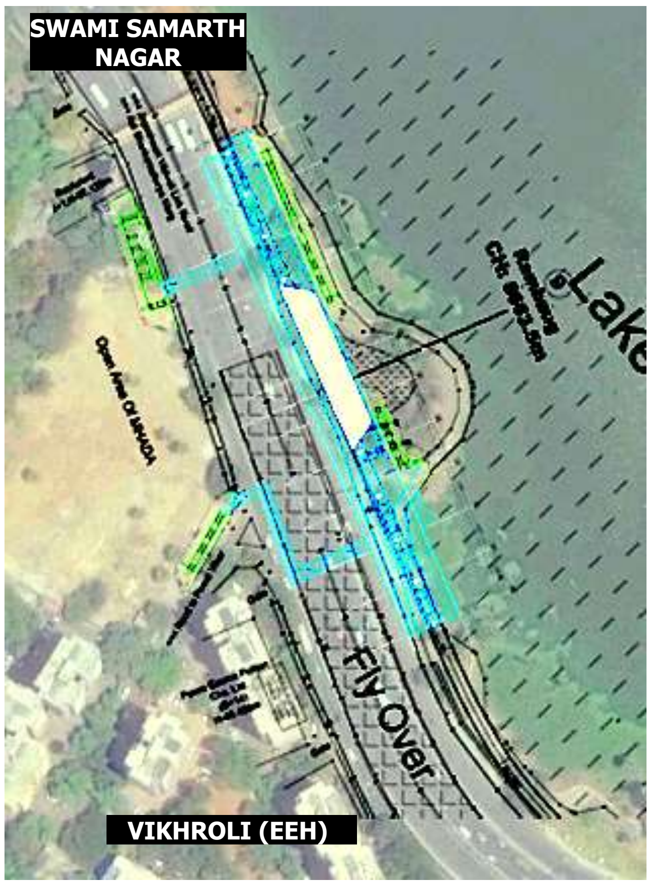

Existing Footpath to the North


Existing Road


Location for South Entry

9. RAMBAUG

Chainage	8663.5m
Inter-station Distance	1012.2
Rail Level	13.102m
Platform Height from Ground	14.192m
Location	To the north of JVLR Road near MTI Institute
Entry / Exit Stairs	On four sides the entry exit structures are located flanking the station.
Catchment Area	Savarkar Nagar, Raheja Vihar, MHADA Colony, Tunga Village



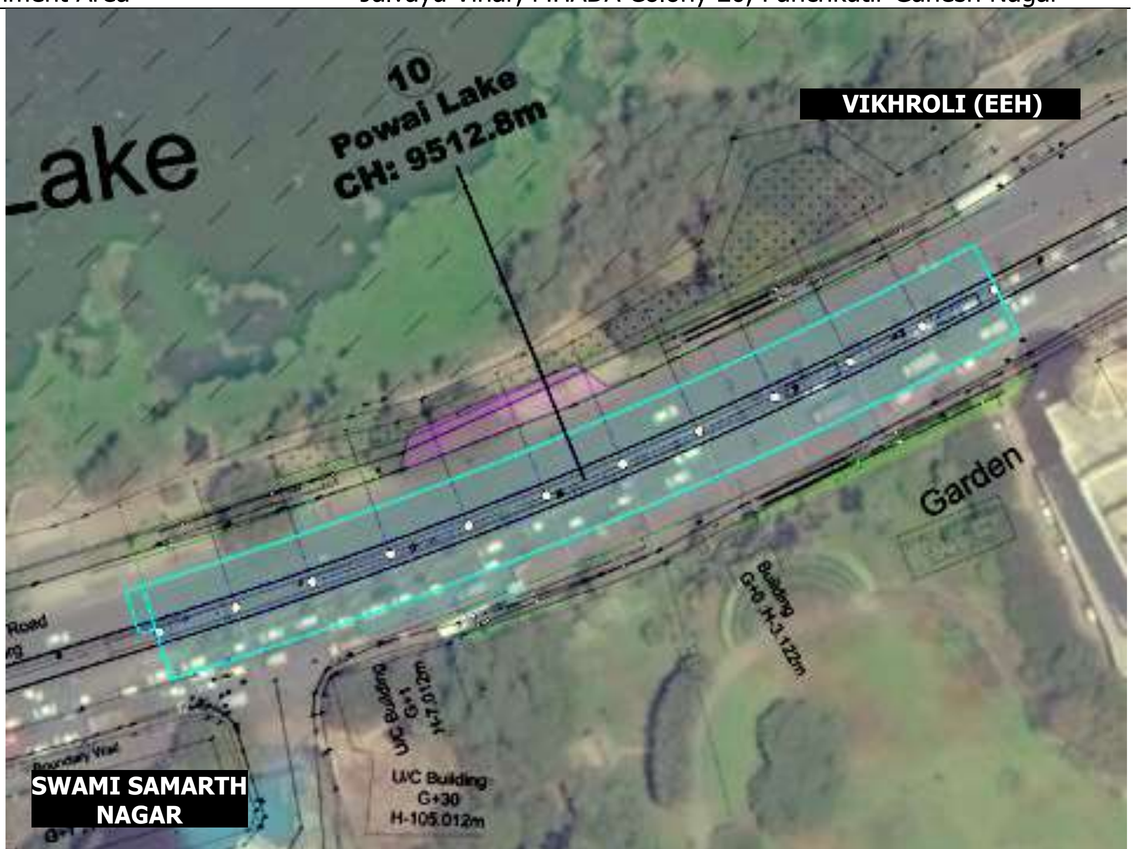

Exisitng building around.


Exisitng road with footpath.


Powai Lake side landscape area.

10. POWAI LAKE

Chainage	9512.8m
Inter-station Distance	849.3m
Rail Level	13.104m
Platform Height from Ground	14.194m
Location	On JVLR Road near Transocean House
Entry / Exit Stairs	On four sides the entry exit structures are located flanking the station.
Catchment Area	Jalvayu Vihar, MHADA Colony 20, Panchkutir Ganesh Nagar




Transocean House.


Existing building.


Landscaped area with lake.

11. IIT POWAI

Chainage	10577.2m
Inter-station Distance	1064.4m
Rail Level	13.101m
Platform Height from Ground	14.191m
Location	On JVLR Road near Powai Plaza & IIT Bombay
Entry / Exit Stairs	On four sides the entry exit structures are located flanking the station.
Catchment Area	IIT Bombay, BSNL Colony, Ramabai Ambedkar Nagar, Sainath Nagar, Jyotiba Phule Nagar

Existing road along with building.

Existing service road.

Powai Plaza building.

12. KANJUR MARG (W) (INTERCHANGE WITH LINE 4)

Chainage	12235.2m
Inter-station Distance	1658.0m
Rail Level	25.962m
Platform Height from Ground	27.052m
Location	On acquired private property off of Lal Bahadur Shastri Marg near Kanjur Marg Railway Station of Indian Railways
Entry / Exit Stair	Off Road Station, entry/exit on ground level itself.
Catchment Area	Kanjur Marg Railway Station, Kanjurmarg West, MMRDA Colony, Surya Nagar

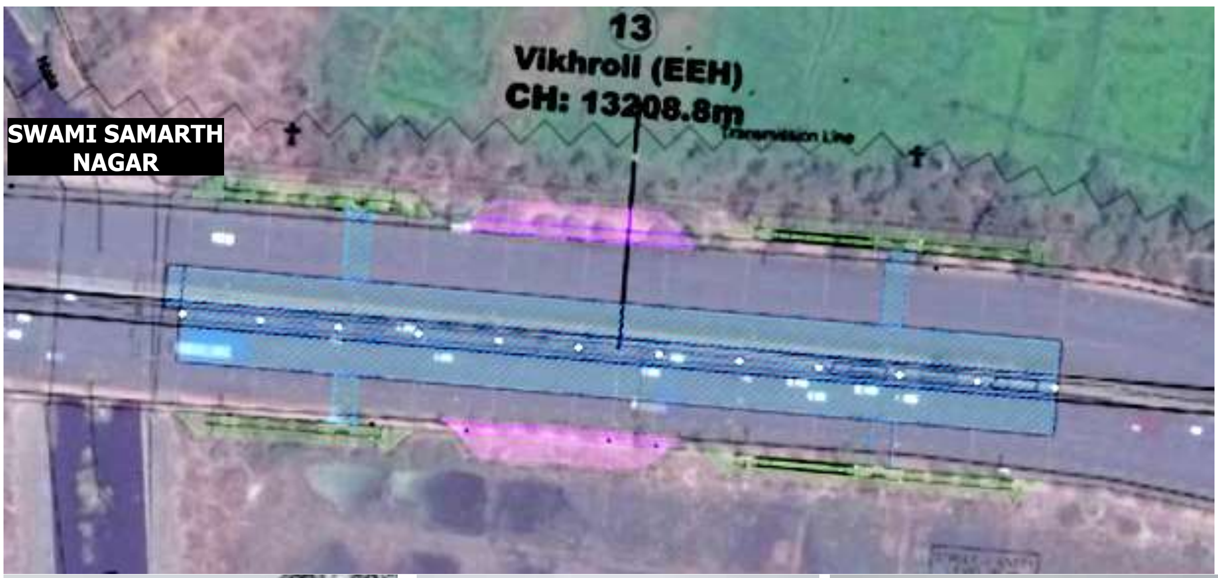

Site Surroundings.


Existing flyover with existing building.


Existing F.O.B and Railway Station.

13. VIKHROLI (EEH)

Chainage	13208.8m
Inter-station Distance	973.6m
Rail Level	14.304m
Platform Height from Ground	15.394m
Location	On JVLR Road (Median) near T junction with Eastern Express Highway
Entry / Exit Stairs	Four structures, one at either corner of the station on the sidewalks
Catchment Area	Nehru Nagar, Indira Nagar Jnc., Kannamwar Nagar II, Rajiv Gandhi Nagar



Existing F.O.B and buildings.

Existing Road.

Existing Nallah.

5.3 PLANNING AND DESIGN CRITERIA FOR STATIONS

Salient features of a typical station are as follows:

1. The stations 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 abnormal scenario.

3. The platform level 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 2-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 around 14.0-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 minimize 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.

10. The DG set, bore well pump houses and ground tank would be located generally in one area on ground under an entrance structure where possible. In the event of space not being available under entry structures, the DG Set & pump rooms have been planned on the median.

11. The system is being designed to maximize its attraction to potential passengers and the following criteria have been observed:

    - Minimum distance of travel to and from the platform.
    - 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 considered:

    - Minimum capital cost is incurred consistent with maximizing 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 minimize 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).

    A list of accommodation required in the non-public area at each station is given below:

Non-Public Area – Station Accommodation	
Station Control Room	Signaling Equipment Room
Excess Fare Collection (Passenger Office)	Ticket Operators Room

Station Master's Room	Staff Mess Room
Auxiliary Substation	Staff Locker Rooms
Switch Room / UPS Room	Security Room
Telecom Equipment Room	Fire Tank & Pump Room
UPS & Battery Room	DG Room

Typical Elevated Station - applicable to Swami Samarth Nagar, Mahakali Caves, Saki Vihar Road, Rambaug, Powai Lake, IIT Powai & Vikhroli (EEH)

The station is located either on the road median except in the case of Saki Vihar Road & Rambaug Stations where it is on the northern side verge. It is ~185m long and is a three-level structure. Passenger area on concourse is spread throughout the length 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 Room, UPS & Battery Room, Signaling Room, Telecom Room, ASS, Staff Mess & Toilets, etc. The public zone is further divided into paid and unpaid areas. Area left over in the unpaid zone, after accommodating passenger movement and other station facilities is earmarked for commercial utilization.

The advantages of having the concourse spread throughout the length of the station are:

a. Station can be made as narrow as 20 m, as equipment rooms can be placed along the length of concourse. This station prototype therefore is suitable for narrow streets.

b. Since the station is narrow, it is possible to make it a balanced cantilever structure supported on a single column, leaving the road underneath more flexible for present use as well as future expansion.

c. Construction is easier, less barricading and infringement with utilities

d. More opportunities for locating entrances as the station has a long surface area for articulating with surroundings, even at the ends, where skywalks can connect the station to street or adjoining properties

e. Long concourse provides opportunities for locating retail outlets along the movement path within the station

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 is about 7.5-m above the road. Consequently, platforms are at a level of about 14.1m from the road. To reduce physical and visual impact of the elevated station, stations have been made transparent with minimum walls on the sides.

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 modern and compatible with the lesser-built, low-rise developments along most 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 and sidewalls would be avoided, thereby enhancing the transparent character of the station building. In order to allow unhindered traffic movement below the stations, cantilevers across the road have been proposed in the concourse part, over which the station structure would rest. The station structure is supported on a single column, which lies unobtrusively on the central verge.

JVLR Station & SEEPZ Village

These stations are double elevated and have a higher rail level than the typical stations. This makes it possible to use the additional height and the same has been used to add an additional floor which has been earmarked for commercial development. The rest of the station is similar to the typical layout.

Jogeshwari (W) & Shyam Nagar (Tower Type Station)

In the case of Jogeshwari (W) & Shyam Nagar, the platform is planned on the road. However, due to proposed or existing flyovers at these locations, a concourse over the median is not feasible and therefore a tower type of station is proposed.

The platform will be 185m long and the station will be housed in a building adjacent to the alignment. For this purpose, land pockets of a size of 60m x 20m will need to be acquired. It will be a multilevel building depending upon the rail level of the station. Layout of the station is such that it provides a most direct and visually legible space. Consequently, the passenger flow is simple. Upon arrival at ground level from street, ticket gates are clearly visible. From here a bank of stairs and escalator takes passengers up vertically up to an FOB level from where separate paid and unpaid connections are provided to the tower / platform in the other direction. This level also has the AFC array, the public toilets in the paid area and stairs to the platforms. A large cut out is proposed in the middle of paid concourse which provides visual connectivity between the concourse and platform levels.

It is proposed that the tower structure is designed as an ultra-modern concrete form clad with glass. Structures that afford maximum transparency and are light looking have been envisaged.

The site earmarked for *Jogeshwari (W) Station* is to the north of the alignment and has the upcoming flyover between the tower block and the platforms. This results in the requirement of columns in the middle of the flyover for the FOBs. A minimum distance of 1.0m has been maintained between the existing school building and the south platform. Further increase in the distance is not possible due to the location of the platforms. The location of the tower block allows the possibility of getting a passenger entry at SV Road as well.

The location for *Shyam Nagar Station* is on top of a flyover but the height for a cross passage / FOB to connect the two platforms is not possible under the platforms due to the restrictions with the alignment. Therefore, the passage / connection in this case has been proposed above the platforms.

Platform roofs that can invariably make a structure look heavy; have been proposed to be of steel frame with aluminum cladding to achieve a light look. Platforms would be protected from the elements by providing an overhang of the roof and sidewalls would be avoided, thereby enhancing the transparent character of the station towers.

Kanjur Marg Station (interchange with line 4)

The station is off road, and the alignment here crosses line 4 which makes for a very rail level of ~25m. The station is~185m long and is a six-level structure. The building on the first four levels has been divided into a circulation zone and a commercial space. The fifth level is the concourse which is concentrated in a width of about 105-m in the middle of the station, with staircases leading up from the sides to the platform level. Passenger facilities like ticketing, information, etc as well as operational areas are provided at the concourse level. Additionally, ticketing has also been provided at the ground level. 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. A connection with the Kanjur Marg Railway station has been provided via an FOB connecting the concourse level of the MTR station to the platforms of the Indian Railways station.

A paid connection with the line 4 station is provided at the second PD level which is the same level as the concourse of the adjoining Line 4 station.

To reduce physical and visual impact of the elevated part of the station, it has been made narrow towards the ends.

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 closer to the site.

Platform roofs that can invariably make a structure look heavy; have been proposed to be of steel frame with aluminum cladding to achieve a light look. Platforms would be protected from the elements by providing an overhang of the roof and sidewalls would be avoided, thereby enhancing the transparent character of the station building. To allow ease of construction, portals 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.

5.4 PASSENGER AMENITIES

Passenger amenities such as ticketing counters / automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Uniform 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 2031 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*.

Concourse

Concourse forms the interface between street and platforms. 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 minimize 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.

Ticketing Gates

Ticketing gates' requirement has been calculated taking the gate capacity as 25 persons per minute per gate. Passenger forecast for the horizon year 2031 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.

Ticket Counters and Ticket Vending Machines (TVMs)

It is proposed to deploy manual ticket issuing in the beginning of the operation of the line. At a later stage, automatic TVMs 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 TVMs 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.

Platforms

A uniform platform width of ~5.35m wide (elevated stations) including staircases and escalators in the central section is proposed for the elevated stations. All platform widths have been checked for holding capacity of the platform for worst-case scenario (two missed headways) in the design year i.e. 2031.

Stairs, Escalators and Lifts for Normal and Emergency Operations

Provision has been made for escalators in the paid as well as entrance on both sides i.e. from ground to concourse and concourse to platforms. On each platform, two escalators have been proposed. In addition, four staircases with a combined width of 8.0 m are provided on each side platform connecting to the concourse. These stairs, escalators and the platform exits to viaduct together provide an escape capacity adequate to evacuate passengers in emergency from platforms to concourse in 5.5 minutes in most stations. Wherever, this is inadequate, additional emergency exit staircases are proposed. (see table SP2) 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 7.5-m, it is proposed to provide escalators and lifts in addition to stairs for vertical movement of passengers from street to concourse.

Passenger Information Kiosks and Commercial Kiosks

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

Summary of passenger amenities required and proposed at stations based on projected traffic for the year 2031 is given in Table SP2.

Table SP2 PASSENGER AMENITY REQUIREMENT IN STATIONS
(Projections for Year 2031)

Corridor Swami Samarth Nagar to Vikhroli (EEH) - Figures for 2031					
No.	Name of the Station	Ticketing Counters (#'s)	AFC's (#'s)	Max Required Platform Width (m)	Additional Emergency Stair (m)
1	Swami Samarth Nagar	8	18	5.36	1.80
2	Adarsh Nagar	2	3	2.93	0.00
3	Jogeshwari (W)	2	5	2.74	0.00
4	JVLR	10	18	5.60	2.40
5	Shyam Nagar	5	5	3.01	0.00
6	Mahakali Caves	2	2	3.49	0.00
7	SEEPZ Village	4	4	3.78	0.00
8	Saki Vihar Road	2	3	3.46	0.00
9	Rambaug	1	2	3.38	0.00
10	Powai Lake	1	2	3.38	0.00
11	IIT Powai	4	8	4.25	0.00
12	Kanjur Marg (W)	15	26	6.93	6.00
13	Vikhroli (EEH)	3	7	2.40	0.00

Table SP3 PASSENGER AMENITY PLANNED PROVISIONS IN STATIONS

Corridor Swami Samarth Nagar to Vikhroli (EEH)									
No.	Name of the Station	Ticketing Counters (#'s)	AFC's (#'s)	Platform Width (m)	Additional Emergency Stair (m)	Lift Ground to Conc	Lift Conc to Plat	Esc Ground to Conc	Esc Conc to Plat
01	Swami Samarth Nagar	11	20	5.38	2.00	2	2	2	4
02	Adarsh Nagar	4	10	5.38	0.00	1	2	1	4
03	Jogeshwari (W)	4	20	4.50	2.00	1	2	2	1
04	JVLR	11	20	5.83	2.40	2	2	4	4
05	Shyam Nagar	8	16	4.50	2.00	2	2	2	2
06	Mahakali Caves	11	20	5.38	0.00	2	2	3	4
07	SEEPZ Village	11	20	5.83	0.00	2	2	2	4
08	Saki Vihar Road	11	20	5.38	0.00	2	2	2	4
09	Rambaug	11	20	5.38	0.00	2	2	2	4
10	Powai Lake	11	20	5.38	0.00	2	2	2	4
11	IIT Powai	11	20	5.38	0.00	2	2	2	4
12	Kanjur Marg (W)	16	26	7.00	6.00	3	4	4	2
13	Vikhroli (EEH)	11	20	5.38	0.00	1	2	2	4

Traffic Integration

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 functions 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.
- 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.

Approach Adopted in Planning Traffic Integration Facilities

Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate circulation areas for various modes likely to come to important stations including feeder bus/mini-buses. Parking for private vehicles has not been proposed.

Operational Integration

Integration at operational level will be required to synchronize 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 minimized. 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.

Chapter - 6

TRAIN OPERATION PLAN

6.1 OPERATION PHILOSOPHY

The underlying operation philosophy is to make the Metro 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, but also during off-peak period.
- Multi-tasking of train operation and maintenance staff.

6.2 STATIONS

Details of stations for Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH) Corridor) are given below:

Details of Stations

S. No	Station Name	Chainage (m)	Inter Distance Between Two Stations.
	DEAD END	-822.5	
1	Swami Samarth Nagar	0.0	822.5
2	Adarsh Nagar	728.8	728.8
3	Jogeshwari(W)	1717.9	989.1
4	JVLR	2877.7	1159.8
5	Shyam Nagar	3839.6	961.9
6	Maha Kali Caves	5387.4	1547.8
7	SEEPZ Village	6510.3	1122.9
8	Saki Vihar Road	7646.6	1136.3
9	Rambaug	8658.9	1012.3
10	Powai Lake	9508.2	849.3
11	IIT, Powai	10572.6	1064.4
12	Kanjur Marg (W)	12230.6	1658.0
13	Vikhroli (EEH)	13204.2	973.6
	DEAD END	13654.2	450.0

6.3 TRAIN OPERATION PLAN

6.3.1 Salient Features

- 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 for this corridor has been taken as 35 Kmph.

6.3.2 Traffic Demand

Peak hour peak direction traffic demands (PHPDT) for the Swami Samarth Nagar to Vikhroli (EEH) Corridor for the year 2021 and 2031 for the purpose of planning are indicated in Attachment I/A & I/B respectively and has been taken as the maximum of the PHPDT in the forward & reverse directions.

6.3.3 Train Formation

To meet the above projected traffic demand, the possibility of running trains with composition of 6 Car trains with different headways have been examined.

The following train formation has been chosen:

- **Composition**

DMC	: Driving Motor Car
MC	: Motor Car
TC	: Trailer Car
6-car train composition	: DMC+TC+MC+ MC+TC+DMC (67% Powering) Or DTC+MC+MC+MC+MC+DTC (67% Powering)

- **Capacity@ 6 passengers per square meter of standee area**

DMC	: 282 passengers (Sitting-42, Standing-240)
MC	: 298 passengers (Sitting-50, Standing-248)
TC	: 298 passengers (Sitting-50, Standing-248)
6 Car Train	: 1756 Passengers (Sitting-284, Standing-1472)

6.3.4 Train Operation Plan

Based on the projected PHPDT demand, train operation has been planned for Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH) Corridor) for the year 2021 and 2031 as detailed below:

Train operation plan for (Swami Samarth Nagar to Vikhroli (EEH) Corridor) with train carrying **capacity @ 6 persons per square meter of standee area** on Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH) Corridor) is given below:

- **Year 2021** (Refer **Attachment I /A**)

Train operation with **6 car Trains** with headway of **4.25 min** between Swami Samarth Nagar to Vikhroli (EEH) Corridor is planned in the first year of operation i.e. **2021** with Peak Hour Peak Direction Capacity of 24791 @ **6 persons per square**

meter of standee area (Capacity of 31680 @ 8 persons per square meter of standee area under dense loading conditions).

- **Year 2031** (Refer **Attachment I/B**)

Train operation with **6 car Trains** with headway of **3.5 min** between Swami Samarth Nagar to Vikhroli (EEH) Corridor is planned in the year **2031** with Peak Hour Peak Direction Capacity of 30103 @ **6 persons per square meter of standee area (Capacity of 38469 @ 8 persons per square meter of standee area under dense loading conditions)**.

The PHPDT capacity provided on this corridor in different years of operation is given below:

PHPDT Capacity Provided

	2021	2031
Cars/trains	6	6
Head way (Minutes)	4.25	3.50
Max. PHPDT Demand	24714	29657
PHPDT Capacity Available	24791* (31680**)	30103* (38469**)

* @ 6 persons per square meter of standee area
** @ 8 persons per square meter of standee area

6.3.4 Train Frequency

Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH) Corridor)

The train operation plan provides for headway of 4.25 & 3.50 minutes in the year 2021 & 2031 respectively during the peak period. No train operation is planned during the maintenance period.

Directional split of 50:50 has been maintained between trains running in either direction and enclosed as **Attachment-III**

6.3.5 Hourly Train Operation Plan

The hourly distribution of daily transport capacity is presented in **Table 1.1 & 1.2** for years 2021 & 2031 and enclosed as **Attachment II.**

6.3.6 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers Swami Samarth Nagar to Vikhroli (EEH) Corridor is given in **Table 3** and enclosed as **Attachment IV**.

6.3.7 Year-wise Rake Requirement

Based on Train formation and headway as decided above to meet Peak Hour Peak Direction Traffic Demand, Rake requirement has been calculated and enclosed as **Attachment V** & has been tabulated below :

Year wise Rake requirement

Corridor	Year	Headway (min)	No. of Rakes	No. of car per rake	No. of Coaches
Swami Samarth Nagar to Vikhroli (EEH)	2021	4.25	16	6	96
	2031	3.50	18		108

Requirement of coaches is calculated based on following assumptions:-

Assumptions -

(i) Train Composition planned as under:
6 Car Train Compositions : DMC+TC+MC+ MC+TC+DMC

Train Carrying Capacity of 6 Car
Train@6 person per square meter : 1756 passengers
Train@8 person per square meter : 2244 passengers

(ii) Coach requirement has been calculated based on headway during peak hours.

(iii) Traffic reserve is taken as one trains to cater to failure of train on line and to make up for operational time lost.

(iv) Repair and maintenance reserve has been estimated as 10 % of total requirement (Bare +Traffic Reserve).

(v) The calculated number of rakes in fraction is rounded off to next higher number.

(vi) Schedule speed is taken as 35 KMPH.

(vii) Total Turn Round time is taken as 6 min at terminal stations.

6.4 ROLLING STOCK (Technical data)

Numbers of cars : 6
Composition : DMC+TC+MC+MC+TC+DMC (67% Powering)
Or DTC+MC+MC+MC+MC+DTC (67% Powering)
Power System [Kv/Hz] : 25 KV AC
Acceleration[m/s^2] : 1.0 @ AW3
: 1.2 @ AW2
Deceleration[m/s^2] : 1.0 @ AW3
: 1.1 @ AW2
Emergency Braking [m/s^2] : 1.3
Maximum Design speed[kmph] : 90
Track Gauge[mm] : 1435
Width over body of rolling Stock[mm]: 3200

The Salient features of Broad Gauge Rolling Stock are enclosed as Attachment-VI.

6.5 COST ESTIMATE

The estimated cost per car at July' 2016 Price level (exclusive of taxes and duties) may be assumed as Rs. 10 Crores per car. Total 16 rakes (96 cars) would be required in horizon year 2021 for Mumbai Metro (Swami Samarth Nagar to Vikhroli (EEH) Corridor). Accordingly budget provision of INR 960 Crores(excluding taxes and duties) is to be kept in the estimate for Rolling Stock, with revenue operation targeted for year 2021.

6.6 RECOMMENDATION

TOP chapter has been prepared considering 6-car train with 67% motoring. Trains with 6 car train consist (with 67% powering cars) operating @ 90 seconds headway can achieve PHPDT of approximately 72,000 with loading of 6 Passengers per sq m. The traffic projections do not suggest such requirements. However, for higher PHPDT requirements in future (upto approximately 96,000 @ average train capacity of 2400 passengers with 62% motoring), the train consist of 8 cars (addition of one 'T+M' Unit) can be adopted in future. In case such scenario is envisaged, platform lengths shall be planned for 8 car trains. Also, it is recommended that 3.2 m wide stock, suitable for SG may be adopted.

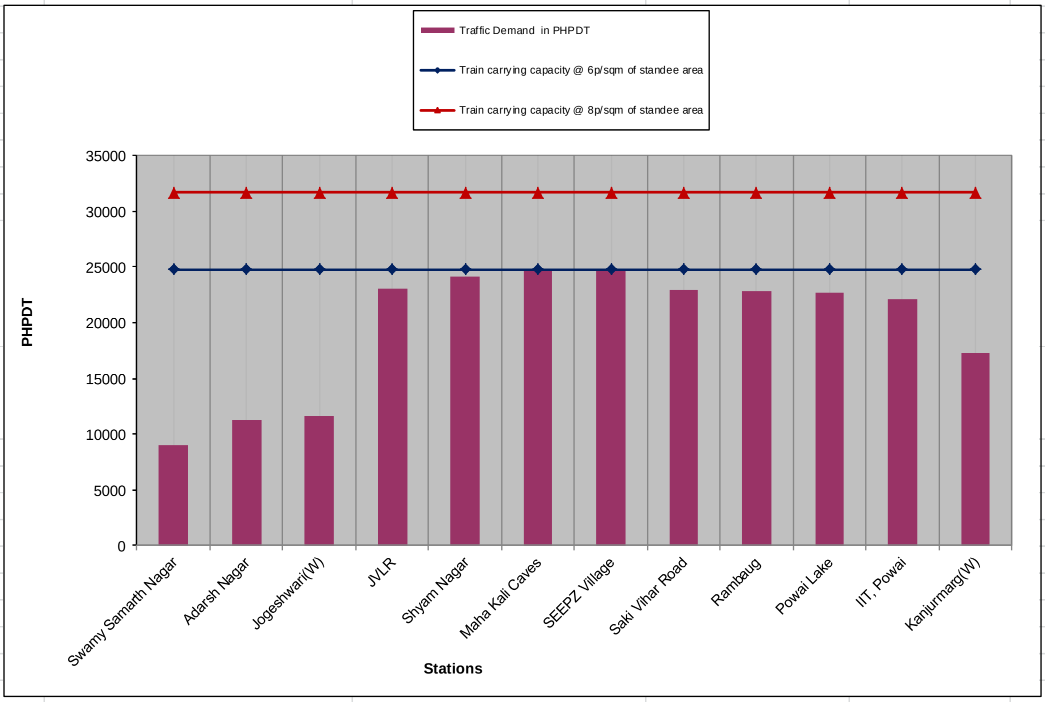
Attachment - I/A

PHPDT Demand and Capacity Chart

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

Year:	**2021**
No. of cars per train	**6**
Passenger Capacity @ 6 persons/sqm of a 6-Car Train:	**1756**
Passenger Capacity @ 8 persons/sqm of a 6-Car Train:	**2244**
Headway (min)	**4.25**

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Swamy Samarth Nagar	Adarsh Nagar	8963	24,791	31,680
2	Adarsh Nagar	Jogeshwari(W)	11,297	24,791	31,680
3	Jogeshwari(W)	JVLR	11,608	24,791	31,680
4	JVLR	Shyam Nagar	23,026	24,791	31,680
5	Shyam Nagar	Maha Kali Caves	24,153	24,791	31,680
6	Maha Kali Caves	SEEPZ Village	**24,714**	24,791	31,680
7	SEEPZ Village	Saki Vihar Road	24,633	24,791	31,680
8	Saki Vihar Road	Rambaug	22,889	24,791	31,680
9	Rambaug	Powai Lake	22,868	24,791	31,680
10	Powai Lake	IIT, Powai	22,653	24,791	31,680
11	IIT, Powai	Kanjurmarg(W)	22,081	24,791	31,680
12	Kanjurmarg(W)	Vikhroli(EEH)	17,247	24,791	31,680



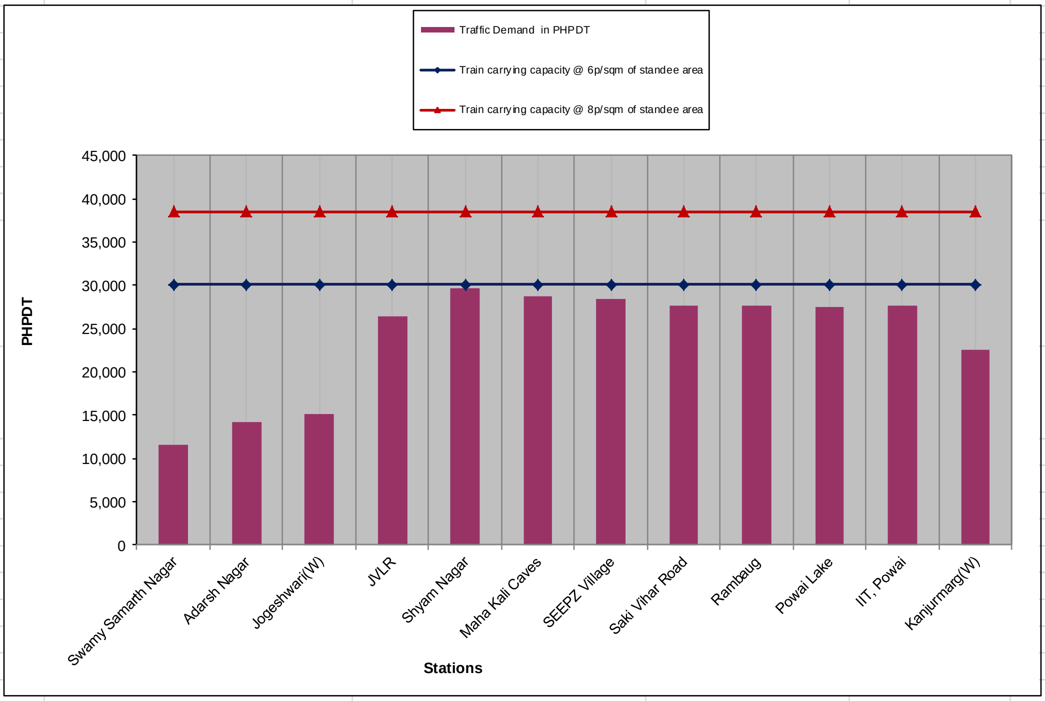
Attachment - I/B

PHPDT Demand and Capacity Chart

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

Year:	**2031**
No. of cars per train	**6**
Passenger Capacity @ 6 persons/sqm of a 6-Car Train:	**1756**
Passenger Capacity @ 8 persons/sqm of a 6-Car Train:	**2244**
Headway (min)	**3.50**

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Swamy Samarth Nagar	Adarsh Nagar	11,493	30,103	38,469
2	Adarsh Nagar	Jogeshwari(W)	14,221	30,103	38,469
3	Jogeshwari(W)	JVLR	15,194	30,103	38,469
4	JVLR	Shyam Nagar	26,387	30,103	38,469
5	Shyam Nagar	Maha Kali Caves	**29,657**	30,103	38,469
6	Maha Kali Caves	SEEPZ Village	28,688	30,103	38,469
7	SEEPZ Village	Saki Vihar Road	28,440	30,103	38,469
8	Saki Vihar Road	Rambaug	27,699	30,103	38,469
9	Rambaug	Powai Lake	27,678	30,103	38,469
10	Powai Lake	IIT, Powai	27,425	30,103	38,469
11	IIT, Powai	Kanjurmarg(W)	27,662	30,103	38,469
12	Kanjurmarg(W)	Vikhroli(EEH)	22,531	30,103	38,469



Attachment- II

TABLE 1.1

Hourly Train Operation Plan

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

Year- 2021

4.25 min Headway

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	16	4	4
6 to 7	12	5	5
7 to 8	6	10	10
8 to 9	**4.25**	**14**	**14**
9 to 10	**4.25**	**14**	**14**
10 to 11	**4.25**	**14**	**14**
11 to12	6	10	10
12 to 13	12	5	5
13 to 14	16	3	3
14 to 15	16	4	4
15 to 16	12	5	5
16 to 17	6	10	10
17 to 18	**4.25**	**15**	**15**
18 to 19	**4.25**	**14**	**14**
19 to 20	**4.25**	**15**	**15**
20 to 21	6	10	10
21 to 22	12	5	5
22 to 23	16	3	3
23 to 24	20	3	3
Total No. of train trips per direction per day		**163**	**163**

TABLE 1.2

Hourly Train Operation Plan

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

Year- 2031

3.5 min 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	**3.5**	**17**	**17**
9 to 10	**3.5**	**17**	**17**
10 to 11	**3.5**	**17**	**17**
11 to12	5	12	12
12 to 13	10	6	6
13 to 14	12	5	5
14 to 15	12	5	5
15 to 16	10	6	6
16 to 17	5	12	12
17 to 18	**3.5**	**18**	**18**
18 to 19	**3.5**	**17**	**17**
19 to 20	**3.5**	**18**	**18**
20 to 21	5	12	12
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
Total No. of train trips per direction per day		**200**	**200**

Attachment III

TABLE 2

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

PHPDT for the year 2021

S.No	From Station	To Station	Peak hour Load	Directional Split to Lokhandwala	Directional Split to Kanjurmarg (Nehru Nagar)
1	Swamy Samarth Nagar	Adarsh Nagar	8963	50%	50%
2	Adarsh Nagar	Jogeshwari(W)	11,297	50%	50%
3	Jogeshwari(W)	JVLR	11,608	50%	50%
4	JVLR	Shyam Nagar	23,026	50%	50%
5	Shyam Nagar	Maha Kali Caves	24,153	50%	50%
6	Maha Kali Caves	SEEPZ Village	**24,714**	50%	50%
7	SEEPZ Village	Saki Vihar Road	24,633	50%	50%
8	Saki Vihar Road	Rambaug	22,889	50%	50%
9	Rambaug	Powai Lake	22,868	50%	50%
10	Powai Lake	IIT, Powai	22,653	50%	50%
11	IIT, Powai	Kanjurmarg(W)	22,081	50%	50%
12	Kanjurmarg(W)	Vikhroli(EEH)	17,247	50%	50%

Attachment IV

TABLE 3

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)

Vehicle Kilometer

Year	2021	2031
Section Length	14.04	14.04
No of cars per train	6	6
No of working Days in a year	340	340
Number of Trains per day each Way	163	200
Daily Train -KM	4578	5617
Annual Train - KM (10^5)	15.57	19.10
Annual Vehicle - KM (10^5)	93.39	114.59

Attachment-V

Rake requirement

Year-2021

S. No.	Section	Length (km)	Schedule speed (kmph)	Year	Headway (min)	Run time (min)	Turn round time (min)	Any other time to be considered* (min)	Total round time+any other time	Total round trip time (min)	Rake Requirement					Total cars
											Bare	Bare	Traffic Reserve	R&M	Total No. Of Rakes(6-car configuration)	
1	Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)	14.04	35	2021	4.25	24.07	3	0	6	54.14	12.74	13	1	2	16	**96**

Year-2031

S. No.	Section	Length (km)	Schedule speed (kmph)	Year	Headway (min)	Run time (min)	Turn round time (min)	Any other time to be considered* (min)	Total round time+any other time	Total round trip time (min)	Rake Requirement					Total cars
											Bare	Bare	Traffic Reserve	R&M	Total No. Of Rakes(6-car configuration)	
1	Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor)	14.04	35	2031	3.50	24.07	3	0	6	54.14	15.47	15	1	2	18	**108**

NOTE Repair & Maintenance Reserve as a percentage of total requirement (Bare + Traffic Reserve) 10%

SUMMARY SHEET AS ON: 26.08.16

Mumbai METRO Swamy Samarth Nagar to Vikhroli (EEH)

1 Corridor: Swamy Samarth Nagar to Vikhroli (EEH)

2 Route Length(Centre to Centre) :

Swamy Samarth Nagar to Vikhroli (EEH) : 13.204km (Avg. Interstation distance:1.100km)

3 Number of Stations:

Swamy Samarth Nagar to Vikhroli (EEH) 13

4 Gauge: 1435 mm (Standard Gauge)

5 Traction Power Supply

i) Voltage: 25 KV A.C.

ii) Current Collection: Overhead Current Collection System

6 Train Operation Plan

i) Composition : :6 Cars= DMC+TC+MC+MC+TC+DMC (67% powering)
or DTC+MC+MC+MC+MC+DTC (67% powering)

ii) Schedule Speed:
Swamy Samarth Nagar to Vikhroli (EEH) : 35 kmph

iii) Capacity Provided & Rake Requirement:

YEAR	***2021***	***2031***
HEADWAY	4.25	3.5
CARS/TRAIN	6	6
Max.PHPDT Demand	24714	29657
PHPTD Capacity	24791*	30103*
@6persons per sqm	31680**	38469**
Rakes Reqd	16	18
Cars Reqd	96	108

* @6 persons per square meter of standee area.
**@8 persons per square meter of standee area.

7 Rolling Stock:

i) Coach Size:

Particular	***Length****	***Width***	***Height***
Driving Motor Car (DMC)/Driving Trailer Car	21.84m	3.2 m	3.9 m
Trailer Car (TC)/MC	21.74m	3.2 m	3.9 m

**Maximum length of coach over couplers/buffers:22 to 22.6m (depending upon Kinematic Envelop)*

ii) Passenger Carrying Capacity

PARTICULAR	**Crush @ 6 passenger/sqm of standee area)**			**Crush @ 8 passenger/sqm of standee area)**		
	SEATED	**STANDING**	**TOTAL**	**SEATED**	**STANDING**	**TOTAL**
DMC	42	240	282	42	320	362
TC/MC	50	248	298	50	330	380
6-CAR	284	1472	1756	284	1960	2244

Seating: Longitudinal

iii) Weight: (Crush @ 6 passenger/sqm of standee area)

PARTICULAR	**TARE**	**PASSENGER**	**GROSS**
DMC	42	18	60
TC	41.5	19	60.5
MC	42	19	61
6-CAR	251	112	363

iv) Axle Load: To be designed for 17T

v) Max Acceleration: 1m/s/s @ AW3.
: 1.2m/s/s @ AW2

vi) Max Deceleration: 1.0m/s/s @ AW3
: 1.1m/s/s @ AW2
≥ 1.3m/s/s(Emergency)

8 Cost per car: INR 10 Crores exclusive of taxes and duties at July' 2016 Price Level (Cost Estimate enclosed)

9 All Infrastructure and maintenance facilities to be planned for 8 -Car trains.Seperate depot is Proposed at Kanjur Marg.

10 Salient features of Rolling stock is enclosed (Attachment-VI of TOP)

Chapter - 7

MAINTENANCE DEPOT

7.1 Corridor: Swami Samarth Nagar to Vikhroli (EEH) Corridor comprises as below:

Corridor	Route length (Km)
Swami Samarth Nagar to Vikhroli (EEH)	14.477

7.2 Depot- cum- Workshop at Kanjur Marg

7.2.1 It is proposed to establish one depot- cum- workshop with following functions:

(i) Major overhauls of all the trains.
(ii) All minor schedules and repairs.
(iii) Lifting for replacement of heavy equipment and testing thereafter.
(iv) Repair of heavy equipments.

7.2.2 The Depot planning is based on following assumptions:

(i) Enough space should be available for establishment of a Depot- Cum- workshop.
(ii) All inspection lines, workshop lines, stabling lines are designed to accommodate one train set of 8- Car each and space earmarked for future provision.
(iii) All Stabling lines are designed to accommodate one trains of 8- Car each.
(iv) Stabling lines are planned in the proposed depot-cum-workshop assuming adequate space availability. In case of space constraints, if any, stabling facilities may need to be created at terminal stations or elsewhere.

In broad terms, based on the planned Rolling Stock requirements, this chapter covers conceptual requirements on following aspects and will work as a guide for detailed design later:

- Layout of Stabling-shed, Inspection-shed, minor repairs and heavy repair overhauling workshop 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.

7.3 MAINTENANCE PHILOSOPHY

- 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 daily check, “A” checks, “B” type checks, "IOH" and "POH". Labour intensive procedures are kept to the minimum. 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 is given due attention.

7.4 ROLLING STOCK MAINTENANCE NEEDS

7.4.1 Maintenance Schedule

The following maintenance schedule has been envisaged for conceptual design of depots assuming approx. 352 kms running per train per day, taking in consideration the passenger load of 2021 & 2031 respectively.

Type of Schedule	Interval	Work Content	Locations
Daily	Daily	Check on the train condition and function at every daily service completion. Interval cleaning/mopping of floor and walls with vacuum cleaner.	Stabling Lines
"A" Service Check	5,000 Km (approx. 15 days)	Detailed inspection and testing of sub - systems, under frame, replacement/ topping up of oils & lubricants.	Inspection Bays
"B" Service Check	15,000 Km (approx. 45 days)	Detailed Inspection of 'A' type tasks plus items at multiples of 15,000 Km ('B' type tasks)	Inspection Bays
Intermediate Overhaul (IOH)	420,000 Km, (3 and half Years approx.) whichever is earlier	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, Compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
Periodical Overhaul (POH)	840,000 Km, (7 Years approx.) whichever is earlier	Dismantling of all sub-assemblies, bogies suspension system, traction motor, gear, control equipment, air-conditioning units etc. Overhauling to bring them to original condition. Checking repair and replacement as necessary. Inspection and trial.	Workshop
Heavy Repairs	-	Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

The above Schedule may need slight revision based on the actual earned kilometers per train and the specific maintenance requirements of Rolling Stock finally procured.

7.4.2 Washing Needs of Rolling Stock

Cleanliness of the trains is essential. Following schedules are recommended for Indian environment:

S. No.	Kind Inspection	Maint. Cycle	Time	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 of cars and roof. Manually)	30 days	2 – 3 hrs.	Automatic washing plant & cleaning & washing shed

7.5 Year-wise planning of maintenance facility setup at depot cum workshop based on planned Rolling Stock requirement in TOP is tabulated below:

(i) Planned rakes as per TOP:

Year	No. of Rakes	No. of coaches
2021	16	96
2031	18	108

ii) Requirement of Stabling Lines (SBL), Inspection Lines (IBL) and Workshop Lines (WSL) in the Depot -cum -Workshop. Stabling, Inspection and Workshop lines:

Year	No. of Rakes	SBLs	IBLs	WSLs
2021	16	11 lines x one train of 8-car length	-One bay of 3 lines with one train of 8- car length. -One bay is required from the year 2021 and catering up to year 2031.	-Two bays of 2 lines each with one train of 8- car length. -All the two bays are required from year 2021 and catering up to year 2031.
2031	18	13 lines x one train of 8-car length		

7.6 Requirement of maintenance/Inspection lines for depot-cum-workshop:

i) Year 2021 - Maximum no. of rake holding is 16 TS x6 (= 96 Cars)		
'A' Checks (5000 km) approx. 15 days	(16X6) Cars = 96 Cars	1 Line x one train of 8- Cars (with Sunken Floor)
'B' Checks (15000 km) approx. 45 days.	(16X6) Cars = 96 Cars	1 Line x one train of 8- Cars (with Sunken Floor)

Unscheduled line & adjustment lines	For minor repairs, testing and after IOH/POH adjustments	1 Line x one train of 8- Cars (with Sunken Floor)
Requirement		One bay of 3 lines, each of 8- car train length. One bay is required from the year 2021 and catering up to year 2031.
ii) Year 2031 -Maximum no. of rake holding is (18 x6 = 108 Cars)		
'A' Checks (5000 km) 15 days	(18 X 6) Cars = 108 Cars	1 Line x one train of 8- Cars (with Sunken Floor)
'B' Checks (15000 km) 45 days	(18 X 6) Cars = 108 Cars	1 Line x one train of 8- Cars (with Sunken Floor)
Unscheduled line & adjustment lines	For minor repairs, testing and after IOH/POH adjustments	1 Line x one train of 8- Cars (with Sunken Floor)
Requirement		One bay of 3 lines, each of 8- car train length. One bay is required from the year 2021 and catering up to year 2031.

7.7 INSPECTION REQUIREMENTS AT DEPOT

Facilities for carrying out inspection activities shall be provided in the inspection bay for following Systems / Equipments of a train:

- Electronics; PA/PIS
- Mechanical components, couplers etc.
- Batteries
- Air conditioner
- Brake modules
- Bogie
- Traction Motor
- Vehicle doors, windows and internal fittings
- Power system including converter, circuit breaker etc.
- Diagnostic data downloading facilities from TCMS and other sub-systems

These activities shall be grouped into "A" checks and "B" checks. The minor scheduled inspections ("A" checks) shall be carried out during the day off peak and night. Since "B" checks take longer time, these cannot be completed in the off peak times. Certain inspection lines will be nominated for "A" checks. For "B" checks, separate line will be nominated where the rakes may be kept for long time.

7.8 DESIGN OF DEPOT- CUM- WORKSHOP FACILITIES

7.8.1 Stabling lines at depot

As per advised dimensions of the Rolling Stock, the length of 8- Car train would be Approx. 184 mts. For the design of the stabling lines in the depot and terminal stations or elsewhere (as may be required), following approximates lengths have been taken in consideration:

(i) Length of one 8- Car rake= 184 m
(ii) Pathway in the entry side=11m
(iii) Free length at outer ends (for cross pathway, Signal and Friction buffers)= 11m
(iv) Total length of Stabling lines = 11+184+11= 206 m approx.

With car width of 3200 mm on SG, 5.3 m "Track Centre" is proposed for all the stabling lines. Thus, space between stabling shall be sufficient to include 1 m wide pathway to be constructed between tracks to provide access for internal train cleaning and undercarriage inspection with provision of following facilities:

a) Each Stabling line to have water connection facility so that local cleaning, if required, is facilitated.
b) Platforms at suitable points at each end of stabling lines to enable train operators to board or de- board conveniently.
c) Room for contractor cleaning staff with toilet facility.

7.8.2 Inspection Bay at depot-cum-workshop

The length of Inspection shed is computed as below:

(i) Length of one 8- Car rake=184 m
(ii) Pathway in the entry side = 11 m
(iii) Free length at outer ends (for cross pathway, Signal and Friction buffers)= 11m
(iv) Total length of Inspection lines = 11+184+11= 206m approx.

The width of the Inspection bay in computed as below:

(i) Centre – to- centre spacing between the lines= 6.25 m
(ii) Centre line of outer lines to column of Shed= 4.5 m
(iii) Width of a 3 line Inspection Bay= 4.5+ 6.25+6.25+4.5= 21.5 meter

a) One inspection bays(one inspection bay of 206 m X 21.5 m size) with provision of accommodating three inspection lines, each having sunken floor and overhead roof inspection platforms at each of the line would be required. The floor will be sunken by 1100mm. The track spacing between the adjacent IBLs shall be 6.25 m.

b) Roof Inspection platforms of 1.2m width and walkways for roof inspection supported on the columns shall be provided. There would be lighting below the rail level to facilitate the under frame inspection. Ramps of 1:8 slopes, 3 meter wide should be provided with sunken floor system for movement of material for the cars. Further, 10m cross pathways are left at each end for movement of material by fork lifter/Leister/Hand trolley. 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. Air-circulators shall be provided on each column. The inspection bay shall be provided with EOT crane of 1.5 T to facilitate lifting of equipment.

Roof and walls shall be of such design that optimum natural air ventilation occurs all the time and sufficient natural light is also available. Each Inspection bay will also have arrangement close by for cleaning of HVAC filter under high pressure water jet.

c) OHE with slewing arrangement can be planned for crane attention to roof equipment.

7.8.3 Workshop Shed at Depot

Requirement of workshop lines is planned as under:

The length of Workshop shed is computed as below:

(i) Length of one 8- Car rake=184 m
(ii) Pathway in the entry side = 11 m
(iii) Free length at outer ends (for cross pathway, Signal and Friction buffers)= 11m
(iv) Total length of workshop lines = 11+184+11= 206m approx

The width of the workshop bay is computed as below:

(i) Centre – to- centre spacing between the lines= 12 m
(ii) Centre line of outer line to inner face of column of Shed= 4.5/5 m
(iii) Width of a 2 line Workshop Bay= 4.5+ 12+5= 21.5 meter

Requirement of workshop lines is planned as under:

Year	IOH & POH	Major Overhauling	Unschedule repairs /lifting	Total	Remarks
2021	2 lines each of 8-Car train and free space for storage of other equipment.		2 lines each of 8 Car train length.	Two bays of 2 lines each with one train of 8- car length. All the two bays are required from year 2021 and catering up to year 2031.	The size of one workshop bay shall be 206 X21.5 m comprising of two lines capable of accommodating one train of 8- Car each with Bogie turn table facility, with free space for storage of wheel/ bogie/ equipments etc.
2031	2 lines each of 8-Car train and free space for storage of other equipment.		2 lines each of 8 Car train length.		

(a) There shall be two bays comprising of two lines (as detailed in 'Remarks' above). Size of the one workshop bay is proposed to be 206m x 21.5m. The unscheduled lifting and heavy repair line shall be fitted with jack system capable to lift the 6-Car unit simultaneously for quick change of bogie, thereby saving down time of Rolling Stock. In future, provision of jack system would be made for lifting of complete 8-car train in case of conversion from 6-car train into 8-car train. The arrangement of jack system shall be such that lifting of any coach in train formation for replacement of bogie/equipments is also individually possible. Space on one line shall be available for stocking of Bogies and wheels. These lines are to be provided with pits at regular intervals for inspection of undercarriage and lines are to be interconnected by turn tables. Each workshop bay shall be equipped with two 15T and 5T overhead cranes, each spanning the entire length of the workshop bay.

(b) There shall be space provided for repairs of HVAC, Door, and Traction motor etc. repairs. Distinct spaces shall be earmarked for dismantling/repairs/ assembling and testing of each of these equipments. Related machinery for Overhauling / Repairs & testing activities of every equipment are also to be housed in the space earmarked.

(c) There shall be washing and cleaning equipments on the workshop floor. Bogie test stand shall be provided in the workshop. Other heavy machinery shall also be suitably installed on the workshop floor. Air-circulators, lights, Powers supply points and compressed air supply line shall be provided on each workshop column.

(d) Workshop lines shall be inter-linked through turn tables, each suitable for movement of a train in AWo (unloaded) condition and shall also be capable to rotate with a fully loaded bogie on it. Repair of heavy equipments such as air conditioners shall be so located so that it does not affect the movement inside workshop.

(e) There shall be walkways on columns for roof inspections, along the workshop lines. These walkways shall not infringe with cars being lifted/ lowered by means of mobile jacks. Suitable space between the nearest exterior of a car and farthest edge of the walkway has to be ensured to avoid conflict in lifting and lowering of cars.

(f) The small component, bogie painting and battery maintenance cells will be located in the workshop with arrangement that fumes are extracted by suitable exhaust systems.

(g) Workshop will have service building with array of rooms along its length. Total size is proposed to be 206 x 8m. These can be made by column and beam structure and architecture made of brick works. These shall cater for overhauling sections, offices, costly store item, locker rooms, toilets etc. Two opposite sides widthwise shall be open to facilitate natural air circulation and cross ventilation besides the egress & ingress for coaches. The sidewalls shall also have sufficient width of louvers for providing adequate ventilation.

(h) There shall be space for bogie/ axle repair shop with necessary infrastructure for disassembly, overhead, assembly and testing of mechanical components of bogies/ axle. The repair shop shall be easily approachable from with the workshop for transportation of components.

Following equipment repair/overhaul facilities are planned in the workshop and wheel repairs shop at the workshops:

1. Body furnishing
2. Bogie
3. Wheels
4. Traction Motors with gear drives

5. Axle Box and Axle Bearing
6. Pantographs
7. Transformer, converter/inverter, circuit breaker
8. Battery
9. Air Compressor
10. Air-conditioner
11. Brake Equipment
12. Door actuators
13. Control and measuring equipments
14. Pneumatic equipment
15. Dampers and Springs
16. Couplers/Gangways
17. Coach Painting (Applicable only for Aluminum coaches, if any)
18. Electronic cards module level

7.9 CAR DELIVERY AREA

There shall be rail connectivity between the Depot-cum- Workshop and mainline and all trains due for scheduled/ unscheduled works shall reach the depot-cum-Workshop by rail.

However in case of newly procured coaches, which are transported by road, these shall reach the Depot-cum Workshop by the road on trailers. To unload the coaches and bring them to the track, provision of space, along the side of shunting neck, has to be made for unloading of cars and other heavy materials. This area shall have an insulated track embedded in the floor facilitating the movement of road trawler, which brings in the cars. The length of the track embedded area shall be about 40m long. There should be enough space available for movement of heavy cranes for lifting of coaches. The unloading area should be easily accessible for heavy duty hydraulic trailers.

7.10 OPERATIONAL FEATURES

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed/workshop area. Movement from depot to the main line is so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line is feasible in the present site scenario. Both of these activities will be done effectively without effecting the train operation on the main line. The stabling lines would be interlocked with the main line thereby induction of train from the stabling would be safe and without loss of time. The proposition for a transfer track on the incoming line as well as on the outgoing line to facilitate the movement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear shall be explored in the detailed design stage depending on the actual availability of land.

An emergency line is also provided from which an emergency rescue vehicle may be dispatched to main line in the event of emergency if necessary.

7.11 INFRASTRUCTURE FACILITIES

(i) Inspection and Workshop facilities:

As indicated in 10.8.2 & 10.8.3 above.

(ii) Stabling Lines in Depot:

a) The requirement of lines shall be in accordance with the details indicated in para 10.8.1 above. A part of the stabling siding in the depot shall be covered with a roof in order to facilitate testing of air conditioning of trains and their pre-cooling under controlled condition of temperature.

b) Separate toilets adjustment to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the working staff.

(iii) Automatic Coach Washing Plant (AWP)
Provision to be made for Rolling Stock exterior surfaces to be washed using a fully automated Train Washing System, with a throughput capacity of approximately ten trains per hour. The AWP shall be situated at such a convenient point on the incoming route so that incoming trains can be washed before entry to the depot and undesirable movement/shunting over ingress and egress routes within the depot is avoided. Additional space for plant room for AWP system shall be earmarked alongside the washing apron as indicated at S. No. 6 of Annexure I.

(iv) Train Operators Booking Office
Suitable office facility adjacent to the stabling lines at each depot should be provided so that train operators reporting 'On' duty or going 'Off' duty can obtain updates regarding 'Special Notices', 'Safety Circulars' and other technical updates/information in vogue. These offices should have an attached a cycle/scooter/car stand facility for convenience of the train operating staff.

(v) Test Track
Ideally a test track of 1000 mts. in length covered & fenced should be provided beside workshop in the depot. It shall be equipped with signaling equipments (ATP/ATO). It shall be used for the commissioning of the new trains, their trials and testing of the trains after the IOH and POH. Entry into the test track shall be planned for a 8- Car train. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized trespassing across or along the track.

(vi) Heavy Cleaning Shed
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 designed for cleaning of one at a time. A line adjacent to inspection shed should be so provided that placement of rakes is possible from workshop or inspection lines & vice – versa conveniently and with ease.

(vii) Power Supply

Auxiliary substations are 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. Two Auxiliary substations are proposed, as the demand by machines in Workshop area would be very large. 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.

(viii) Compressed Air Supply

Silent type compressor units shall be suitably installed inside the depots at convenient location for the supply of compressed air to workshop and Inspection sheds. Thus, the pneumatic pipeline shall run within the workshop and inspection bays as to have compressed air supply line at all convenient points.

(ix) Water Supply, Sewerage and Drainage Works

In house facilities shall be developed for the water supply of each depot. Sewerage, storm water drainage shall be given due care while designing the depots for efficient system functioning. Past records of Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphases to charge the under ground reserves.

(x) Ancillary Workshop

This workshop will have a line at floor level with provision of pits. Arrangement for repairs of Shunters, Rail Road Vehicles and other ancillary vehicles will be provided. These vehicles will also be housed here itself. Heavy lifting works can be carried out in main workshop.

Ancillary workshop will be used for storing OHE/rigid OHE parts and their maintenance/ repair for restoration of 25 kV feed system.

(xi) Watch Towers

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

(xii) Administrative Building

An administrative building close to the main entrance is planned. It can be suitably sized and architecturally designed at the detailed design stage. A time and security office is also provided close to main entrance. It shall be equipped with suitable Access control system for all the staff working in the complex.

(xiii) Parking Facilities

a) Ample parking space shall be provided for the two wheelers and four wheelers at the following points.
   i) Close to the depot entry.
   ii) Close to the stabling lines.
   iii) Close to the Workshop/IBL.

b) Space for parking of road and re-railing equipments
Enough space for parking of road vehicle/ trailers/ trucks etc. Enough space will also have to be earmarked adjacent to workshops. Similarly, provision of space for parking of re-railing equipments will have to be made close to the main exit gate of the Depot.

(xiv) Shed and Buildings
The shed and buildings normally provided in the depot with their sizes and brief functions are indicated at Para 10.12.1. At the detailed design stage depending upon the land availability, the decision to locate these buildings can be taken. These can then be architecturally and functionally grouped.

(xv) Plant and Machinery
a) A separate building is planned for housing pit wheel lathe (PWL), approachable from workshop, inspection bay and stabling lines through rail and road for placement of cars for re- profiling of wheels within the depot along with space for depot of scrap.
b) Requirement of buildings and major plants and machinery, is given at Paras 7.12.1 & 7.12.2.

7.11.1 Following Safety features should be incorporated in the design of the Maintenance Depot-cum-Workshop:

a) 1.5 EOT cranes in the inspection bay should be interlocked with 25 kV ac OHE in such a way that, the cranes become operational only when the OHE is isolated and grounded.

b) Red flasher lights should be installed along the inspection lines at conspicuous location to indicate the OHE is 'Live'.

c) Multi level wheel and TM stacking arrangement should be an inbuilt feature at the end of Workshop Lines.

d) Pillars in the inspection bay & workshop should have provision for power sockets.

e) Placement of rakes from inspection/workshop lines on to washing lines for interior cleaning on their own power should be possible. Linking of OHE and its isolation at the cleaning area should be provided. Necessary requirements of safety should be kept in view.

f) The roof inspection platform should have open-able doors to facilitate staff to go up the roof for cleaning of roof. Suitable safety interlock should be provided to ensure maintenance staff are enabled to climb on the roof inspection platform only after the OHE is isolated.

g) Control Centre, PPIO & store depot must be close to Workshop.

h) Width of the doors of the sections wherein repairs of equipments are done should be at least 2 meters wide to allow free passage of equipment through them.

i) Provision of water hydrants should be done in workshops & stabling yards also.

j) Compressed air points along with water taps should be available in interior of buildings for cleaning.

k) Ventilation arrangement inside the inspection shed and workshop should be ensured. Arrangement for natural cross ventilation from one side to another of inspection & workshop bays to be incorporated along with optimum availability of natural light at floor level.

7.12 LIST OF BUILDINGS & LIST OF PLANTS & EQUIPMENTS AT DEPOT-CUM-WORKSHOP

7.12.1 List of Buildings at Depot-cum-workshop:

S. No	Name of Building	Size	Remarks
1.	Inspection Shed	206m x 21.5m(each inspection shed)	Servicing of Cars for 15 days & 45 days inspection.
	Workshop Shed	206 x 21.5 m(each workshop shed)	Major repair & overhaul of rolling stocks, diesel shunters, electric tractors, tower wagons. All heavy lifting jobs.
	Associated Sections	206m x 8m	Rooms for carrying out the inspection & workshop activity.
	Stabling line shed	-206m x 59m(for stabling the 11 rakes initially)	Initially stabling lines to be made for 11 rakes only but future provision to be available for total rake requirement of 13 rakes in the year of 2031.
2.	Stores Depot & Offices including Goods Platform with Ramp	45m x 45m	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. iv. Loading/Unloading of material received by road.
3.	Elect. Substation & DG set room	20m x 15m	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.	Traction repair depot and E &M repair shop	80m x 30m (partly double storey)	Stabling and routine maintenance of shunting engine etc. & Traction maintenance depot. For maintenance of lifts/escalators and other General service works.
5.	Cycle / Scooter / Car Parking	100m x 6m 60m x 6m	i. Close to the depot entry. ii. Close to the stabling lines.
6.	Auto coach washing plant	60m x 10m	For automatic washing of coaches. Provision of Washing apron for collection of dripping water and its proper drainage to be ensured.
7.	Washing apron for Interior Cleaning	206m x 6.5m	Heavy wet washing of rakes from inside, under frame, roof at 30 days interval.

S. No	Name of Building	Size	Remarks
8.	P-way office, store & Workshop including Welding plant	80m x 20m	i. For track maintenance of section and depot. ii. To weld rails for construction period only. iii. To stable track Tamping machine.
9.	Security office & Time Office Garages (4 Nos.)	15m x 8m	For security personnel. For time punching For parking vehicle jeep, truck etc.
10.	Check Post (2 Nos.)	5m x 3m	For security check of incoming/outgoing staff material and coaches.
11.	Depot control centre & Crew booking centre	25mx20m (double storey)	To control movement of trains in and out of the depot and for crew booking.
12.	O.H raw water Tank	1,00,000 Ltrs. Capacity	For Storage of water.
13.	Pump house Bore well	7.3mx5.4m (200 mm bore)	Submersible type pump planned with 200 mm diameter bore well.
14.	Dangerous goods Store	15m x 10m	For Storage of paints, inflammables & Lubricants
15.	a)Traction 25/33kV/66kV sub station b) Feeding Post	a)120m x 80m b) 15m x30m	Traction Power Supply
16.	Waste Collection Bin	10m x 10m	Garbage dumping
17.	Repair shops for S & T	40m x 20m	For the AFC gates, Signaling and telecom equipment.
18.	Work shop Manager Office	30m x 20m	Office of Depot in charge
19.	ATP & ATO Room	10m x 8m	To keep equipments of ATP/ATO
20.	Waste Water Treatment Plant	12m x 6m	For treating the discharge waters of the depot and remove the oil, acids etc. before discharging into the river, with U/G tank.
21.	Canteen	200 sqm.	To cater staff of depot and workshop. Should be in a separate building with modern kitchen ware and facilities. Obligatory as per statutory requirements.
22.	Toilets -Gents -Ladies	10m x 7m 10m x 7m	These toilets shall be approachable both from workshop as well as from inspection bay and ladies toilets shall be completely insulated from gent's toilet.

7.12.2 List of Plants & Equipments at Depot-cum-Workshop at Kanjur Marg:

S. No.	Description	Unit	Depot	Approximate procurement cost (INR Lac)
			Inspection Lines	Depot M&P
			3	
			Workshop Lines	
			4	
1	Under floor Pit Wheel lathe	No.	**1**	**621**
2	RRM for wheel lathe	No.	**1**	**184**
3	Battery Shunting Loco	No.	**1**	**318**
4	Electric Tractors (RRM)	No.	**1**	**200**

S. No.	Description	Unit	Depot	Approximate procurement cost (INR Lac)
			Inspection Lines	Depot M&P
			3	
			Workshop Lines	
			4	
5	Pit Jacks-for 6 car unit	No.	**1**	**1000**
6	Mobile Jacks for Lifting cars (6 car unit)	No.	**2***	**600**
7	Automatic Train Washing Plant	No.	**1**	**268**
8	Bogie Test Stand	No.	**1**	**360**
9	CNC Wheel Press	No.	1	**600**
10	Rel Fed Bogie Wash Plant	No.	1	**278**
11	CNC Vertical Turret Lathe	No.	1	**600**
12	Coach Underframe/Blow Down Plant	No.	1	**218**
13	Mobile jib Cranes(1T Manual)	No.	**2**	**2**
14	Mobile Lifting Table(1T for Insp)	No.	**2**	**3**
15	Mobile Lifting Table (3T for WS)	No.	**1**	**3**
16	Work Lift Platform	No.	**1**	**18**
17	Bogie Turn table (25T roll over capacity)	No.	**4**	**100**
18	High Pressure Wash Pumps	No.	**2**	**23**
19	High capacity vacuum cleaner	No.	**1**	**5**
20	AC Filter cleaning machine	No.	**1**	**21**
21	Mobile Compressor(10bar at 20 CFM)	No.	**1**	**4**
22	Air Compressor	No.	**1**	**5**
23	EMU Battery Charger	No.	**3**	**13**
24	Rerailling equipment (set) and rescue equipment	No.	**1**	**75**
25	Road cum rail vehicles with crane for rerailing equipment	No.	**1**	**42**
26	container for rerailing equipment	No.	**1**	**4**

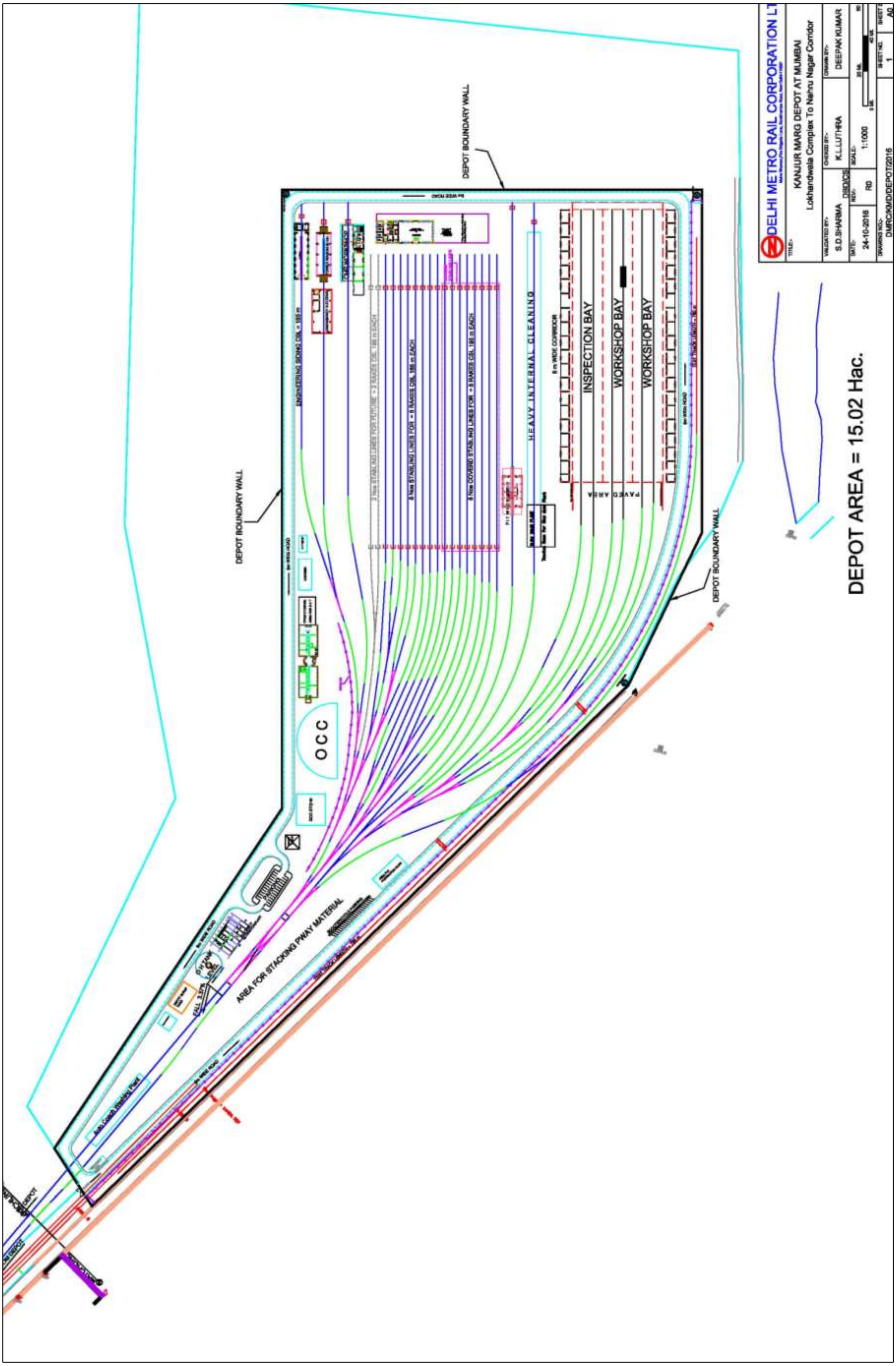
S. No.	Description	Unit	Depot	Approximate procurement cost (INR Lac)
			Inspection Lines	Depot M&P
			3	
			Workshop Lines	
			4	
27	Truck	No.	**1**	**13**
28	Welding and Cutting Equipments	No.	**1**	**2**
29	Work Test Benches	No.	**LS**	**10**
30	Weighing scales(5T)	No.	**1**	**1**
31	Storage Bins and pallets	No.	**1**	**8**
32	Pallet Trucks	No.	**4**	**5**
33	Fork Lift Truck-3T(Elect)	No.	**2**	**19**
34	Stackers (1T for DCOS)	No.	**1**	**10**
35	Mobile Safety Steps	No.	**5**	**2**
36	Set of Pallets	No.	**LS**	**10**
37	Storage racks (W/shop & DCOS stores)	No.	**1**	**85**
38	Electric and Pneumatic Tools	No.	**LS**	**25**
39	Measuring and calibration equipment Instruments	No.	**LS**	**25**
40	Special Jigs and Fixtures	No.	**LS**	**50**
41	Industrial Furniture	No.	**LS**	**55**
42	Miscellaneous	No.	**LS**	**40**
43	Minor diagnostic equipment/ Electronic equipment	No.	**LS**	**15**
44	Induction heater	No.	**1**	**8**
45	Bearing puller	No.	**1**	**8**
46	Training equipment/ diagnostic software/computer equipment/laptop etc.	No.	**LS**	**10**
47	Auto wheel profile meter	No.	**1**	**20**
48	High Rise Work lift Platform (HRWP)	No.	**1**	**35**

S. No.	Description	Unit	Depot	Approximate procurement cost (INR Lac)
			Inspection Lines	Depot M&P
			3	
			Workshop Lines	
			4	
49	Video diagnostic equipment for TM	No.	1	**15**
50	Impluse Tester for TMs	No.	1	**18**
51	Pentograph checking fixture	No.	1	**30**
	Total			**6084**

***Wiring & conduiting for mobile jacks to be ensured for all 3 balance workshop lines.**

7.13 COST ESTIMATE

The total estimated cost at March'2016 Price level may be assumed as Rs. 60.84 Crores for M&P equipments.


DEPOT BOUNDARY WALL
DEPOT BOUNDARY WALL
DEPOT BOUNDARY WALL
HEAVY INTERNAL CLEANING
INSPECTION BAY
WORKSHOP BAY
WORKSHOP BAY
OCC
AREA FOR STACKING PWAY MATERIAL
DEPOT AREA = 15.02 Hac.
DELHI METRO RAIL CORPORATION LT
KANJUR MARG DEPOT AT MUMBAI
Lokhandwala Complex To Nehru Nagar Corridor
S.D.SHARMA
K.L.LUTHRA
DEEPAK KUMAR
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Chapter - 8

POWER SUPPLY ARRANGEMENTS

Power supply is the lifeline of Metro System

8.1 POWER REQUIREMENTS

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc.) and workshops, depots & 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 – 80 KWh/1000 GTKM
(ii) Regeneration by rolling stock – 30%
(iii) Elevated/at –grade station load – initially 350 kW, which will increase to 450 kW in the year 2031
(iv) Depot auxiliary load - initially 2000 kW, which will increase to 2500 kW in the year 2031.

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirements projected for the year 2021 and 2031 are summarized in table 8.1 below:

Table 8.1 Power Demand Estimation (MVA)

Corridor	Load	Year	
		2021	2031
Swami Samarth Nagar to Vikhroli (EEH), 13 stations (14.477 km)	Traction	11.40 MVA	14.04 MVA
	Auxiliary	8.52 MVA	10.87 MVA
	Total	**19.92 MVA**	**24.91 MVA**

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 29,657 passengers per direction during peak hours when trains are expected to run at **3.50** 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 signages, 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 220, 110 or 100 kV 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 220, 110 and 100 kV network to cater to various types of demand in vicinity of the proposed corridors.

Keeping in view the reliability requirements, two Receiving Sub-stations are proposed to be set up for the line. This is an economical solution without compromising reliability. It is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations of M/s Reliance Infrastructure Ltd (RIL) at 220, 110 & 100 kV voltage through cable feeders:

Table 8.2 Sources of Power Supply

S. No.	Corridor	Grid sub-station (GSS) (Input voltage)	Location of RSS of Metro Authority	Approx. length b/w GSS & RSS
1	Swami Samarth Nagar to Vikhroli (EEH), 13 stations (14.477 km)	220 kV Goregaon GSS	Near JVLR station	3 km
2		220 kV Aarey GSS	Depot RSS	8 km

DMRC has done a joint survey/ meeting with M/s MMRDA, M/s Reliance Infrastructure Ltd and M/s TATA Power Company Ltd on 22.08.2016 & 23.08.2016 for this corridor for feasibility of Power Supply (Annexure-8.2). Accordingly, availability of power supply has been planned and tabulated above. Projected Power demand is calculated on each RSS and furnished below: -

Table 8.3 – Power Demand projections for various sources

Corridor	Input Source	Peak demand – Normal (MVA)		Peak demand** – Emergency (MVA)	
		Year (2021)	Year (2031)	Year (2021)	Year (2031)
Swami Samarth Nagar to Vikhroli (EEH), 13 stations (14.477 km)	**RSS Near JVLR Station**				
	Traction	4.87	5.91	11.40	14.04
	Auxiliary	3.03	3.89	8.52	10.87
	Sub-total (A)	**7.90**	**9.80**	**19.92**	**24.91**
	RSS Near Depot				
	Traction	6.53	8.12	11.40	14.04
	Auxiliary	5.50	6.98	8.52	10.87
	Sub-total (B)	**12.03**	**15.10**	**19.92**	**24.91**

** Incase of failure of other source of power

The 110 kV power supply will be stepped down to 3 Φ 33 kV and 1 Φ 25 kV level at the RSS's of metro authority. The 1 Φ 25 kV will be fed to the OHE to cater to traction load and the 33 kV power will be distributed along the alignment through 33 kV Ring main cable network for feeding auxiliary loads. These cables will be laid in dedicated ducts/cable brackets along the viaduct.

In case of tripping of One RSS of the line on fault or input supply failure, train services can be maintained from stand-by source of the same line. However, in case of total grid failure, all trains may come to a halt but station lighting, fire and hydraulics & other essential services can be catered to by stand-by DG sets. However, no train services can be run with power supply received from DG Sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well, except for the train running.

Typical High Voltage Receiving Sub-station

The 110/220 kV cables will be laid through public pathways from the Sub-stations of Supply Authority to RSS of Metro Authority. RSS Near JVLR Station shall be provided with 2 Nos. (One as standby) 220/25 kV 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 220/33 kV 15 MVA (ONAN) three phase Transformers for feeding auxiliary loads, RSS Near Depot shall also be provided with 2 Nos (One as standby) 220/25 kV, 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 220/33 kV, 15 MVA (ONAN) three phase Transformers for feeding auxiliary loads. The capacity of transformers may be reviewed considering the load requirement/distribution of Swami Samarth Nagar to Vikhroli (EEH) corridor also at the time of detailed design.

Gas Insulated Switchgear (GIS) type Switchgear will be planned due to less space in Mumbai and reduced maintenance. 220 kV GIS substation land requirement will be approx. 60 X 50 m (3000 sq. m).

8.4 VARIOUS OPTIONS OF TRACTION SYSTEM

There are three options available for power supply system for MRTS: -

- 25 kV & 2X25 kV AC Overhead Catenary system
- 750 V DC third rail system
- 1500 V DC Overhead Catenary system

A sub- committee set up by "Ministry of Urban Development" on Traction system for metro railway has studies various aspects of merits and demerits of various traction system. The following are the highlights of Report: -

Merits and Demerits of various traction systems

a) 25 kV AC with OCS (Flexible/rigid): -Merits

- **Reduced cost –** Unlike dc traction this system, does not require substations at frequent intervals due to high voltage, reduced current levels and lower voltage drops as a result, there is substantial reduction in cost. Cost of 25 kV AC traction systems is about 15% less as compared to 750V DC 3rd rail traction system for the estimated level of traffic.

- **Energy regeneration & line losses-** Energy regeneration is more than 30% in 25 kV AC traction system as compared to 18% in 750V DC 3rd rail traction system. In 25 kV AC traction system line losses are 12% less as compared to 750V DC 3rd rail traction system

- **Cost of rolling stock-** The cost of rolling stock & maintenance cost of traction system are comparable.

- **Capacity** – The system can cater to traffic needs even in excess of 75000 PHPDT, which, however, is restricted on account of other constraints.

- **Easy of capacity enhancement** – Capacity enhancement can be easily achieved by simply enhancing the transformer and its associated equipment at the receiving substation.

- **Higher efficiency of operation** – The efficiency of regeneration is substantially more than DC systems and line losses are very less of the order of 5%. 100% recovery of regenerated energy is possible in the case of 25 kV AC traction compared to a figure of 75% in the case of 1500 V DC systems and 60% in the case of 750 V DC systems.

- **Less Fire hazards**-AC system poses lesser fire hazards as current levels are much lower than DC system.

- **Stray current** - There are no problem of stray currents and hence nearby metallic structures are not affected by corrosion. However, there are problems of EMC / EMI which can be controlled by using return conductor & screened cables in signaling applications & fiber optic cable in telecommunication system without using booster transformer as per recent developments. This also helps in avoiding use of booster transformer which causes 2%-line loss and excessive voltage drops besides involving maintenance & reliability issues.

- Traction equipments in 25 kV AC system are standardized & mostly indigenously available.
- Though in underground section higher side tunnel diameter because an issue but this is not the case here.

b) 750-850 V DC third rail traction system:-Demerits

- **High operating currents and High voltage drops necessitating reduction in spacing of sub-station-** This leads to larger voltage drops along the Third Rail distribution system, which necessitates closer spacing of sub- stations at an interval of almost every 2 Km, leading to higher costs of construction.

- **Low levels of regeneration-** 60% of re-generated energy in a 750 V DC system is possible to be retrieved.

- **Safety hazards with use of high voltage at ground level-** Due to existence of the "live" third rail at ground level, this system can be hazardous to safety of commuters and maintenance personnel if they fail to adopt safety precautions.

- **Line losses-** Line losses are more due to higher current. Transmission line losses on 750 V DC traction system are around 21% as against 5% of 25 kV AC traction system.

- **Phenomenon of stray current-** In a third rail system, where the running rails are used as a return path, a part of the return current leaks into track structure. This current is called stray current. It is necessary to manage the stray current to ensure minimal corrosion effect and consequent damages to metallic components in the track structure as well as metallic reinforcement and metal pipes of building of metro and public areas adjacent to the Metro alignment.

c) 1500 V dc system with Overhead Catenary System:-Demerits

- Higher maintenance requirement and costs as compared to 750V DC third rail system.

- Theoretical traffic capacity with 1500 V traction system is less as compared to 25 kV AC system.

- Line losses are more due to higher current as compared to 25 kV AC. It may be in the range of 10 to 12% as against 5% of 25 kV AC system.

In view of above techno-economic consideration 25 kV ac Traction System is suggested for this corridor.

8.5 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

25 kV 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 25 kV OHE and the elevated viaduct.

Detailed specification of equipment 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 AUXILIARY SUPPLY ARRANGEMENTS FOR ELEVATED STATIONS

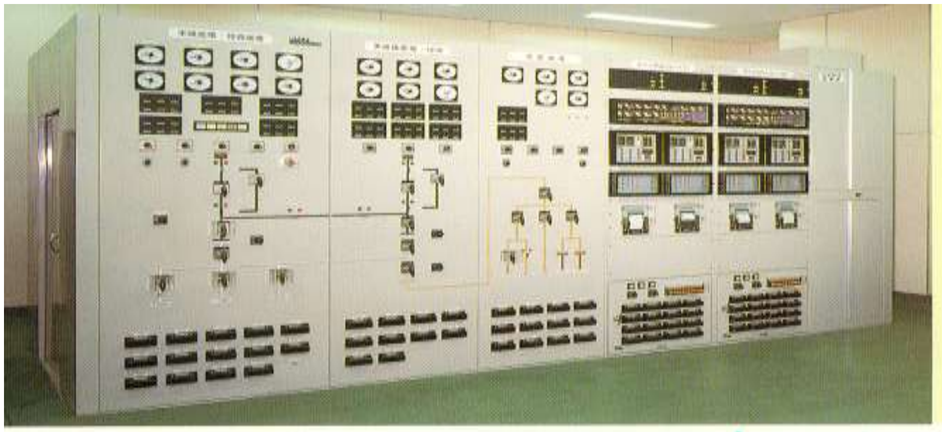
Auxiliary sub-stations (ASS) are envisaged to be provided at each station. The ASS will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 450 kW for elevated/at-grade stations. Accordingly, two dry type cast resin transformers (33/0.415 kV) of 500 kVA capacity are proposed to be installed at the stations (one transformer as standby).

8.7 AUXILIARY SUPPLY ARRANGEMENTS FOR DEPOT

The Following major plant and machinery are to be provided in Depot:-

- RRV for carrying re railing equipments
- Road vehicles (pick up van/ truck)
- Flat wagon for carrying material.
- Diesel/Electric battery powered locomotive with traction battery charger.
- Under floor Pit wheel lathe, chip crusher and conveyor for lathe on pit, Electric tractor for movement over under floor wheel lathe.
- Travelling O/H crane workshop 15T/3T,1.5T capacity(IBL), ETU shed 5T crane
- Mobile Jib crane

A separate ASS is required at the depot. The Depot ASSs will also be provided with 2x2500 kVA auxiliary transformers.



Typical Indoor Auxiliary Sub-station

8.8 25 KV AC FLEXIBLE OVERHEAD EQUIPMENT (OHE) SYSTEM

25 kV AC flexible OHE system shall comprise 107/ 150 sq.mm silver copper contact wire and 65 sq.mm Cd-copper catenary wires. Because of the advancements in telecom technology, booster transformer has not been in the scope & Return conductor (RC) shall be All Aluminum Conductor (AAC) of 93.3 sq.mm cross section. For tensioning of OHE, ATD shall be a mix of spring ATD (50%) and 5 pulley ATD (balance 50%) spring ATD shall not be having counterweight and shall be provided at critical location like road crossing etc. Proven catenary fittings are proposed similar to DMRC system.

8.9 RATING OF MAJOR EQUIPMENT

Based on emergency demand expected at each RSS as shown in Table 8.3, and expected power demand during emergency, RSS Near JVLR Station shall be provided with 2 Nos. (One as standby) 220/25 kV 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 220/33 kV 15 MVA (ONAN) three phase Transformers for feeding auxiliary loads, RSS Near Depot shall also be provided with 2 Nos (One as standby) 220/25 kV, 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 220/33 kV, 15 MVA (ONAN) three phase Transformers for feeding auxiliary loads. The incoming cable shall be 3-phase single core XLPE insulated with 800 mm^2 Aluminum conductors to meet the normal & emergency loading requirements and fault level of the 220 kV supply.

33 kV and 25 kV switchgear shall be rated for 1250 A being standard design. 33 kV cable ring network shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations and accordingly 3 number of Single core 300 mm^2 FRLSH Aluminum conductor cable XLPE insulated 33 kV cable is proposed for ring main network.

Adequate no. of cables are required for transfer of traction power from Metro's RSS to 25 kV OHE. Single-phase XLPE insulated cables with 240 mm^2 copper conductor are proposed for traction power. Based on current requirements, 2 cables are required for each of the two 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 required to be revised for better accuracy during design stage of project implementation.

8.10 MV/LV SYSTEM

Following major E&M Equipments/system shall be required for elevated stations:-

- MV/LV panels
- DG set
- UPS & Battery system
- Lifts
- Escalators
- Fire suppression and detection system
- Lights & fans
- Air conditioning system
- BMS system
- Lightning protection system
- Earthing system

Panels shall be front operated front access cubical type indoor duty floor mounted totally enclosed dust and vermin proof with neoprene gaskets fabricated from CRCA sheet with powder coated finish suitable for 415 V 3 Phase 4 wire 50 Hz system.

8.11 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 180 kVA capacity at the elevated 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.

8.12 SOLAR PHOTO VOLTAIC (PV) POWER SYSTEM

In DMRC solar PV power system are installed at various sites in RESCO (Renewable Energy Service Company) model. In DMRC Stations and Depots 6.3 MWp solar PV power system has been installed in RESCO model.

Solar PV Power panel

"RESCO Model" means where the developers intend to provide solar power system on rooftop/sites owned by DMRC on mutually agreed terms and conditions from DMRC and enters into the PPA (Power purchase agreement) with DMRC for supply of Solar power for 25 years from the date of Commissioning of project.

In elevated stations about 50 kWp to 150 kWp capacity of Solar PV power system can be provided depending upon type of roof availability, shadow free roof area, orientation of stations. In DMRC receiving sub-station 20 kWp to 50 kWp capacity Solar PV systems are generally provided. In DMRC Depot area, approx.1000 kWp to 1500 kWp of solar capacity has been provided. Solar PV system in station parking area can also be planned as per availability of area.

8.13 SEWAGE TREATMENT SYSTEM USING INTEGRATED CONSTRUCTED WETLANDS (ICW)

Following are the objectives for providing Sewage Treatment System using Integrated Constructed Wetlands (ICW): -

1) To establish an effective option for treatment of wastewater that is generated from campus.

2) Establish an onsite treatment solution which is effective and cost effective option without producing any by products.
3) To establish a sustainable and environmental friendly solution with minimal maintenance.
4) The treated water can be reused for various non-portable applications landscaping, flushing and cleaning.

The objective of Constructed Wetlands is to utilize the decomposable organic matter present in sewage, which can be disposed of into the environment without causing health hazards or nuisance. The degree of treatment to be adopted would meet the regulatory agencies (surface water discharge standards).

Constructed wetlands (CW) are complex and modular system provides an efficient and sustainable purification treatment method that is applicable to practically all pollutant sources and in all climate and environmental conditions. CW relies on Constructed Wetlands, and is based on the activity of plants together with microorganism communities in the root zone. Together they degrade, accumulate, extract, and volatilize contaminants of all kinds in water, soil and the air, resulting in clean and purified outflow.
In DMRC Faridabad RSS 1 KLD capacity Sewage Treatment System provided through integrated constructed wetland method.

8.14 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. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fiber 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 33 kV AC switchgear, transformers, 25 kV 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.

8.15 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 benefit 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 25 kV 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%) 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 has 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) has 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.
(viii) LED lights to be used in the station area and Depot area.

8.16 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 58.29 million units in initial years 2021, which will be about 72.54 million Units in the 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 110/220 kV voltage level) plus nominal administrative Charges i.e. on a no profit no loss basis. The power tariff of Maharashtra Electricity Regulatory Commission for M/s TATA power Company and M/s Reliance Infrastructure Ltd for FY 2015 – 16 demand charges Rs 200/ kVA per month and energy charges Rs 7.63/ kWh. Therefore, it will be in the range of **Rs 7.91 to Rs 8.00 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. Similar approach has been adopted for Delhi Metro.

MUMBAI METRO					**Annexure-8.1**
Swamy Samarth Nagar to Vikhroli (EEH)					
POWER REQUIREMENT		**Swamy Samarth Nagar to Vikhroli (EEH)**			
S.No.	**Particulars**	**Year 2021**		**Year 2031**	
A	**Traction Power Requirements**	1	2	3	4
1	No. of cars	6	(2DMC +2TC +2MC)	6	(2DMC +2TC +2MC)
2	Passenger Weight	145.86	T	145.86	T
3	Train Tare Weight	251.00	T	251.00	T
4	Total Train Weight	396.86	T	396.86	T
5	Section Length	14.04	km	14.04	km
6	Headway	4.25	mts	3.50	mts
7	Specific Energy Consumption	80	KWhr/ 1000 GTKM	80	KWhr/ 1000 GTKM
8	No. of Trains/hr in both directions	28	Nos.	34	Nos.
9	Peak Traction Power Requirement	12.59	MW	15.28	MW
10	Less Regeneration @ 30%	3.78	MW	4.59	MW
11	Depot Power Requirements	1.50	MW	2.00	MW
12	No. of Depot	1	No	1	No
13	Total Traction Power Requirement	10.31	MW	12.70	MW
	Total Traction Power Requirement (MVA) assuming 5% energy losses and 0.95 pf	**11.40**	**MVA**	**14.04**	**MVA**
B	**Aux. Power Requirements**				
1	Elevated/at-grade Station Power Consumption	0.35	MW	0.45	MW
2	Underground station Power Consumption	2.00	MW	2.50	MW
3	No. of Elevated/at-grade Stations	14	Nos.	14	Nos.
4	No. of Underground stations	0	No.	0	No.
5	Total Station Aux Power Requirement	4.90	MW	6.30	MW
6	Depot Aux Power Requirement	2.00	MW	2.50	MW
7	No. of Depot	1	No.	1	No.
8	Total Aux Power Requirement	6.90	MW	8.80	MW
	Total Aux. Power Requirement (MVA) assuming 5% energy losses and 0.85 pf for aux loads	**8.52**	**MVA**	**10.87**	**MVA**
C (A+B)	**Total Traction & Aux. Power Requirement (MVA)**	**19.92**	**MVA**	**24.91**	**MVA**
Note: The requirement of PD load is not consided in estimation of power calculation.					

MUMBAI METRO					Annexure-8.2
Swamy Samarth Nagar to Vikhroli (EEH)					
ENERGY CONSUMPTION		Swamy Samarth Nagar to Vikhroli (EEH)			
S.No.	Particulars	Year 2021		Year 2031	
A	**Traction Energy**	1	2	3	4
1	Section Length	14.04	KM	14.04	KM
2	No. of Trains per direction in a day*	163	Nos.	200	Nos.
3	Weight of Train & Passenger	396.9	T	396.9	T
4	SFC (NET) with 30% regen	56	KWH/ 1000 GTKM	56	KWH/ 1000 GTKM
	Yearly Traction Energy consumption with 365 days working with 30% regen	**37.13**	**million units**	**45.56**	**million units**
B	**Station Aux. Energy**				
1	Elevated/at-grade Station	0.35	MW	0.45	MW
2	Underground Station	2.00	MW	2.50	MW
3	No. of Eevated/at-grade Stations	14	Nos.	14	Nos.
4	No. of Underground Stations	0	No.	0	No.
5	Total Station Aux. Power Requirement	4.90	MW	6.30	MW
6	Depot Aux power requirement	2.00	MW	2.50	MW
7	No. of Depot	1	No	1	No
8	Total Aux. Power Requirement	6.90	MW	8.80	MW
9	Total Aux. Power Requirement (MVA) assuming 5% energy losses and 0.85 pf for Aux. loads	**8.52**	**MVA**	**10.87**	**MVA**
10	Diversity Factor of Aux. loads	0.40		0.40	
	Yearly Aux. Energy Consumption 20 hrs/day and 365 days working (million units)	**21.16**	**million units**	**26.98**	**million units**
C (A+B)	**Net Annual Energy Consumption (Traction & Aux.)**	**58.29**	**million units**	**72.54**	**million units**

Note: The requirement of PD load is not consided in energy calculation.

MUMBAI METRO								Annexure 8.3
LINE No. 6 SWAMY SAMARTH NAGAR TO VIKHROLI (EEH) (14.477 km, 13 Stations)								
								(25 kV AC TRACTION SYSTEM)
S.No.	Description	Unit	Rate at per awarded	LOA date	Rate with Escalation @ 5% per annum-Sept 2016	Qty	Amount (Rs in Crores)	Remarks
3.0	**Station Buliding**							
3.1	Elevated Stations							
	E&M work	Each	2.85	22.04.13	3.30	14	46.22	Cost taken from Phase-III Contract CE-1 Lot-2.
	DG sets	Each	0.20	15.02.13	0.23	14	3.24	Cost taken from Phase-III Contract CE-2 Lot-1.
	Lifts	Each	1.40	08.01.15	1.47	14	20.58	Cost taken from Kochi Contract KE-11.Considered four Elevators per station.
	Escalator	Each	2.40	07.10.14	2.65	14	37.04	Cost taken from Kochi Contract KE-12.Considered four Escalators per station.
	Elevated Station with DG, Lift & Escalator	**Each**			**7.65**	**14**	**107.09**	
3.3	Metro Bhawan, OCC bldg.							
b	EM Works etc.	LS	10.0		10.0	1	10.00	
	Sub-Total						**117.09**	
4.0	**Depot**							
4.1	Depot							
b	EM Works	Each	21.41	05.06.13	24.19	1	24.19	Cost taken from Phase-III Contract CE-5 Lot-2 (Kalindikunj Depot)
	Sub-Total						**24.19**	
6.0	**Traction & Power Supply including OHE, ASS etc.**							
6.1	Elevated Section							
a	25 kV AC Traction with ASS, Cabling including depot OHE	R.km	6.63	29.10.15	6.80	14.04	95.42	Cost taken from Contract NE - 01 Cost is lower as compare to cost of CE-7 Lot-1
b	CMV	LS	7.00		7.00	1.00	7.00	
c	RSS (GIS)	Each	49.79	20.10.15	51.03	2	102.07	Cost taken from Noida - Greater Noida Contract (NE-02)
	220 kV HV Cable Single Run Double Circuit	R.km	4.00		4	10	40.00	1. Aarey to Kunjurmarg-8km 2. Goregaon to JVLR-3km.
c	Cost of installation/ modification of bays for RSS	Each RSS	5.00		5	2	10.00	Per RSS two bays modification/ installation is required.
	Total cost of 25 kV Traction with RSS and bays modification						**254.49**	
8.0	**Misc. Utilities**							
a	EM Works Utility diversion	R.km	3.50		3.5	14.04	49.15	
	Sub-Total						**49.15**	
	Grand Total						**444.92**	

Chapter – 09

ENVIRONMENT AND SOCIAL IMPACT ASSESSMENT

9.1 LEGAL, POLICY AND INSTITUTIONAL FRAME WORK

The available national and state level legal Acts and Legislation referred during the study are:

- The Water (Prevention and Control of Pollution) Act, 1974 (Amendment 1988).
- The Water (Prevention and Control of Pollution) Cess Act 1977, (Amendment), 2003.
- The Water (Prevention and Control of Pollution) Cess Rules, 1978, 1991.
- The Air (Prevention and Control of Pollution) Act 1981, amended 1987.
- The Air (Prevention and Control of Pollution) (Union Territories) Rules, 1982, 1983
- Noise Pollution (Regulation and Control) Rules, 2000 amendment 2002, 2006.
- Municipal Solid Waste Rules, 2000
- The Environment (Protection) Act, 1986, amended 1991.
- The Environment (Protection) Rules,1986.
- The Indian Forest Act, 1927.
- Forest (Conservation) Act, 1980, amended 1988.
- Forest (Conservation) Rules, 2003.
- Maharashtra (Urban Area) Protection of Trees Act 1975
- The Wild Life (Protection) Act 1972, Amendment, 2002

9.1.1 ENVIRONMENTAL CATEGORIZATION

The proposed project do not passes through any Wildlife Sanctuary, National Park, or any other environmentally sensitive or protected areas. The proposed project is between Swami Samarth Nagar - Vikhroli (EEH) is proposed on the centre of the road. As per the checklist of Multilateral Funding Agencies, the Environmental Assessment may be required to be done for the project considering the aspects of project siting, potential environmental impacts including climate change and disaster risk. Although, the proposed project will bring in many benefits to the area, there is potential for environmental impacts on the above ground structures due to vibration construction and operation of the metro. Depending upon the categorization of project, Environmental Impact Assessment (EIA) Report may be required as per the policy of Multilateral Funding Agencies.

Requirement of Environmental Clearance

As per provisions of the EIA Notification, 14 September 2006 as amended up to 1 December 2009, any person who desires to undertake any new project in any part of India or the expansion or modernization of any existing industry or project listed in Schedule-I of the said notification shall submit an application to the Ministry of Environment and Forests, Government of India in accordance with the guidelines issued by the Central Government in the Ministry of Environment and Forests from time to time. Metro Rail project is not included in the Schedule-I of the EIA Notification, 2006. Thus, the project does not require an environmental clearance certificate from the Ministry of Environment and Forests, Government of India.

Requirement of Forest Clearance

As per Indian "Forests Conservation Act (1980), every project requiring diversion of forest land for non-forestry purposes require forest clearance from MoEF. The forestry clearance is granted through two-stage process: Stage 1 refers, in principle agreement, to the project proposal in which usually the conditions relating to transfer, mutation and declaration as RF/ PF under the Indian Forest Act, 1972, of equivalent non-forest land for compensatory afforestation and funds for raising compensatory afforestation thereof are stipulated. Stage II involves formal approval under the Act after receipt of compliance report from the State Government in respect of the stipulated conditions. Since alignment is not passing through any forest land and no diversion of forest land is involved in the proposed project, no forest clearance is required for this project.

Required Clearances/Permissions

For the proposed project, required clearances/ permissions related to environment have been summarized below.

Table 9.1: Permissions/Clearances Required for the Project

S. No.	Permissions/ Clearances	Acts / Rules / Notifications / Guidelines	Concerned Agency	Responsibility
A. Pre-construction Stage				
1	Permission for felling of trees	Forest Conservation Act (1980) Procedural Guidelines developed by the Department of Environment, GoM; Tree removal will be guided as per state government rules.	MCGM / District Collector	MMRDA
B. Implementation Stage				
2	Consent to operate hot mix plant, crushers, batching plant	Air (Prevention and Control of Pollution) Act 1981	Maharashtra State Pollution Control Board	Contractor
3	Permission for withdrawal of groundwater	Environment (Protection) Act, 1986	Central Ground Water Authority	Contractor
4	Permission for sand mining from river bed	Environment (Protection) Act, 1986	Mining Department/ MoEF	Contractor
5	Authorization for Disposal of Hazardous Waste	Hazardous Waste (Management and Handling) Rules 1989	Maharashtra State Pollution Control Board	Contractor
6	Disposal of bituminous and other wastes	Hazardous Waste (Management and Handling) Rules 1989	Local civic body to use local solid waste disposal site	Contractor

S. No.	Permissions/ Clearances	Acts / Rules / Notifications / Guidelines	Concerned Agency	Responsibility
7	Consent for disposal of sewage from labour camps.	Water (Prevention and Control of Pollution) Act 1974	Maharashtra State Pollution Control Board	Contractor
8	Pollution Under Control Certificate	Central Motor and Vehicle Act 1988	Department of Transport, Govt. of Maharashtra authorised testing centres	Contractor
9	Roof Top Rain Water Harvesting (RWH)	Central Groundwater Authority (CGWA) Guidelines	Central Ground Water Authority/ MCGM	Contractor
10	Permission for groundwater extraction for drinking purpose	Environment (Protection) Act, 1986	CGWA	Contractor
11	Employing Labour/ workers	The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996	District Labour Commissioner	Contractor

9.1.2 OBJECTIVE AND SCOPE OF THE STUDY

The objective of the Environment and Social Impact Assessment study is to facilitate the Mumbai Metropolitan Region Development Authority (MMRDA) evaluate the environmental impacts of its proposed activity. MMRDA proposes to apply for loan to seek financial support from Multilateral Funding Agencies. Thus, the objective of the study is to conduct Environmental Impact Assessment as per requirement of Multilateral Funding Agencies. The scope of EIA includes the impacts resulting from pre-construction, during construction and operation phases of Swami Samarth Nagar – Vikhroli (EEH) Metro corridor at Mumbai. In addition, it is proposed to establish environmental baseline and safeguard measures for protection of environment for sustainable development during project cycles.

9.1.3 APPROACH AND METHODOLOGY

The MMRDA has considered different alternative corridors. The underlying principles for evaluation for each corridor, without affecting the overall usefulness of the corridor, are minimum private land acquisition, least disturbance to properties, minimal disturbance to ecology/biodiversity. In the analysis of alternatives, a comparison of scenario with and without the project has also been made. The final alternative was fixed based on Technical Feasibility, Socio-economic acceptability, and Environmental sustainability for Metro Corridors. The environmental study is carried out for the alignment proposed by MMRDA. The approach is to follow the sequence of steps adopted in an EIA study. The basic concept is to ascertain the existing baseline conditions and assess the impacts as a result of construction and operation of the project. The changes likely to occur in different components of the environment viz. physical, biological / ecological, environmental and socio-economic etc. have been studied, analyzed and quantified, wherever possible. The identification of parameters for data generation and impact assessment are important. The analysis of assessment depends upon the reliable data generated/

available on environmental attributed. This study has documented the baseline data for various parameters of physical, ecological and environmental pollution (air, water and noise). The impacts are assessed for various phases of project cycle namely:

- Impacts due to project location,
- Impacts due to project design,
- Impacts due to project construction, and
- Impacts due to project operation.

The impacts are categorized as negative and positive. The cost of management and monitoring programs were estimated and budgeted for.

9.2 PROJECT AREA

The metro project in Mumbai is proposed between Swami Samarth Nagar – Vikhroli (EEH). The proposed alignment would serve the city by providing connectivity between Swami Samarth Nagar – Vikhroli (EEH) alongwith the intermediate eastern suburban areas of Mumbai. The project area also includes the maintenance depot and construction depots in addition to viaduct and station areas. This metro corridor is proposed in Mumbai to cater the requirement of the city for a length of about 15.25 Km. Entire corridors will be elevated. The Metro corridor will have standard Guage alignment.

9.3 ENVIRONMENTAL SCOPING

Baseline environmental status in and around the proposed project depicts the existing environmental conditions of the location. Baseline data was collected for various/environmental attributes so as to compute the impacts that are likely to arise due to proposed project.

The scope of the present study includes detailed characterization of following environmental components, which are most likely to be influenced by the proposed project:

- ❖ Land Environment
- ❖ Water Quality (Surface + Ground water)
- ❖ Meteorological conditions
- ❖ Ambient Air Quality
- ❖ Noise Levels
- ❖ Biodiversity
- ❖ Socio Economic studies.

The information presented in this chapter has been acquired from various sources. Data on land environment has been collected and compiled from various reports and field surveys. The data on water, air, noise quality, and biodiversity were collected through field studies, sampling in September 2016. Climatological data was collected from India meteorological Department. Efforts have been made to compile the available data from literature, books, maps and reports. The methodology adopted for data collection is highlighted wherever necessary. Environmental Attributes and Frequency of Baseline Survey is presented in **Table 9.2**.

Table 9.2 Environmental Attributes and Frequency of Monitoring

S. No	Attribute	Parameter	No. of Samples	Source
LAND ENVIRONMENT				
1	Geology	Geological Status	---	Literature review
2	Seismology	Seismic Hazard	---	Literature review
WATER ENVIRONMENT				
3	Ground Water	Physical, Chemical and Biological parameters	Two	Sampling/Monitoring locations
4.	Surface Water	Physical, Chemical and Biological parameters	One	Sampling/Monitoring locations
AIR, NOISE AND METEOROLOGY				
4	Ambient Air Quality	PM_{10}, SO_2, NO_x	Three	Sampling/Monitoring locations
5	Noise	Noise levels in dB (A) Leq, Lmax, Lmin, L_{10}, L_{50}, L_{90}	Four	Sampling/Monitoring locations
SOCIO-ECONOMIC				
6	Socio-economic aspects	Socio-economic profile	Once	Field Studies, Literature review.
Ecology				
7	Trees	Number	Once	Filed Studies

Sampling locations of Water Quality, Noise Levels, and Ambient Air Qaulity are depicted in **Fig. 9.1**.

Fig. 9.1 Air Quality, Noise level and Water Sampling/Monitoring Sites

Table 9.3 Sampling / Monitoring Locations:

S. No	Monitoring Requirement	No of samples/ Locations	Location
1.	AA Q Monitoring – Pm10, Pm2.5, So2, Nox	03	1. Nr Shah, Hospital Jogeshwari 2. Nr. L & T Infotech, Powai 3. Powai Hospital, POwai
2.	Ground Water Sampling for Analysis – General Chemical & Micro Parameters	02	1. Shah Hospital, Jogeshwar 2. Powai Hospital
3	Surface Water Sampling for Analysis -	01	1. Powai Lake, Powai
4.	Noise Level Monitoring – 24 Hourly	04	1.Shah Hospital, Jogeshwar 2. L & T Infotech, Powai 3. Care and Cure Hospital, Powai 4. Powai Hospital, Powai

9.3.1 LAND ENVIRONMENT

The Project area is situated in Mumbai. The elevation of the project area is ranging between 3m near Vikhroli to 72 m above the mean sea level (a-MSL) near Mahakali Caves. Parameters involved in land environment are, physiography, geology and soils, and seismicity. These are discussed in the following paragraphs.

9.3.1.1 Geography, Geology and Soil

The total area of Mumbai is 437.71 km^2. Of this, the island city spans 67.71 km^2 while the suburban area spans 370 km^2 together accounting for 437.71 km^2 under the administration of Municipal Corporation of Greater Mumbai (MCGM).

Mumbai lies at the mouth of the Ulhas River on the western coast of India, in the coastal region known as the Konkan. It sits on Salsette Island (Sashti Island), which it partially shares with the Thane district. Mumbai is bounded by the Arabian Sea to the west. Many parts of the city lie just above sea level, with elevations ranging from 1m to 15; the city has an average elevation of 14 m. Northern Mumbai (Salsette) is hilly, and the highest point in the city is 450 m at Salsette in the Powai–Kanheri ranges. The Sanjay Gandhi National Park (Borivali National Park) is located partly in the Mumbai suburban district, and partly in the Thane district, and it extends over an area of 103.09 km^2.

Apart from the Bhatsa Dam, there are six major lakes that supply water to the city: Vihar, Lower Vaitarna, Upper Vaitarna, Tulsi, Tansa and Powai. Bhatsa supply about 50% of city water requirement. Tulsi Lake and Vihar Lake are located in Borivili National Park, within the city's limits. The supply from Powai lake, also within the city limits, is used only for agricultural and industrial purposes. Three small rivers, the Dahisar River, Poinsar (or Poisar) and Ohiwara (or Oshiwara) originate within the park, while the polluted Mithi River originates from Tulsi Lake and gathers water overflowing from Vihar and Powai Lakes. The coastline of the city is indented with numerous creeks and bays, stretching from the Thane creek on the eastern to Madh Marve on the western front. The eastern coast of Salsette Island is covered with large mangrove swamps, rich in biodiversity, while the western coast is mostly sandy and rocky.

Soil cover in the city region is predominantly sandy due to its proximity to the sea. In the suburbs, the soil cover is largely alluvial and loamy. The underlying rock of the region is composed of black Deccan basalt flows, and their acidic and basic variants dating back to the late Cretaceous and early Eocene eras.

9.3.1.2 Seismicity

The country has been classified into different zones indicating the intensity of damage or frequency of earthquake occurrences. Mumbai sits on a seismically active zone owing to the presence of 23 fault lines in the vicinity. Mumbai falls in zone III according to IS 1893: 2002 which means an earthquake upto magnitude 6.5 on Richer scale may be expected (Figure 9.2).

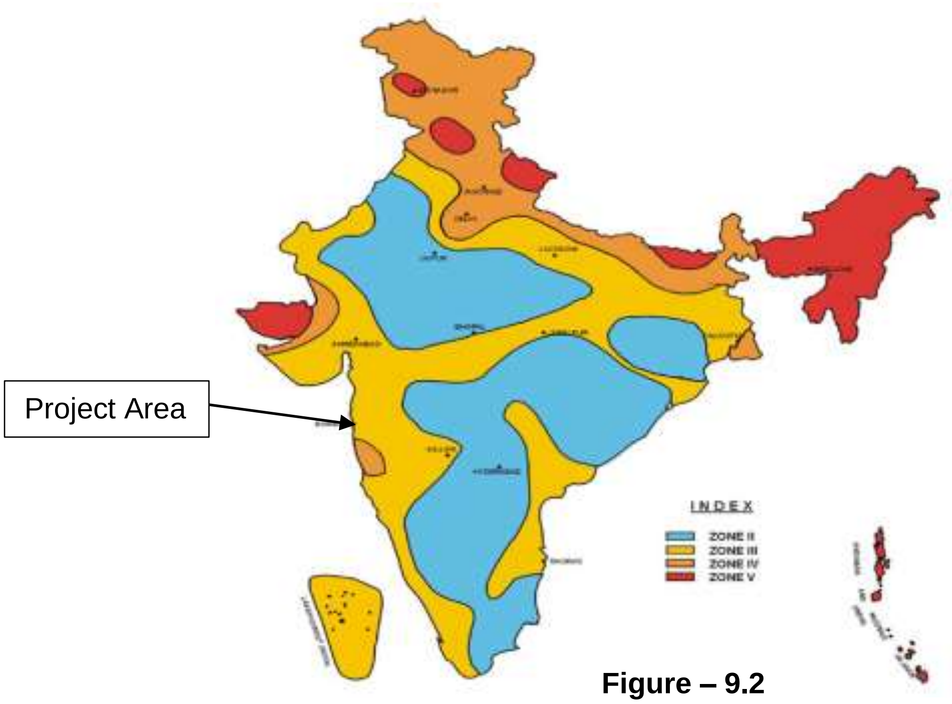


Figure – 9.2

9.4 WATER ENVIRONMENT

Water environment consists of water resources and its quality. Its study is important from the point of view of assessing the sufficiency of water resources for the needs of the project in its various stages of the project cycle and also to assess the impact of the project on water environment. In the proposed project, ground water is proposed to be used during operations to meet out domestic water requirements of the project in case water is not made available by Municipal Corporation of Greater Mumbai (MCGM). Hence its quality has been tested to evaluate its suitability for the intended purpose. Anticipated impacts of the proposed project on water environment have also been addressed.

9.4.1 WATER RESOURCES

Under colonial rule, tanks were the only source of water in Mumbai, with many localities having been named after them. The MCGM supplies potable water to the city from six lakes, most of which comes from the Tulsi and Vihar lakes. The Tansa lake supplies water to the western suburbs and parts of the island city along the Western Railway. The water is filtered at Bhandup, which is Asia's largest water filtration plant. India's first underground water tunnel was completed in Mumbai to supply water to the Bhandup filtration plant.

About 700 million litres of water, out of a daily supply of 3500 million litres, is lost by way of water thefts, illegal connections and leakages, per day in Mumbai. Almost all of Mumbai's daily refuse of 7,800 metric tonnes, of which 40 metric tonnes is plastic waste, is transported to dumping grounds in Gorai in the northwest, Mulund in the northeast, and to the Deonar dumping ground in the east. Sewage treatment is carried out at Worli and Bandra, and disposed of by two independent marine outfalls of 3.4 km and 3.7 km at Bandra and Worli respectively.

9.4.2 HYDROGEOLOGY AND GROUND WATER

The entire Mumbai district is underlain by basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow Alluvium formation of Recent age also occur as narrow stretch along the major river flowing in the area. Hydrogeologicla map of Mumbai is given in **Fig. 9.3**.

Hard Rock Areas: Deccan Trap Basalt

The 'Pahoehoe' flows in the district consist of highly vesicular bottom layer having closely spaced horizontal joints but the thickness is generally less. The vesicles are generally filled with secondary minerals and green earths. In such cases, they do not serve as aquifer. However, such vesicular zones are weathered in most part of the area, thus, making them moderately permeable. But if, vesicles are not filled, they act as highly permeable aquifers. The simple and compound "Pahoehoe" flow comprises a basal vesicular zone, middle relatively massive portion followed by a vesicular top. The vesicles of "Pahoehoe" flows are generally not interconnected and thus there is a variation in water holding capacity from the base to the top of the flow.

The ground water exists in fractures, joints, vesicles and in weathered zone of Basalt. The occurrence and circulation of ground water is controlled by vesicular unit of lava flows and through secondary porosity and permeability developed due to weathering, jointing, fracturing etc., of Basalt. The ground water occurs under phreatic, semi confined and confined conditions. The leaky confined conditions are also observed in deeper aquifers. Generally, the phreatic aquifer ranges down to depth of 15 m bgl. The water bearing zone down to depth of 35 m bgl forms the semi confined aquifer and below this deeper aquifer down to depth of 60 m bgl is observed. The yield of the dugwells varies from 10 to 1000 m^3/day, whereas that of borewells ranges between 50 and 1000 m^3/day. It is expected that the potential of deeper aquifers would be much more limited as compared to the unconfined/phreatic aquifer.

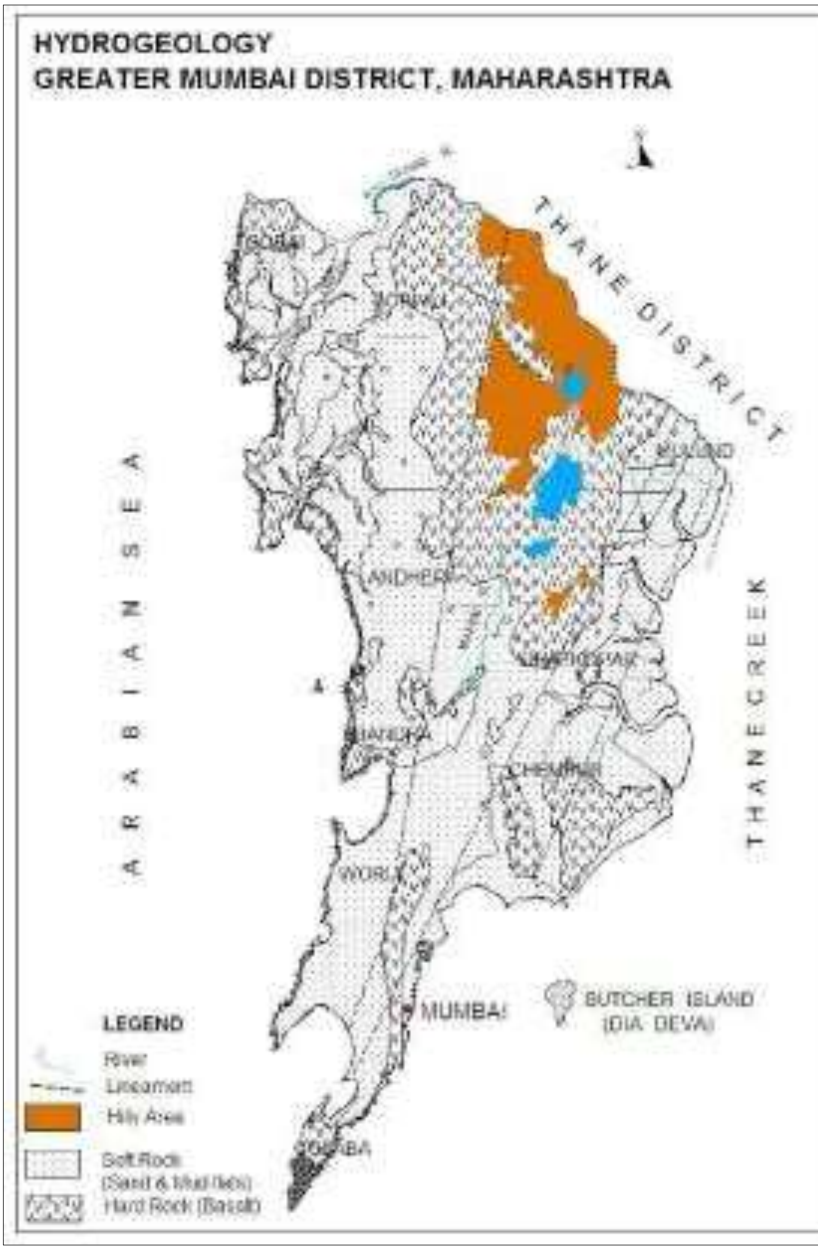


Fig. 9.3 Hydrogeological map of Greater Mumbai.

Soft Rock Areas: Alluvium

River Alluvium patches along the course of rivers and Marine Alluvium in the coastal area, are highly potential aquifer but with limited areal extent. The ground water occurs under water table condition in sandy / gritty layers. The alluvial fill of low lying areas underlain by weathered basalt has relatively better ground water potential.

Yields of Wells

The yields of the wells are the functions of the permeability and transmissivity of aquifer encountered. This varies with location, diameter and depth of wells. There are mainly two types of ground water structures i.e. dugwells and borewells in the area. The yields of the dugwells varies form 10 to 1000 m^3/day, whereas that of borewells ranges between 50 and 1000 m^3/day tapping the promising aquifer in the depth range of 60 to 80 m bgl, however, majority of the borewells are low yielding. The variation in yield between pre-monsoon and post-monsoon is quite high.

9.4.3 Water Quality

Water quality is the physical, chemical and biological characteristics of water. It is most frequently used with reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality are related to drinking water, safety of human contact, and for health of ecosystems. An understanding of the various factors influencing water quality is thus very important as human health is largely dependent on the quality of water available for our use. Water sampling Sites have been shown in **Fig. 9.1.**

Groundwater quality is quite good. However, total dissolved solids are a little higher than the desirable limits but within permissible limits. All other parameters are well within the desirable limits.

Table 9.4 Ground Water Quality at Project Site

Physical Parameters	Results		Limits
Sample	**Shah Hospital, Jogeshwari**	**Powai Hospital, Powai**	
Date of Sampling	**18-09-2016**	**18-09-2016**	
Colour, Hazen	Colourless	Colourless	5 (15) Max
Odour	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Agreeable	Agreeable	Agreeable
Turbidity, NTU	3.2	2.9	1 (5) Max
PH	7.81	7.85	6.5-8.5 Max
Total Hardness as Caco3, Mg/l	248	254	200 (600) Max
Chloride as Cl, Mg/l	139	127	250 (1000) Max
Total Iron as Fe, Mg/l	0.09	0.07	0.3 Max
Total Dissolved Solids, Mg/l	1495	1396	500 (2000) Max
Sulphates as So4, Mg/l	170	129.0	200 (400) Max
Nitrates as No3, Mg/l	64.9	39.9	45 Max
Fluorides as F, Mg/l	2.61	2.24	1.0 (1.5) Max
Lead as Pb, Mg/l	BDL	BDL	0.01 Max
Copper as Cu,Mg/l	BDL	BDL	0.05 (1.5) Max
Manganese as Mn,Mg/l	BDL	BDL	0.1 (0.3) Max
Phenolic Compound as C6H5OH,Mg/l	BDL	BDL	0.001 (0.002) Max
Mercury as Hg,Mg/l	BDL	BDL	0.001 Max
Cadmium as Cd,Mg/l	BDL	BDL	0.01 Max
Selenium as Se, Mg/l	BDL	BDL	0.01 Max
Arsenic as As,Mg/l	BDL	BDL	0.05 Max
Cyanide as Cn,Mg/l	BDL	BDL	0.05 Max
Zinc as Zn, Mg/l	1.17	1.23	5 (15) Max
Detergent as MBAS, Mg/l	BDL	BDL	0.2 (1.0) Max
Chromium as Cr+6 ,Mg/l	BDL	BDL	0.05 Max
Total Alkalinity as Caco3,Mg/l	188.2	171.4	200 (600) Max
Aluminum as Al,Mg/l	BDL	BDL	0.03(2) Max
Boron as B, Mg/l	BDL	BDL	0.5(1) Max
Bacteriological Analysis Coliform,MPN/100Ml E-Coli/Ml	 Nil Negative	 Nil Negative	 10 Max Negative

9.5 METEOROLOGY

9.5.1 GENERAL

Mumbai has a tropical climate, specifically a tropical wet and dry climate (Aw) under the Köppen climate classification, with seven months of dryness and peak of rains in July. The cooler season from December to February is followed by the summer season from March to June. The period from June to about the end of September constitutes the south-west monsoon season, and October and November form the post-monsoon season.

Between June and September, the south west monsoon rains lash the city. Pre-monsoon showers are received in May. Occasionally, north-east monsoon showers occur in October and November. The maximum annual rainfall ever recorded was 3,452 mm for 1954. The highest rainfall recorded in a single day was 944 mm on 26 July 2005. The average total annual rainfall is 2,146.6 mm for the Island City, and 2,457 mm for the suburbs.

The average annual temperature is 27.2 °C, and the average annual precipitation is 2,167 mm. In the Island City, the average maximum temperature is 31.2 °C, while the average minimum temperature is 23.7 °C. In the suburbs, the daily mean maximum temperature range from 29.1 °C to 33.3 °C, while the daily mean minimum temperature ranges from 16.3 °C to 26.2 °C. The record high is 42.2 °C set on 14 April 1952, and the record low is 7.4 °C set on 27 January 1962.

9.5.2 TEMPERATURE

The temperature data for Mumbai has been taken. The month-wise minimum & maximum temperatures have been given in **Table 9.5.**

Table 9.5 Normal Temperature at Mumbai

Month	Mean Daily Maximum Temperature, °C	Mean Daily Minimum Temperature, °C
January	30.7	16.8
February	31.2	17.8
March	32.5	21.0
April	33.0	23.9
May	33.3	26.3
June	32.1	26.0
July	30.0	24.9
August	29.6	24.7
September	30.4	24.3
October	33.2	23.4
November	33.5	20.9
December	32.0	18.6
Annual	31.8	22.4

Source: India Meteorological Department, Govt. of India.

9.5.3 RAINFALL

The detail of rainfall at the Mumbai (Santacruz) is given in **Table 9.6.**

Table 9.6 Month-wise Rainfall at Mumbai

S. No.	Month	Rainfall	Peak Rainfall
1	January	0.6	
2	February	1.3	
3	March	0.2	
4	April	0.7	
5	May	12.5	
6	June	523.1	2220.6
7	July	799.7	
8	August	529.7	
9	September	312.3	
10	October	55.8	
11	November	16.8	
12	December	5.3	
Annual	Annual	2258.0	

Source: India Meteorological Department, Govt. of India.

9.5.4 AIR ENVIRONMENT

The atmospheric concentrations of air pollutants were monitored at 7 locations near the proposed alignment during the month of February 2016. Locations of air monitoring station are shown in Figure 9.1. Air Monitoring was carried out for PM_{10}, NOx, SO_2 and CO. Results of the air quality monitoring are presented in Table 9.7.

Table 9.7 Ambient Air Quality Results µg/m3

Sl. No	Parameter	Shah Hospital, Jogeshwari	Nr. L&T Infotech	Nr, Powai Hospital, Powai	Regulatory Standards (NAAQS) Residential/ Sensitive 24 hourly
Date of Monitoring September 2016		17 to 19	17 to 19	17 to 19	
1	RSPM PM-10	182	194	212	100
2	Oxides of Sulphur - SO_2	34.2	32.1	31.1	80
3	Oxides of Nitrogen – NOx	45.4	42.9	42.8	80
4	Carbon Monoxide CO	1468	1623	1840	2000

RSPM= Respirable Suspended Particulate Matter.

The results show that the concentration of RSPM (PM_{10}) is higher at all the locations whereas all other parameters are within permissible limits.

9.5.5 NOISE ENVIRONMENT

Noise is responsible for adverse impacts on physical and mental health of the people. The other impacts are:

- Physiological effects,
- Hearing impairment,
- Communication interference, and
- Sleep disruption

Noise level survey was conducted along the alignment with an objective to establish the baseline noise levels and assess the impacts of total noise expected due to the proposed metro. Noise levels were measured at four locations on 17-18 September 2016 for 24 hours. The locations of Noise level monitoring have been shown in **Fig. 9.1**. The noise levels so obtained are summarized in **Table 9.8.**

Table 9.8 Noise Levels

Location		L Max	L Min	Leq	L_{10}	L_{50}	L_{90}
Shah Hospital, Jogeshwari	Day	88.9	57.1	75.5	81.4	75.2	60.4
	Night	848	49.5	67.9	74.7	62.4	55.4
L & T Infotech, Powai	Day	85.6	55.9	72.8	77.6	69.6	61.7
	Night	74.1	50.6	62.2	66.7	56.1	54.2
Care and Cure Hospital, Powai	Day	80.2	51.6	70.3	76.9	62.3	55.8
	Night	75.0	49.9	61.9	73.3	61.3	53.6
Powai Hospital, Powai	Day	78.2	53.1	76.6	82.6	71.7	69.8
	Night	78.4	48.5	59.7	68.5	56.7	52.8

Allowable Noise Levels dB (A):

Category of Area/Zone	Day Time	Night Time	
Industrial Area	75	70	EPA-1986, Noise pollution (Regulation Control), Rule-2000, PCLS/02/1992, IVth Edition.
Commercial Area	65	55	
Residential Area	55	45	
Silence Area	50	40	

Day Time (6.00 Am-10.00 Pm); Night Time (10.00 Pm-6.00Am)

The observed noise level is higher than the permissible limits at all locations which may be due to heavy traffic movement and other activities on the roads.

9.5.6 TREES

Tree survey has been carried out along the proposed alignment. Tree with Girth at Breast Height (GBH) 30 cm have been counted. The alignment does not pass through any forest area. A total of 57 trees are located along the alignment and station area. Depot area may be having more trees. Thus, there is likelihood of felling of 57 trees. No endangered species of trees have been noticed during field survey. Trees have been found of indigenous and common species like Pipal, Jamun, Neem, Coconut, Palm, Babool, Ber, Gulmohar and Tadi etc.

9.5.7 FLORA AND FAUNA

Sanjay Gandhi National Park earlier known as Borivali National Park is the nearest reserve area which is about 4 Km on northern direction of the alignment. This is the miraculously preserved green oasis in the center of urban sprawl. This national park is "one of the very few" that is surrounded by a metropolis like Mumbai, yet sustaining sizable population of big cats like panthers. It is hard to believe that with in just less then an hour and half from Gateway of India, one is transported from hectic and fast life of Mumbai city to a serene and tranquil atmosphere of pleasing verdant wilderness. The rich and diverse forest holds more than one thousand species of plants, 40 species of mammals, 251 of birds, covering migratory, land and water birds, 38 species of reptiles, 9 species of amphibians besides a large variety of fishes.

Flora: The park is a tree lovers delight in all seasons with the great amount of bio-diversity, ranging from Adina cardifolia (kadamb), Albizzia lebbek (Shirish), Pongamia pinnata (Karanj), Tectona grandis (Teak) Dalbergia latifolia (Sishum) to Acacia, Zizyphus and evergreen patches of Euphorbial in the dry month of February to May, spectacular flowering of Butea monosperma (Flame of Forests) is a real feast to eye. Flowering of Bombax malabaricum (Semal) and Erythrina indica (Indian coral tree) add colour. There are large patches of Bamboo, which make the feel of the jungle even better. The forest has a lot of Liana (woody climbers), a remnant from wetter evergreen past, many species of orchids and a large variety of shrubs. Every monsoon is a riot of colors from violet of Zingiberaceae species to the stark white of costus species. Among the many spectacular sights one that is definitely is mostworthy, is seven yearly mass flowering of Strobilanthus species (Karvi). Thousands and thousands of these flowers cover the hill slopes giving purple touch to this beautiful landscape.

Fauna: The national Park is a bird watcher paradise. From the tiny Tickell's flower pecker (small bird in India), many species of sun bird (humming birds) to the majestic white bellied sea eagle, it is virtual visual feast with birds like paradise flycatcher, the elusive Trogon, many species of Kingfishers, Woodpeckers, and Drongos. The continuous calling of large large green barbet, the wildly screeching parakeets, the metallic calls of the Racket-trailed Drongo, the musical call of the Blue flycatcher or the extremely melodious some of the Malabar whistling thrush or the familiar refrain of the Spotted babbler are just a few facets of nature's symphony in this forest.The Reptilian world is well represented from Crocodiles in Tulsi lake to Monitor lizards to Pythons, Cobras, Russess' viper, Bamboo pit viper. Smaller reptiles add to the wonder of this part. The invertebrate world from Crabs to Spiders to insects, Giant wood spiders, Signature spiders, Black wood spider with their large webs in monsoon are a real treat. The insect world from Silk cotton bugs to Beetles to various kinds of Mantis. The Butterfly world is represented in such a fascinating range of sizes and colours, from the spectacular Blue Mormon to the phenomenal artist of camouflage the Blue Oak leaf, the bright jezebels and Large Yellow and White Orange tips, Monarchs, Egg flies, Sailers are some of the many attractive butterflies one can find here.

9.6 SOCIO- ECONOMIC CONDITIONS

Socially and culturally this area is cosmopolitan in nature. According to the 2011 census, the population of Mumbai was 12,479,608. The population density is estimated to be about 20,482 persons per square kilometre. The living space is 4.5sq metre per person. As Per 2011 census, Greater Mumbai, the area under the administration of the MCGM, has a literacy rate of 94.7%, higher than the national average of 86.7%.

The sex ratio was 838 (females per 1,000 males) in the island city, 857 in the suburbs, and 848 as a whole in Greater Mumbai, all numbers lower than the national average of 914 females per 1,000 males. The low sex ratio is partly because of the large number of male migrants who come to the city to work.

Residents of Mumbai call themselves Mumbaikar, Mumbaiite, Bombayite or Bombaiite. Mumbai has a large polyglot population like any other metropolitan city of India. Sixteen major languages of India are also spoken in Mumbai, most common being Marathi, Hindi, Gujarati and English. English is extensively spoken and is the principal language of the city's white collar workforce. A colloquial form of Hindi, known as Bambaiya – a blend of Marathi, Hindi, Gujarati, Konkani, Urdu, Indian English and some invented words – is spoken on the streets.

Mumbai suffers from the same major urbanisation problems seen in many fast growing cities in developing countries: widespread poverty and unemployment, poor public health and poor civic and educational standards for a large section of the population. With available land at a premium, Mumbai residents often reside in cramped, relatively expensive housing, usually far from workplaces, and therefore requiring long commutes on crowded mass transit, or clogged roadways. Many of them live in close proximity to bus or train stations although suburban residents spend significant time travelling southward to the main commercial district. With a literacy rate of 69%, the slums in Mumbai are the most literate in India.

9.7 SOCIO-ECONOMIC SURVEY

A socio-economic survey was undertaken for the proposed corridor to assess the socio-economic conditions of project-affected families/people and to examine the impacts of the proposed metro alignment on their conditions. There can be two types of impacts on the PAPs. One is the displacement of residential house and another is displacement of commercial establishments

On the other hand, the area on link road is being acquired by BMC for road widening project and construction of Road Overbridge at JVLR junction to Adarsh Nagar. Therefore, the details of families have not been taken from these families. Land is mainly required for viaduct, construction of stations and allied services, construction of Depot including laying of stabling lines, workshops, washing lines, administrative buildings and Water, Sewage and Effluent treatment systems in addition to storage facilities. Additionally, land is also required for RSS.

The survey has been undertaken on the corridors using structured questionnaire. It has been found that a total of 99 residential and 38 commercial structures are getting affected by the construction of proposed project. The commercial establishments have also employed 48 employees who are working for a period of 2 to 5 years.

9.8 ARCHAEOLOGICAL SITES

There are many heritage sites in Mumbai which are very much far off from the corridor alignment. The Chhatrapati Shivaji Terminus, formerly known as Victoria Terminus, is the headquarters of the Central Railway and a UNESCO World Heritage

Site. The architecture of the city is a blend of Gothic Revival, Indo-Saracenic, Art Deco, and other contemporary styles. Most of the buildings during the British period, such as the Victoria Terminus and Bombay University, were built in Gothic Revival style. Their architectural features include a variety of European influences such as German gables, Dutch roofs, Swiss timbering, Romance arches, Tudor casements, and traditional Indian features. There are also a few Indo-Saracenic styled buildings such as the Gateway of India. Art Deco styled landmarks can be found along the Marine Drive and west of the Oval Maidan. The proposed alignment of Mumbai Metro corridor does not pass through or near any of the Archaeological monuments or heritage sites.

9.9 ENVIRONMENTAL IMPACTS ASSESSMENT

9.9.1 ENVIRONMENTAL IMPACTS

This section identifies and appraises the negative impacts on various aspects of the environment likely to result from the proposed development. It is pertinent to mention that the negative environmental impacts listed below are based on the assumption that no negative impact mitigation measure or benefit enhancements are adopted.

- Land Environment
- Water Environment
- Air Environment
- Noise Environment
- Biological Environment
- Socio-Economic Environment

The impacts on the above environmental components have been further assessed during various phases of project cycle namely project location, project design, construction and operation.

9.9.2 IMPACTS DUE TO PROJECT LOCATION

During this phase, those impacts, which are likely to take place due to the layout of the project, have been assessed. These impacts are:

- Project Affected People (PAPs)
- Change of Land use;
- Loss of trees/forest;
- Utility/Drainage Problems,
- Socio-economic impacts;
- Impact on Historical and Cultural Monuments;

9.9.2.1 Project Affected People (PAPs)

There will be acquisition of private land and property in this project hence there are many PAPs as a result of the project activity. Detailed socio-economic assessment has been made for PAPs in Social Impact Assessment.

9.9.2.2 Change of Land Use

The details of land required (permanent and temporary) and change in land use are presented in **Table 9.9.** The required land (permanent & temporary) for the construction of the proposed alignment is both government as well as private land which shall be allotted by Mumbai Metropolitan Regional Development Authority. Private land will be acquired as per the provisions of The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act 2013 (Act 30 of 2013) and Resettlement and Rehabilitation Policy for Mumbai Urban Transport Project (MUTP) notified in March 1997 and amended in December 2000.

Table 9.9 Change in Land Use

S.No.	Corridor	Land Requirement (m^2)		Temporary casting yard/ site office	Total
		Govt.	Private	Govt.	
1.	Station & facilities	11332	6417	-	17749
2.	Running Sections	5362	32024	-	37386
3.	Depot	150000	-	-	150000
4.	Staff Quarters	5000	-	-	5000
5.	OCC	5000	-	-	5000
6.	Receiving Sub Station	11200	-	-	11200
7.	Temporary Office/ Site Office	6000	-	-	6000
8.	Segment Casting Yards	-	-	60000	60000
	Total	193894	38441	60000	292335

Source: DPR

9.9.2.3 Loss of Forests/ Trees

The proposed metro lines are in urban/ city area and will not pass through any forests. Hence no loss to forest is anticipated due to the project. However, trees do exist in patches in the corridor selected for the project. There are about 57 trees which are likely to be felled during construction.

Trees are assets in purification of urban air, which by utilizing CO_2 from atmosphere, release oxygen into the air. However, with removal of these trees, the process for CO_2 conversion will get effected and the losses are reported below:

i) Total number of Trees : 57
ii) Decrease in CO_2 absorption @ 21.8 Kg/ year tree for 8 years : 9940.8 kg
iii) Oxygen production @ 49 kg/ year tree For 8 years : 22344 kg

The average consumption of oxygen for a person is about 182 kg/ year. It means these trees will meet the requirement of about 123 people round the year. Trees help carbon sequestration acting as a carbon sink. By removing the carbon and storing it as cellulose, trees release oxygen back into the air.

9.9.2.4 Utility/ Drainage Problems

Metro lines are mostly planned to run through the urban area. The alignment will cross many properties, drains/ nalas, large number of sub-surface, surface and utility services, viz. sewer, water mains, storm water drains, telephone cables, overhead electrical transmission lines, electric pipes, roads, traffic signals etc. These utilities/ 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 affect construction and project implementation time schedule/ costs for which necessary planning/ action needs to be initiated in advance.

9.9.2.5 Socio-Economic Impact on PAPs

The area between link road and Jogeshwari including Momin Nagar etc. is being acquired by BMC for road widening and overbridge project. Therefore, the details of families have not been taken from these families. Land is mainly required for viaduct, construction of stations and allied services, construction of Depot including laying of stabling lines, workshops, washing lines, administrative buildings and Water, Sewage and Effluent treatment systems in addition to storage facilities. Additionally, land is also required for RSS. A total of 99 residential and 38 commercial establishments are getting affected due to the project due to viaduct and stations. The commercial establishments are having 48 employees.

9.9.2.6 Impact on Archaeological Sites

There is no historical monument having any archeological value in the vicinity of the proposed alignment. Thus on this aspect there would be no impact.

9.9.2.7 Impact on Sensitive Receptors

There are many sensitive receptors along the alignment like hospitals, schools and religious places but care has been taken to keep safe distance between the alignment and sensitive receptors. However, during operation stage care would be taken to provide noise barriers of suitable design between hospitals and the alignment to minimize the impact.

9.9.3 IMPACTS DUE TO PROJECT DESIGN

Considered impacts, due to project designs are:

- Lighting,
- Risk Due to Earthquake.

9.9.3.1 Lighting

The platforms, concourse, staircase and escalator areas for the elevated stations will have adequate and uniform fluorescent lighting to provide pleasant and cheerful environment. It is proposed to adopt the norms prevailing in Metro for illumination. It is pertinent to note that care has been taken at design stage itself to avoid too much illuminating the stations. Maximum illumination level proposed is 200Lux which provides normal lighting.

9.9.3.2 Risk Due to Earthquake

The project area lies in Zone III of Bureau of Indian Standards (BIS) Seismic Zoning Map (**Fig. 9.2**). Seismic factor proposed by India Meteorological Department (IMD) for the purpose of design of Civil Engineering structures shall be incorporated suitably while designing the structures.

9.9.4 IMPACTS DUE TO PROJECT CONSTRUCTION

Although environmental hazards related to construction works are mostly of temporary nature. Appropriate measures should be included in the work plan and budgeted for. The most likely negative impacts related to the construction works are:

- Top Soil erosion, pollution and health risk at construction site,
- Traffic diversion and risk to existing building,
- Excavated soil disposal problems,
- Dust Generation,
- Increased water demand,
- Impact due to Supply of Construction Material,
- Disposal of Construction and Demolition Waste,
- Impacts due to batching plant and casting yard,
- Noise Pollution,

9.9.4.1 Soil Erosion, Pollution and Health Risk at Construction Site

Every care has to be taken to avoid damage to the top soil. It has to be preserved and utilized. Problems could arise from dumping of construction spoils (Concrete, bricks) waste materials (from contractor camps) etc causing surface and ground water pollution. However, it is proposed to have mix concrete directly from batching plant for use at site. Health risks include disease hazards due to lack of sanitation facilities in labour camps (water supply and human waste disposal) and insect vector disease hazards of local workers and disease hazards to the local population. Mitigation measures should include proper water supply, sanitation, drainage, health care and human waste disposal facilities. In addition to these, efforts need to be made to avoid water spills, adopt disease control measures and employment of local labour. Problems could arise due to difference in customs of workers from outside and local residents. These risks could be reduced by providing adequate facilities in worker's camps, raising awareness amongst workers and by employment of preferably local labour.

9.9.4.2 Traffic Diversions and Risk to Existing Buildings

During construction period, complete/ partial traffic diversions on road will be required, as most of the construction activities are on the central verge of road. Traffic would get affected on the roads. Rather than completely blocking the roads it will be advisable to make the narrow portion of roads as one way to allow for operation of traffic together with construction activities. Advance traffic updates/ information on communication systems will be an advantage to users of affected roads. The rail corridor does not pose any serious risk to existing buildings since there is safe distance between buildings and proposed corridor except at a few places where shops and JJ clusters are affected due to the alignment. Moreover, at many places station area would affect many buildings which may be avoided by suitably adjusting the station layouts. Special care has to be taken for safety of the structures during construction when they will be shifted for short duration.

9.9.4.3 Problems of Excavated Soil and Bentonite Disposal

The proposed alignment is elevated and thus the excavation would be limited to piers and their piling. The soil would be used for refilling at station site. If there would be some residual soil, it would be utilized by MMRDA for internal use for refilling Depot sites and, if surplus, it would be disposed off at designated locations as per Mumbai Authority directions. Some Bentonite muck would also be generated in the project. Disposal of Bentonite would be at designated land fill site.

9.9.4.4 Air Pollution and Dust Generation

Transportation of earth and establishment of the material will involve use of heavy machinery like compactors, rollers, water tankers, and dumpers. This activity is machinery intensive resulting in dust generation. Simultaneously there would be fugitive gas emissions due to vehicular and machinery exhausts during their working during construction. However, this activity will be only short-term. Protective measures shall be undertaken during construction phase. Movement of trucks and other heavy equipment at construction site would generate dust during construction phase.

9.94.5 Water Pollution

Source of Water contamination will be from the washings and the surplus water from curing the structures which shall be diverted and passed through desilting chambers before letting it go outside the working site. Muck shall not be allowed to confluence with any water course.

9.9.4.6 Increased Water Demand

The water demand will increase during construction phase for meeting out drinking and domestic water requirement of workers. Sufficient water for construction purpose would be made available by MCGM as it is responsible for water supply in Mumbai. Water requirement for construction of Metro will be met through the public supply. It is suggested to use treated STP water for the purpose of Construction. Proper care shall be taken while drawing water from public facilities to avoid any negative impact on the residents living in the vicinity of the project whose water demand is, in any case, met by Municipal Corporation of Greater Mumbai supplied water.

9.9.4.7 Impact due to Supply of Construction Material

Metro construction is a material intensive activity. Huge quantity of different construction materials will be required for construction of metro corridor. These shall be sourced from the nearest source. Quarry operations are independently regulated activities and outside the purview of the project proponent. It is nonetheless, appropriate to consider the environmental implications in selection of quarry sources since poorly run operations create dust problems, contribute noise pollution, ignore safety of their employees, or cause the loss of natural resources. Although quarry operation is out of perview of the metro construction but, the construction material shall be sourced only from legalized and approved quarries.

9.9.4.8 Generation of Construction and Demolition Waste

Construction and demolition (C&D) debris is defined as that part of the solid waste stream that results from land clearing and excavation, and the construction, demolition, remodeling and repair of structures, roads and utilities. C&D waste includes concrete, stones and dirt generated during excavation (sometimes collectively referred to as "fill material" or rubble). C& D Waste may be generated from Pile caps, residual cement bags, residual steel scrap, excess construction material stacked at site etc. It is a waste stream that is separate and distinct from residential and commercial waste, commonly called municipal solid waste (MSW).

About 10-15% of the construction material such as waste material from contractor camps is left behind by the contractor as construction waste/ spoils. Dumping of construction waste/spoil in haphazard manner may cause surface and ground water pollution near the construction sites. The C& D waste would be handled and disposed off to C&D waste processing facility or for back filling of low lying areas, leaving no significant impact on environment.

9.9.4.9 Impacts due to Casting Yard and Batching Plant

During construction phase there would be establishment and operation of Batching Plant and Casting Yard which would be located in an area designated and allotted by MMRDA away from habitation. There would be requirement to get NOC (Consent to establish) and Consent to operate under water and air Acts from Maharashtra Pollution Control Board at the time of establishing the facilities. Simultaneously, there would be requirement to get the authorization for storage and handling of hazardous chemicals to store and handle used oils and other such materials. The Application forms for seeking Consent to establish, Consent to Operate and Authorization for storage of Hazardous chemicals are available from the office of Maharashtra Pollution Control Board at Mumbai.

There would be significant movement of men, material and machinery in batching plant and casting yard. It is expected that both batching and casting yard would be located at same complex. Huge quantity of Cement, aggregetes and other construction materials would be used in batching plant and casting yard. There would be generation of dust, noise, flue gases and other contaminants from the working of heavy machinery for handling and transporting the construction materials. The mitigation measures have been elaborated in EMP.

9.9.4.10 Noise Pollution

The major sources of noise pollution during construction are movement of vehicles for transportation of construction material to the construction site and the noise generating activity at the construction site itself. The Metro construction is equipment intensive.

9.9.4.11 Vibrations

There may be vibration during piling operations due to working of heavy construction machinery and the movement of heavy transport vehicles, loading and unloading of materials etc. This would be a short term activity and effort will be made to avoid piling operations during night between 11.00 pm to 5.00 am.

9.9.4.12 Loss of Historical and Cultural Monuments

No historical/ cultural monuments will be lost because of the proposed development.

9.9.5 IMPACTS DUE TO PROJECT OPERATION

Along with many positive impacts, the project may cause the following negative impacts during operation of the project due to the increase in the number of passengers and trains at the stations:

- Noise pollution,
- Water supply and sanitation at Stations,

- Station refuse disposal and sanitation,
- Pedestrianization and visual issues

9.9.5.1 Noise Pollution

During the operation phase the main source of noise will be from running of metro trains. Noise radiated from train operations and track structures generally constitute the major noise sources. Airborne noise is radiated from elevated structures. The noise level at 2 m distance from the rail alignment is about 73 dB(A) as per the experience in operating metro system. The noise level reduces with distance logarithmically. At places, the alignment is likely to be passing close to the buildings which may affect the residents. At such places noise barriers would be used to minimize the noise impact in the vicinity of the alignment.

9.9.5.2 Water Supply and Sanitation at Stations

Public facilities such as water supply, sanitation and wash rooms are very much needed at the stations. The water requirement for stations would be for drinking, toilets, cleaning and also for other purpose like AC. Water Demand as per existing Metro corridors is calculated and presented in **Table 9.10**. It is assumed that there would be similar water requirements in Mumbai Metro as well. Raw water should be treated and brought to national drinking water standards, before used for consumption. In addition, water will be required for contractor's camps during construction. The water requirement for the stations will be met through the public water supply system or purpose built tubewells after taking necessary approvals from CGWA. However, as an environmental conservation measure, rainwater harvesting structure will also be constructed at stations and along the via-duct.

Table 9.10 Water Requirement at Stations

S. No.	Particular	Water Demand for each station KLD
1	At Stations for Drinking Purpose	6
2	At Elevated stations for AC, cleaning, chiller and other purposes	17
Total		**23**

Thus there would be total water requirement of 299 KLD in 13 stations. However, arrangement of water will have to be made at each station separately.

9.9.5.3 Station Refuse

The collection and removal of refuse from stations in a sanitary manner is of great importance for effective vector control, nuisance abatement, aesthetic improvement and fire protection. The refuse from station includes;

- Garbage,
- Rubbish, and
- Floor Sweepings.

As per the available data from Delhi Metro Phase I and II and other operational metros, the solid waste generation is about 0.8 – 1.2 cum/day at elevated stations. At elevated stations, the solid waste generation is more due to airborne dust. Thus about 10 to 15.6 cum of solid waste will be generated from the thirteen stations of this corridor of Mumbai metro. The maintenance of adequate sanitary facilities for temporarily storing refuse on the premises is considered a responsibility of the project authorities. The storage containers for this purpose need to be designed. However, it is suggested that the capacity of these containers should not exceed 50 litres and these should be equipped with side handles to facilitate handling. To avoid odour and the accumulation of fly-supporting materials, garbage containers should be washed at frequent intervals.

9.9.5.4 Visual Impacts

The introduction of MRTS implies a change in streets through which it will operate. An architecturally well designed elevated section can be pleasing to the eyes of beholders. Recent MRTS projects have attempted to incorporate this objective in their designs. Since a low profile would cause the least intrusion, the basic elevated section has been optimised at this stage itself.

9.9.5.5 Vibrations

This corridor is elevated throughout the alignment. As per the experience from working metros particularly Delhi Metro it is found that the problem of ground vibration is felt in case of Underground sections only. In elevated corridors there has been no complaint of vibration in the vicinity of alignments. Therefore the vibration impact is not considered significant. However preventive measures to reduce the vibration at source would be applied in the rail design itself.

9.9.6 IMPACTS DUE TO DEPOT

One Depot is proposed at Kanjur Marg (W). The depot will have following facilities:

- Washing Lines,
- Operation and Maintenance Lines,
- Workshop, and
- Offices.

These facilities could generate water and noise issues. The depot area may have to be filled up. Problems anticipated at depot sites are:

- Water supply,
- Oil Pollution,
- Cutting of trees
- Sanitation,
- Effluent Pollution,
- Noise Pollution,
- Loss of livelihood,
- Impact due to filling of area, and
- Surface drainage.

- **Water Supply**

Water supply will be required for different purposes in the depot. The water requirement for drinking will be 500 litre per day and 1,00,000 litre per day for other requirements (Departments and Contractors office). The water after conventional treatment can be processed through Reverse Osmosis (RO) technology for specific use such as final washing of equipment/ trains.

- **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 oil and grease trap. The collected oil would be disposed off to authorised collectors, so as to avoid any underground/ surface water contamination.

- **Noise Pollution**
  The main source of noise from depot is the operation of workshop. The roughness of the contact surfaces of rail and wheels and train speed are the factors which influence the magnitude of rail - wheel noise. The vibration of concrete structures also radiates noise. Due to less activity, no impact on the ambient noise is anticipated.

- **Solid Waste**
  At per available data, it is estimated that about 2 Ton per month of solid waste will be generated from the Depot site which will be taken by the cleaning contractor weekly and disposed to the Municipal waste disposal sites.

  Sludge of the order of 250 kg/year is expected to be generated from the ETP/STP that will be stored in leak proof containers and disposed off as per State Pollution Control Board site.
  According to experience and observation at operational DMRC depots, Oil and grease of the order of 2652 litres/ year will be produced in the Depot which will be disposed off through approved re-cyclers.

  About 2.5 ton/month of iron turning of the PWL for the wheel profiling is likely to be generated from the Depot.

9.10 POSITIVE ENVIRONMENTAL IMPACTS

Based on project particulars and existing environmental conditions, potential impacts that are likely to result from the proposed Mumbai metro corridors development have been identified and wherever possible these have been quantified. This section deals with the positive impacts of the project. The introduction of the corridor will also yield benefits from non-tangible parameters such as savings due to equivalent reduction in road construction and maintenance, vehicle operating costs, less atmospheric air pollution and socio-economic benefits of travel time, better accessibility, better comfort and quality of life. However, all benefits cannot be evaluated in financial terms due to non-availability of universally accepted norms. The parameters such as economic growth, improvement in quality of life, reduction in public health problems due to reduction in pollution, etc have not been quantified.

Various positive impacts have been listed under the following headings:

- Employment Opportunities;

- Enhancement of Economy;
- Mobility, Safety and reduced accidents;
- Traffic Congestion Reduction;
- Reduced Fuel Consumption;
- Reduced Air Pollution;
- Reduction in Number of Buses/ Auto rickshaws, and

- **Employment Opportunities**
  The project is likely to be completed in a period of about 4 years. During this period manpower will be needed to take part in various activities. About 1500 persons are likely to work during peak period of activity. In operation phase of the project about 35 persons per kilo meter length of the corridor, ie (approx. 525 persons) will be employed for operation and maintenance of the proposed system in shifts. Thus, the project would provide substantial direct employment. Besides, more people would be indirectly employed in allied activities and trades.

- **Enhancement of Economy**
  The proposed transport facility of MMRDA will facilitate sub-urban population to move quickly. With the development of Swami Samarth Nagar - Vikhroli (EEH) corridor, it is likely that more people will be involved in trade, commerce and allied services. MMRDA will, however, make it convenient for more people to move in the present suburban areas. This will reduce population pressure on transport facilities in the urban area.

- **Mobility Safety and Reduced Accidents**
  The metro network increases the mobility of people at faster rate. The proposed corridor will provide more people connectivity to other parts of the city. Metro journey is safe and result in reduced accidents on roads.

- **Traffic Congestion Reduction**
  To meet the forecast transport demand in the year 2031, it is estimated that the number of buses will have to be more. During this period personalised vehicles may also grow. Together, they will compound the existing problems of congestion and delay. The proposed development will reduce journey time and hence congestion and delay. The substitution of 76934persons on this metro corridor of Mumbai metro for an average trip length of 6.5 Km may reduce about 19233 Petrol Car Equivalent (PCE) units assuming a switchover of 4 Person per PCE. The Asian Development Bank's "Transport Emissions Model" for the National Environment Commission has been used to predict/calculate the fuel consumption as well as the emissions of the harmful pollutants into the environment.

- **Reduced Fuel Consumption**
  On implementation of the project, it is estimated that both petrol and diesel consumption will get reduced. The saving will be due to two factors namely Reduction in vehicles and decongestion on roads. On the basis of assumption of 19233 vehicles for 6.5 Km (Average trip length for the corridor in 2031) at the speed of 40 KM/hr, the daily reduction in fuel consumption would be app 7604 litre Petrol and 1540 litre Diesel.

- **Reduced Air Pollution**

  Based on available data and assumptions, an attempt has been made to model the air quality scenario for future using Asian Development Bank's "Transport Emissions Model". On the basis of above referred assumptions, daily reduction in pollutants would be as given below:

CO	:	590.302 Kg
CO_2	:	21060.774 Kg
NOx	:	100.698 Kg
VOC	:	87.235 Kg
Particulates	:	1.573 Kg
SO_2	:	2.626 Kg

- **Carbon Credits**

  Due to savings in fuel and reduction in air pollution etc. carbon credit would be generated during operation of the metro rail similar to the experience with Delhi Metro Rail Corporation Ltd. However, at this stage calculation of carbon credits is not feasible which would be worked out after the system become operational.

- **Improvement of Quality of Life**

  Development of Metro rail in the city would lead to overall improvement of quality of life of local populace by virtue of availability of better transport facility at competitive rates, better road safety, reduced pollution, improved general health etc.

9.11 CHECKLIST OF IMPACTS

The impact evaluation determines whether a project development alternative is in compliance with existing standards and regulations. It uses acceptable procedures and attempts to develop a numeric value for total environmental impact. A transformation of the review of multiple environmental objectives into a single value or a ranking or projects is the final step in impact assessment. There are about hundred methods for carrying out impact assessment, which can be grouped into the following categories:

- Ad-hoc method,
- Checklist,
- Matrix,
- Network,
- Overlays,
- Environmental Index and
- Cost Benefit analysis.

Each of the methods is subjective in nature and none of these is applicable in every case. Of the 7 methods listed above, checklist has been used and presented. Checklist is a list of environmental parameters or impact indicators which encourages the environmentalist to consider and identify the potential impacts. A typical checklist identifying anticipated environmental impacts is shown in **Table 9.11**.

Table 9.11 Checklist of Impacts

S. No.	Parameter	Negative Impact	No Impact	Positive Impact
A.	**Impacts due to Project Location**			
i.	Displacement of People	*		
ii.	Change of Land use and Ecology	*		
iii.	Loss of Cultural and Religious Structures		*	
iv.	Socio-economic Impacts	*		
v.	Loss of Trees	*		
vi.	Drainage & Utilities Problems	*		
B.	**Impact due to Project Design**			
i.	Platforms - Inlets and Outlets		*	
ii.	Ventilation and Lighting		*	
iii.	Station Refuse	*		
iv.	Risk due to Earthquakes		*	
C.	**Impact due to Project Construction**			
i.	Top Soil Erosion, Pollution and Health risk	*		
ii.	Traffic Diversions and	*		
iii.	Risk to Existing Buildings	*		
iv.	Problems of Soil Disposal and Seepage Risk	*		
v.	Dust Generation	*		
vi.	Increased Water Demand	*		
vii.	Supply of Construction Material	*		
viii.	Construction and Demolition Waste	*		
ix.	Batching Plant and Casting Yard	*		
x.	Noise	*		
D.	**Impact due to Project Operation**			
i.	Oil Pollution	*		
ii.	Noise	*		
iii.	Water supply and sanitation	*		
iv.	Pedestrian Issues		*	
v.	Visual Impacts		*	
vi.	Station Illumination		*	
vii.	Employment Opportunities			*
viii.	Enhancement of Economy			*
ix.	Mobility			*
x.	Safety			*
xi.	Traffic Congestion Reduction			*
xii.	Less fuel Consumption			*
xiii.	Less Air Pollution			*
xiv.	Carbon dioxide Reduction			*
xv.	Reduction in Buses			*
xvi.	Reduction in Infrastructure			*

9.12 ANALYSIS OF ALTERNATIVES AND PUBLIC CONSULTATION AND INFORMATION DISCLOSURE

ANALYSIS OF ALTERNATIVES

Historically, 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:

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

All the above reports have been submitted to MMRDA.

An SPV named as Mumbai Metro rail Corporation Ltd. (MMRC) was incorporated and implementation of Line -3 between Colaba- BKC-Aarey was proposed to be done by the SPV.

Line no 1 viz. Versova - Andheri - Ghatkopar has been implemented and commissioned on 8th June 2014 The work was done on Public Private Partnership (PPP) mode by a Special Purpose Vehicle, Mumbai Metro one, comprising of Government of Maharashtra, Reliance Infrastructure and VOELIA of France.

A special purpose vehicle (SPV) was formed for line no 2, viz. Charkop - Bandra - Mankhurd corridor. SPV comprises of Government of Maharashtra, Reliance Infrastructure and SNC Lavalin of Canada. However, the implementation of this Line did not take off.

In November / December 2009, MMRDA awarded the work of preparing Detailed Project Reports for following corridors to parties as indicated below:

Charkop - Dahisar (7.5 Km)	M/s SPAN Consultants
Andheri (E) - Dahisar	M/s SPAN Consultants
BKC Kanjur Marg (19.5 Km) with extension from BKC to Mahim	M/s RITES
Ghatkopar - Mulund (12.5 Km)	M/s Consulting Engineering Services
Wadala - Carnac Bunder	M/s Consulting Engineering Services

All the above reports were submitted to MMRDA. An SPV named as Mumbai Metro rail Corporation Ltd. (MMRC) was incorporated and implementation of Line -3 between Colaba- BKC-Aarey was proposed to be done by the SPV. MMRDA now intends to implement all other corridors by itself.

Various alternatives were explored by the DMRC before arriving at the preferred mode of transport and technical design. The project is unique in the sense that alternative alignments were not evaluated as it was the principal objective of the Comprehensive Mobility Plan to connect various parts of suburbs.

Need to Increase Public Transport Share

The proposed corridor is part of MMRDA's Comprehensive Mobility Plan (CMP), which included strategies on motorized and non-motorized modes to enhance mobility and economic development. The metro was conceived in recognition to the heavy reliance of the population to private buses as public transport that is inadequate and routes are unregulated causing confusion and congestion.

9.13 PUBLIC CONSULTATION AND DISCLOSURE

Public consultation and participation is a continuous two way process, involving, promoting of public understanding of the processes and mechanisms through which developmental problems and needs are investigated and solved. The public consultation, as an integral part of environmental and social assessment process throughout the project preparation stage not only minimizes the risks and unwanted political propaganda against the project but also abridges the gap between the community and the project formulators, which leads to timely completion of the project and making the project people friendly.

Public consultations with the people of different sections of the society along the project alignment, shopkeepers, and influential persons of the project area will be made. Attention shall be given to potential vulnerable people like, squatters, encroachers, schedule caste, and other backward section (OBC) of society shall be consulted to make them aware and identify adverse impacts of the project.

A. Consultation with Stakeholders

As required for Category A projects, preliminary consultations were conducted at the early stage of EIA preparation, mostly involving local communities. Successive consultations shall be conducted by the MMRDA after the finalization of this report that includes representatives of local communities and entities tasked with the regulation of the road development and environmental protection.

B. Compliance with Regulatory and Funding Agency Requirement

As per Indian Environmental Regulations, public hearing is not required, as railway projects do not attract EIA Notification 2006, amended 2009. Meaningful consultations will be undertaken consistent with the ADB requirements. All the five principles of information dissemination, information solicitation, integration, co ordination and engagement into dialogue will be incorporated in the consultation process.

C. Disclosure of the EIA and Monitoring Reports

In compliance to the policy of Multilateral Funding Agencies, this report may be required to be disclosed in the websites of MMRDA and Multilateral Funding Agencies at least 120 days prior to consideration by board of Multilateral Funding Agency. Further, semi-annual monitoring reports may be required to be prepared by the MMRDA and may be required to be disclose in the website of MMRDA & Multilateral Funding Agencies.

9.14 ENVIRONMENTAL MANAGEMENT PLAN

9.14.1 MANAGEMENT PLANS

The Mumbai Metro Project will provide employment opportunity, quick mobility service and safety, traffic congestion reduction, less fuel consumption and air pollution on one hand and problems of muck disposal, traffic diversion, utility dislocation etc. on the other hand.

Protection, preservation and conservation of environment have always been a primary consideration in Indian ethos, culture and traditions. Management of Environment by provision of necessary safeguards in planning of the project itself can lead to reduction of adverse impacts due to a project. This chapter, therefore, spells out the set of measures to be taken during project construction and operation to mitigate or bring down the adverse environmental impacts to acceptable levels based on the proposed Environmental Management Plan (EMP).

The most reliable way to ensure that the plan will be integrated into the overall project planning and implementation is to establish the plan as a component of the project. This will ensure that it receives funding and supervision along with the other investment components. For optimal integration of EMP into the project, there should be investment links for:

- Funding,
- Management and training, and
- Monitoring.

The purpose of the first link is to ensure that proposed actions are adequately financed. The second link helps in embedding training, technical assistance, staffing and other institutional strengthening items in the mitigation measures to implement the overall management plan. The third link provides a critical path for implementation and enables sponsors and the funding agency to evaluate the success of mitigation measures as part of project supervision, and as a means to improve future projects. This chapter has been divided into three sections:

- Mitigation measures,
- Disaster management, and
- Emergency measures.

9.14.2 MITIGATION MEASURES

The main aim of mitigation measures is to protect and enhance the existing environment of the project. Mitigation measures have to be adopted during construction at all the construction sites including Batching Plant and Casting Yards on all the aspects. The mitigation measures to be adopted have been described under following heads:

- Compensatory Afforestation,
- Construction Material Management,
- Labour Camp,

- Energy Management
- Hazardous Waste Management
- Environmental Sanitation,
- Utility Plan,
- Air Pollution Control Measures,
- Noise Control Measures,
- Vibration Control Measures,
- Traffic Diversion/Management,
- Soil Erosion Control,
- Water Supply, Sanitation and Solid Waste management,
- Rain water harvesting
- Management Plans for Depot
- Training and Extension

9.14.3 COMPENSATORY AFFORESTATION

The objective of the afforestation program should be to develop natural areas in which ecological functions could be maintained on a sustainable basis. According to the results of the present study, it is found that about 57 trees are likely to be lost due to the project. Ten saplings are to be planted for felling a single tree. Hence 570 trees need to be planted. Plantation program will be finalized in consultation with MCGM and project proponent would provide the funds for compensatory afforestation as per government policy.

9.14.4 CONSTRUCTION MATERIAL MANAGEMENT – STORAGE AND PROCUREMENT

The major construction material to be used for construction of the proposed corridor are coarse aggregates, cement, coarse sand, reinforcement steel, structural steel, water supply, drainage and sanitary fittings etc. The material will be loaded and unloaded by engaging labour at both the locations by the contractor.

The duties of the contractor will include monitoring all aspects of construction activities, commencing with the storing, loading of construction materials and equipment in order to maintain the quality. During the construction period, the construction material storage site is to be regularly inspected for the presence of uncontrolled construction waste. Close liaison with the MMRDA Officer and the head of the construction crew will be required to address any environmental issues and to set up procedures for mitigating impacts. The scheduling of material procurement and transport shall be linked with construction schedule of the project. The Contractor shall be responsible for management of such construction material during entire construction period of the project. Sufficient quantity of materials should be available before starting each activity. The contractor should test all the materials in the Government labs or Government approved labs in order to ensure the quality of materials before construction. This is also the responsibility of the contractor, which would be clearly mentioned in the contractor’s agreement. Care shall be taken to avoid spillage of material during construction. Procurement of material would be from environment friendly source. The materials shall be procured from nearest available source and shall be transported in coverd trucks. All the material would be stored in a manner to avoid multiple handling for use in construction activities.

9.14.5 LABOUR CAMP

The Contractor during the progress of work will provide, erect and maintain the necessary (temporary) living accommodation and ancillary facilities for labour to standards and scales approved by the MMRDA. All temporary accommodation must be constructed and maintained in such a fashion that uncontaminated water is available for drinking, cooking and washing. Safe drinking water should be provided to the dwellers of the construction camps. Adequate washing and bathing places shall be provided, and kept in clean and drained condition. Construction camps are the responsibility of the concerned contractors and these shall not be allowed in the construction areas but sited away. Adequate health care is to be provided for the work force.

Sanitation Facilities: Construction sites and camps shall be provided sanitary latrines and urinals. Mobile STP/ septic tanks should be provided for the flow of used water outside the camp. Drains and ditches should be treated with bleaching powder on a regular basis. The sewage system for the camp must be properly designed, built and operated so that no health hazard occurs and no pollution to the air, ground or adjacent watercourses takes place. Garbage bins must be provided in the camp and regularly emptied and the garbage disposed off in a hygienic manner

Shelter at Workplace: At every workplace, shelter shall be provided free of cost, separately for use of men and women labourers. Sheds shall be maintained in proper hygienic conditions.

First aid facilities: At every workplace, a readily available first-aid unit including an adequate supply of sterilized dressing materials and appliances shall be provided. Suitable transport shall be provided to facilitate taking injured and ill persons to the nearest hospital.

Day Crèche Facilities: At every construction site, provision of a day crèche shall be worked out so as to enable women to leave behind their children. At construction sites where 25 or more women are ordinarily employed, at least a hut shall be provided for use of children under the age of 6 years belonging to such women. Huts shall be provided with suitable and sufficient openings for light and ventilation. Size of crèches shall vary according to the number of women workers employed.

9.14.6 ENERGY MANAGEMENT

The contractor shall use and maintain equipment so as to conserve energy and shall be able to produce demonstrable evidence of the same upon MMRDA request. Measures to conserve energy include but not limited to the following:

- Use of energy efficient motors and pumps,
- Use of energy efficient lighting, which uses energy efficient luminaries,
- Adequate and uniform illumination level at construction sites suitable for the task,
- Proper size and length of cables and wires to match the rating of equipment, and
- Use of energy efficient air conditioner.

The contractor shall design site offices maximum daylight and minimum heat gain. The rooms shall be well insulated to enhance the efficiency of air conditioners and the use of solar films on windows may be explored.

9.14.7 HAZARDOUS WASTE MANAGEMENT

The contractor shall identify the nature and quantity of hazardous waste generated as a result of his activities and shall file a 'Request for Authorization' with Maharashtra Pollution Control Board along with a map showing the location of storage area. Outside the storage area, the contractor shall place a 'display board', which will display quantity and nature of hazardous waste, on date. Hazardous Waste needs to be stored in a secure place. It shall be the responsibility of the contractor to ensure that hazardous wastes are stored, based on the composition, in a manner suitable for handling, storage and transport. The labeling and packaging is required to be easily visible and be able to withstand physical conditions and climatic factors. The contractor shall approach only Authorized Recyclers for disposal of Hazardous Waste, under intimation to the MMRDA.

9.14.8 ENVIRONMENTAL SANITATION

Environmental sanitation also referred to as Housekeeping, is the act of keeping the working environment cleared of all unnecessary waste, thereby providing a first-line of defense against accidents and injuries. Contractor shall understand and accept that improper environmental sanitation is the primary hazard in any construction site and ensure that a high degree of environmental sanitation is always maintained. Environmental sanitation is the responsibility of all site personnel, and line management commitment shall be demonstrated by the continued efforts of supervising staff towards this activity.

General environmental sanitation shall be carried out by the contractor and at all times at Work Site, Construction Depot, Batching Plant, Labour Camp, Stores, Offices and toilets/urinals. The contractor shall employ a special group of environmental sanitation personnel to carry out following activities:

- Full height fence, barriers, barricades etc. shall be erected around the site in order to prevent the surrounding area from excavated soil, rubbish etc, which may cause inconvenience to and endanger the public. The barricade especially those exposed to public shall be aesthetically maintained by regular cleaning and painting as directed by the Employer. These shall be maintained in one line and level.
- The structure dimension of the barricade, material and composition, its colour scheme, MMRDA logo and other details.
- All stairways, passageways and gangways shall be maintained without any blockages or obstructions. All emergency exits passageways, exits fire doors, break-glass alarm points, fire-fighting equipment, first aid stations, and other emergency stations shall be kept clean, unobstructed and in good working order.
- All surplus earth and debris are removed/disposed off from the working areas to officially designated dumpsites. Trucks carrying sand, earth and any pulverized materials etc. in order to avoid dust or odour impact shall be covered while moving.
- No parking of trucks/trolleys, cranes and trailers etc. shall be allowed on roads, which may obstruct the traffic movement.
- Roads shall be kept clear and materials like: pipes, steel, sand boulders, concrete, chips and brick etc. shall not be allowed on the roads to obstruct free movement of road traffic.
- Water logging or bentonite spillage on roads shall not be allowed.

- Proper and safe stacking of material are of paramount importance at yards, stores and such locations where material would be unloaded for future use. The storage area shall be well laid out with easy access and material stored / stacked in an orderly and safe manner.
- Flammable chemicals / compressed gas cylinders shall be safely stored.
- Unused/surplus cables, steel items and steel scrap lying scattered at different places within the working areas shall be removed to identified locations.
- All wooden scrap, empty wooden cable drums and other combustible packing materials, shall be removed from work place to identified location(s).
- Empty cement bags and other packaging material shall be properly stacked and removed.

9.14.9 UTILITY PLAN

The proposed Metro alignment runs along major arterial roads of the city, which serve Institutional, Commercial and Residential areas. A number of sub-surface, surface and overhead utility services, viz. sewers, water mains, storm water drains, telephone cables, electrical transmission lines, electric poles, traffic signals etc. exists 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. As such, these may affect construction and project implementation time schedule /costs, for which necessary planning / action needs to be initiated in advance. Prior to the actual execution of work at site, detailed investigation of all utilities and location will be undertaken well in advance by making trench pit to avoid damage to any utility. While planning for diversion of underground utility services e.g. sewer lines, water pipe lines, cables etc., during construction of Metro alignment, the following guidelines could be adopted:

- Utility services shall 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 any serious difficulty in negotiating the underground utility services, especially those running across the alignment. In such situation, the spanning arrangement of the viaduct may be suitably adjusted to ensure that no foundation need be constructed at the location, where utility is crossing the proposed Metro alignment. In case of utility services running along the alignment either below or at very close distance, the layout of piles in the foundations shall be suitably modified such that the utility service is either encased within the foundation piles or remains clear of them.

9.14.10 AIR POLLUTION CONTROL MEASURES

During the construction period, the impact on air quality will be mainly due to increase in PM_{10} along haul roads and emission from vehicles and construction machinery. Though the estimation of air quality during construction shows some impact on ambient air quality, nevertheless certain mitigation measures which shall be adopted to reduce the air pollution are presented below:

- The Contractor shall take all necessary precautions to minimise fugitive dust emissions from operations involving excavation, grading, and clearing of land and disposal of waste. He shall not allow emissions of fugitive dust from any transport, handling, construction or storage activity to remain visible in atmosphere beyond the property line of emission source for any prolonged period of time without notification to the Employer.
- The Contractor shall use construction equipment to minimize or control of air pollution. He shall maintain evidence of such design and equipment and make these available for inspection by Employer.
- Contractor's transport vehicles and other equipment shall conform to emission standards fixed by Statutory Agencies of Government of India or the State Government from time to time. The Contractor shall carry out periodical checks and undertake remedial measures including replacement, if required, so as to operate within permissible norms.
- The Contractor shall cover loads of dust generating materials like debris and soil being transported from construction sites. All trucks carrying loose material should be covered and loaded with sufficient free - board to avoid spills through the tailboard or sideboards.
- The temporary dumping areas shall be maintained by the Contractor at all times until the excavate is re-utilized for backfilling or as directed by Employer. Dust control activities shall continue even during any work stoppage.
- The Contractor shall place material in a manner that will minimize dust production. Material shall be minimized each day and wetted, to minimize dust production. During dry weather, dust control methods must be used daily especially on windy, dry days to prevent any dust from blowing across the site perimeter.
- The Contractor shall water down construction sites as required to suppress dust, during handling of excavation soil or debris or during demolition. The Contractor will make water sprinklers, water supply and water delivering equipment available at any time that it is required for dust control use. Dust screens will be used, as feasible when additional dust control measures are needed especially where the work is near sensitive receptors.
- The Contractor shall provide a wash pit or a wheel washing and/or vehicle cleaning facility at the exits from work sites such as construction depots and batching plants. At such facility, high-pressure water jets will be directed at the wheels of vehicles to remove all spoil and dirt.

9.14.11 CONSTRUCTION AND DEMOLITION WASTE

Waste prevention, reuse and recycling can not only save money, but also generate broad environmental benefits, including the conservation of natural resources. Reuse and waste prevention reduce the air and water pollution associated with materials manufacturing and transportation. This saves energy and reduces attendant greenhouse gas production. The recycling of many materials requires less energy than production from virgin stock, and can also reduce transportation requirements and associated impacts.

Opportunities for reducing C&D waste focus on three approaches, typically expressed as **Reduce-Reuse-Recycle**.

The source of C & D waste are pile caps, excess RMC and demolition material. An effort shall be made to recover embedded energy and to recycle the maximum quantity of C & D Waste to manufacture tiles, curb stones, paver block etc. The contractor shall store C&D waste separately at the site and sent to recycling facility periodically.

There shall be no disposal of any waste along storm water drains, canals and/ or any other water body or depression. Rather C & D waste shall be collected and sent to any authorized waste recycling facility.

9.14.12 NOISE CONTROL MEASURES

There will be an increase in noise level in nearby ambient air due to construction and operation of the Metro corridors. During construction the exposure of workers to high noise levels especially near the machinery need to be minimized. This could be achieved by:

- Job rotation,
- Automation,
- Construction of permanent and temporary noise barriers,
- Use electric instead of diesel powered equipment,
- Use hydraulic tools instead of pneumatic tools,
- Acoustic enclosures should be provided for individual noise generating construction equipment like DG sets,
- Scheduling and staggering truck loading, unloading and hauling operation,
- Schedule and stagger work to avoid simultaneous activities which generate high noise levels,
- 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 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, and
- Sound proof compartments control rooms etc.

Special acoustic enclosures should be provided for individual noise generating equipments, wherever possible. Workers in sections where periodic adjustment of equipment/ machinery is necessary, should be provided with sound proof control rooms so that exposure to higher noise level is reduced. During construction, there may be high noise levels due to pile driving, use of compressors and drilling machinery. Effective measures should be taken during the construction phase to reduce the noise from various sources. The noise from air compressor can be reduced by fitting exhaust and intake mufflers.

The pile driving operation can produce noise levels up to 100 dB (A) at a distance of 25-m from site. Suitable noise barriers can reduce the noise levels to 70 dB (A) at a distance of 15m from the piles. A safety precaution 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.

9.14.13 TRAFFIC DIVERSION/ MANAGEMENT

During construction, traffic is likely to be affected. Hence Traffic Diversion Plans are required in order to look for options and remedial measures so as to mitigate any traffic congestion situations arising out due to acquisition of road space during Metro construction of the corridor. Any reduction of road space during Metro construction results in constrained traffic flow. In order to retain satisfactory levels of traffic flow during the construction period; traffic management and engineering measures need to be taken. They can be road widening exercises, traffic segregation, one-way movements, traffic diversions on influence area roads etc. Maintenance of diverted roads in good working condition to avoid slow down and congestion shall be a prerequisite during construction period.

Various construction technologies are in place to ensure that traffic impedance is done at the minimum. They are:

- The requirement would be mainly along the central verge/ side of the road.
- As regards to the alignment cutting across a major traffic corridor, 'Box Girder Construction Technology' would be applied to prevent traffic hold-ups or diversions of any kind.

Only temporary diversion plans will be required during construction of the proposed Metro corridor. At the onset, all encroachments from road ROW will have to be removed. These encroachments vary from 'on-street' parking to informal activities.

Keeping in view the future traffic growth and reduction of carriageway due to Metro construction, implementation of traffic management/diversion plans shall become inevitable for ensuring smooth traffic movement and similar traffic diversion plans shall be formulated and followed during the execution stage.

Traffic Management Guidelines: The basic objective of the following guidelines is to lay down procedures to be adopted by contractor to ensure the safe and efficient movement of traffic and also to ensure the safety of workmen at construction sites.

- All construction workers should be provided with high visibility jackets with reflective tapes as most of viaduct and station works are on the right-of-way. The conspicuity of workmen at all times shall be increased so as to protect from speeding vehicular traffic.
- Warn the road user clearly and sufficiently in advance.
- Provide safe and clearly marked lanes for guiding road users.
- Provide safe and clearly marked buffer and work zones
- Provide adequate measures that control driver behavior through construction zones.
- The primary traffic control devices used in work zones shall include signs, delineators, barricades, cones, pylons, pavement markings and flashing lights.

9.14.14 SOIL EROSION CONTROL

Prior to the start of the relevant construction, the Contractor shall submit to the MMRDA for approval, his schedules for carrying out temporary and permanent erosion/sedimentation control works are as applicable for the items of clearing and grubbing, roadway and drainage excavation, embankment/sub-grade construction, bridges and/ or other structures across water courses, pavement courses and shoulders. He shall also submit for approval his proposed method of erosion/sedimentation control on service road and his plan for disposal of waste materials. Work shall not be started until the erosion/sedimentation control schedules and methods of operations for the applicable construction have been approved by the project authority.

The surface area of erodible earth material exposed by clearing and grubbing, excavation shall be limited to the extent practicable. The Contractor may be directed to provide immediate control measures to prevent soil erosion and sedimentation that will adversely affect construction operations, damage adjacent properties, or cause contamination of nearby streams or other watercourses. Such work may involve the construction of temporary berms, dikes, sediment basins, slope drains and use of temporary mulches, fabrics, mats, seeding, or other control devices or methods as necessary to control erosion and sedimentation. Top soil shall be preserved by the contractor and stacked separately at designated place and utilize it to cover the refilled area and to support vegetation.

The Contractor shall be required to incorporate all permanent erosion and sedimentation control features into the project at the earliest practicable time as outlined in his accepted schedule to minimize the need for temporary erosion and sedimentation control measures.

Temporary erosion/sedimentation and pollution control measures will be used to control the phenomenon of erosion, sedimentation and pollution that may develop during normal construction practices, but may neither be foreseen during design stage or associated with permanent control features on the Project. Under no conditions shall a large surface area of credible earth material be exposed at one time by clearing and grubbing or excavation without prior approval of the project authority.

The MMRDA may limit the area of excavation, borrow and embankment operations in progress, commensurate with the Contractor's capability and progress in keeping the finish grading, mulching, seeding and other such permanent erosion, sedimentation and pollution control measures, in accordance with the accepted schedule.

Temporary erosion is sometimes caused due to the Contractor's negligence, carelessness or failure to install permanent controls. Sedimentation and pollution control measures then become necessary as a part of the work as scheduled or ordered by the project authority, and these shall be carried out at the Contractor's own expense. Temporary erosion, sedimentation and pollution control work required, which is not attributed to the Contractor's negligence, carelessness or failure to install permanent controls, will be performed as ordered by the project authority.

9.14.15 WATER SUPPLY, SANITATION AND SOLID WASTE MANAGEMENT

During Construction

The public health facilities, such as water supply, sanitation and toilets are much needed at the stations. Water should be treated before use up to national drinking water standards. 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 mobile STP/ septic tanks should be adopted for sewage disposal. The water for domestic consumption shall be sourced from public water supply or alternatively designated borewells may be installed with due permission from statuatory authority prior to installation of borewell.

For Construction activity, there is a restriction to utilize groundwater all over the nation as per order of National Green Tribunal (NGT). Thus, construction water shall be sourced from Mumbai Municipal Corporation which is responsible for sewage disposal in Mumbai area. Alternatively, contractor shall arrange tie up for surface water supply or tanker water supply for construction activity. Best option is to use treated STP water for construction activity.

Solid waste shall be stacked at designated place and when sufficient quantity accumulates it shall be disposed off through covered trucks to land fill site designated and authorized by MMRDA.

During Operations

Practically, public facilities at stations have to be operated by regular staff or may be designated to any NGO working in the area in the field of sanitation as per policy of MMRDA.

Requirement of drinking water supply at an elevated station is about 6 KL/day. The water consumption for an elevated station to meet the requirements of its activities is 17 KLD. This shall be provided from MCGM/ Mumbai authority sources.

Solid waste will be generated at station is about 0.8 – 1.2 m^3/Day. The maintenance of adequate sanitary facilities for temporarily storing refuse on the premises is considered a responsibility of the project authority. The storage containers for this purpose need to be designed. However, it is suggested that the capacity of these containers should not exceed 50 litres and these should be equipped with side handles to facilitate handling. To avoid odour and the accumulation of fly-supporting materials, garbage containers should be washed at frequent intervals. This should be collected and transported to local municipal bins for onward disposal to disposal site by municipality. During operation, as mitigation measures rainwater harvesting will be carried out at stations and along the viaduct.

9.14.16 RAIN WATER HARVESTING

To conserve and augment the storage of groundwater, it is suggested to construct rainwater harvesting structures of suitable capacity along the alignment and at stations. The stations shall be provided with the facility of rainwater harvesting and artificial recharge. The total length of the proposed alignment is about 15.247 km and there would be 13 stations. The estimated cost of rain water harvesting for elevated corridor is about 11 lakhs per km and 3.5 lakhs per station. The total cost of rainwater harvesting would be Rs. 213.25 Lakh.

9.14.17 TREE PROTECTION

There is requirement of felling 57 trees during construction of Metro corridors in Mumbai. An attempt shall be made to minimize the tree felling. As remediation of tree felling it is suggested to plant 3 trees for each tree felled. Thus 171 trees would be planted. Moreover, MMRDA would chalk out the plantation program in close coordination with Tree Authority MCGM or will get plantation done through MCGM by making the payment for plantation work including after care for three years. An attempt would be made to minimize the felling of trees to the bare minimum while working and undertaking construction work. The left out trees shall be protected by providing metal or brick tree guard around the tree at a distance of one metre surrounding the tree. Scope of transplantation of trees would also be explored with discussion with the Tree Authority MCGM. A provision of 3.42 Lakh has been made @ Rs. 2000/- per tree to be planted and maintained for a period of three years.

9.14.18 MANAGEMENT PLANS FOR DEPOT

The management plans for depot site includes:

- Water Supply,
- Oil Pollution Control,
- Sewage/Effluent Pollution Control,
- Surface Drainage,
- Green belt development,
- Rain water harvesting, and
- Recycling of treated waste water.
- Solid Waste Disposal

Water supply: About 300KLD of water will be required for operation and functioning of depot. This could be either taken from water supply Authority or through boring tube well into the ground after taking permission from Central Ground Water Authority. The ground water will need treatment depending upon its use. Domestic and some of the industrial application, a reverse Osmosis (RO) plant of 8 liter/ minute capacity will be appropriate. The water treatment plant flow chart is given in **Figure 9.4**. The estimated cost of water supply plant is about 120.50 Lakh.

Oil Pollution Control: The 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 initial stage of effluent treatments. Such tanks usually employ compressed air to coagulate the oil and grease and cause it to rise promptly to the surface. Compressed air may be applied through porous plates located in bottom of the tank. The tank may be designed for a detention period of 5 to 15 minutes.

Sewage/Effluent Pollution Control: About 80 KLD of sewage is likely to be generated at depot. The sewage could be treated up to the level so that it could be used for horticulture purpose in the campus and can also be discharged into the stream a process flow chart is presented in **Figure 9.5.** The estimated cost of sewage treatment plant is about Rs 78.00 Lakh.

Expectedly about 63 KLD of effluent would be generated at Depot. The effluent will have oil, grease and, detergent as main pollutants. This has to be treated as per requirement of regulatory pollution control agency of the state (MSPCB). Process flow chart of effluent treatment plant is shown in **Figure 9.6.** The estimated cost of effluent treatment plant is about Rs 88.50 Lakh.

Surface Drainage: The depot area should have proper drainage. The Storm water of the depot will be collected through the drain. Rain water harvesting structures at different locations in the drains and for surplus storm water, the drainage system is to be connected to nearby disposal site. The drainage costs have been included in project cost.

Green belt development: The greenbelt development / plantation in the depot area not only functions as landscape features resulting in harmonizing and amalgamating the physical structures of proposed buildings with surrounding environment but also acts as pollution sink / noise barrier. In addition to augmenting present vegetation, it will also check soil erosion, make the ecosystem more diversified and functionally more stable, make the climate more conducive and restore balance. It is recommended to have a provision of Rs 40.00 Lakh in the cost estimate for the green belt development.

Rain water harvesting: To conserve and augment the storage of groundwater, it has been proposed to construct roof top rainwater harvesting structure of suitable capacity in the constructed depot site. A provision of Rs 35.00 Lakh for depot has been kept in the cost estimate.

Recycling of treated waste water: The Waste Water to be generated at depots shall be treated by ETP & STP in each Depot. The treated waste water shall be recycled for horticulture work of the depot. About 64 KLD of treated waste water will be used for horticulture. The estimated cost of recycling of treated waste water is about Rs. 41 Lakh in the depot.

Solid Waste Disposal

Effort shall be made to minimize the generation of solid wastes in the workshop by using preventive methods and recycling. Solid Wastes generated in the depot from the workshop in the form of filings and packaging materials etc. shall be stacked and stored separately and disposed-of periodically.

The costs of environment management measures have been included in the project cost as construction and civil costs of Depot.

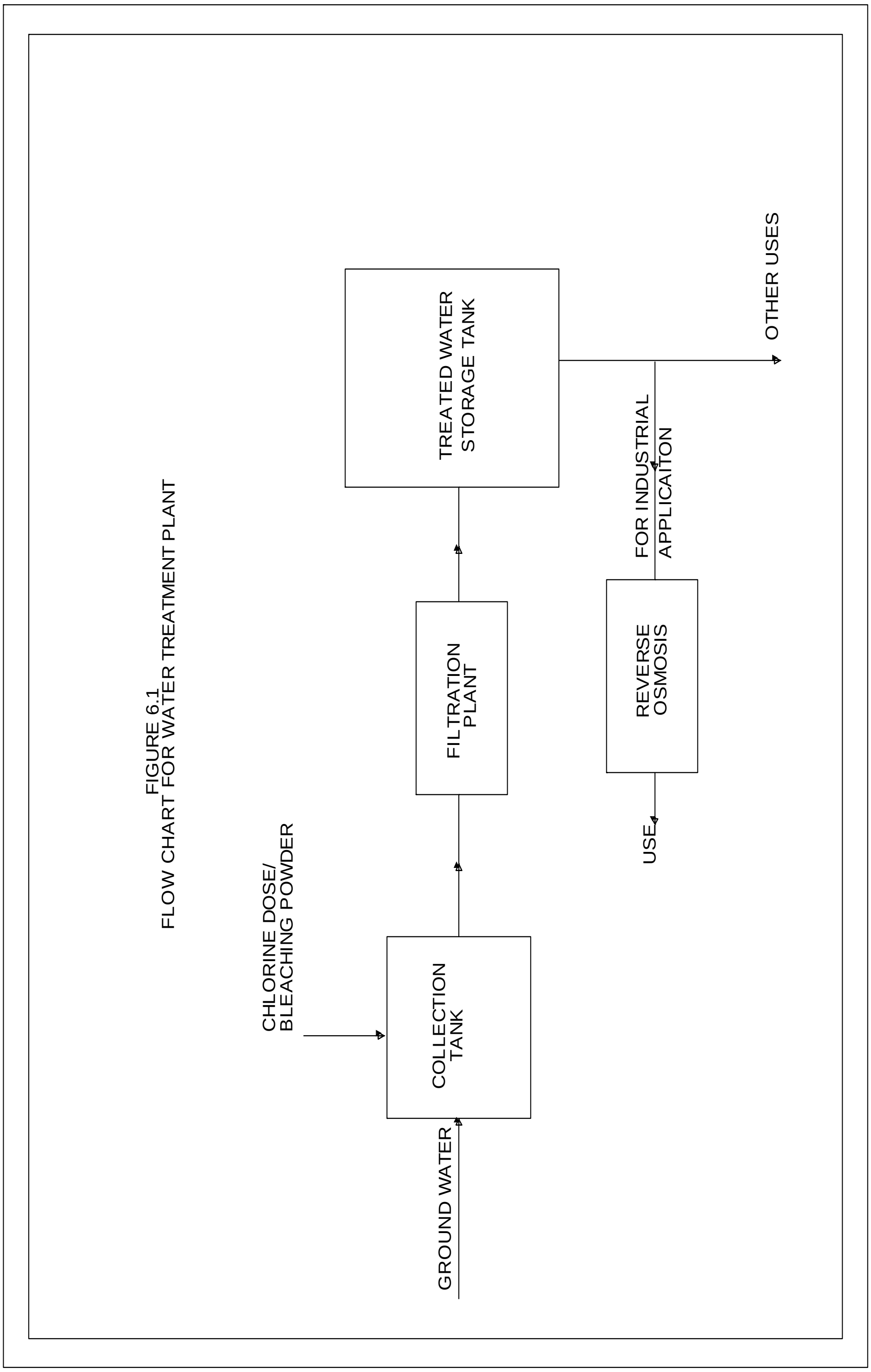


Fig. 9.4 Flow Chart for Water Treatment Plant

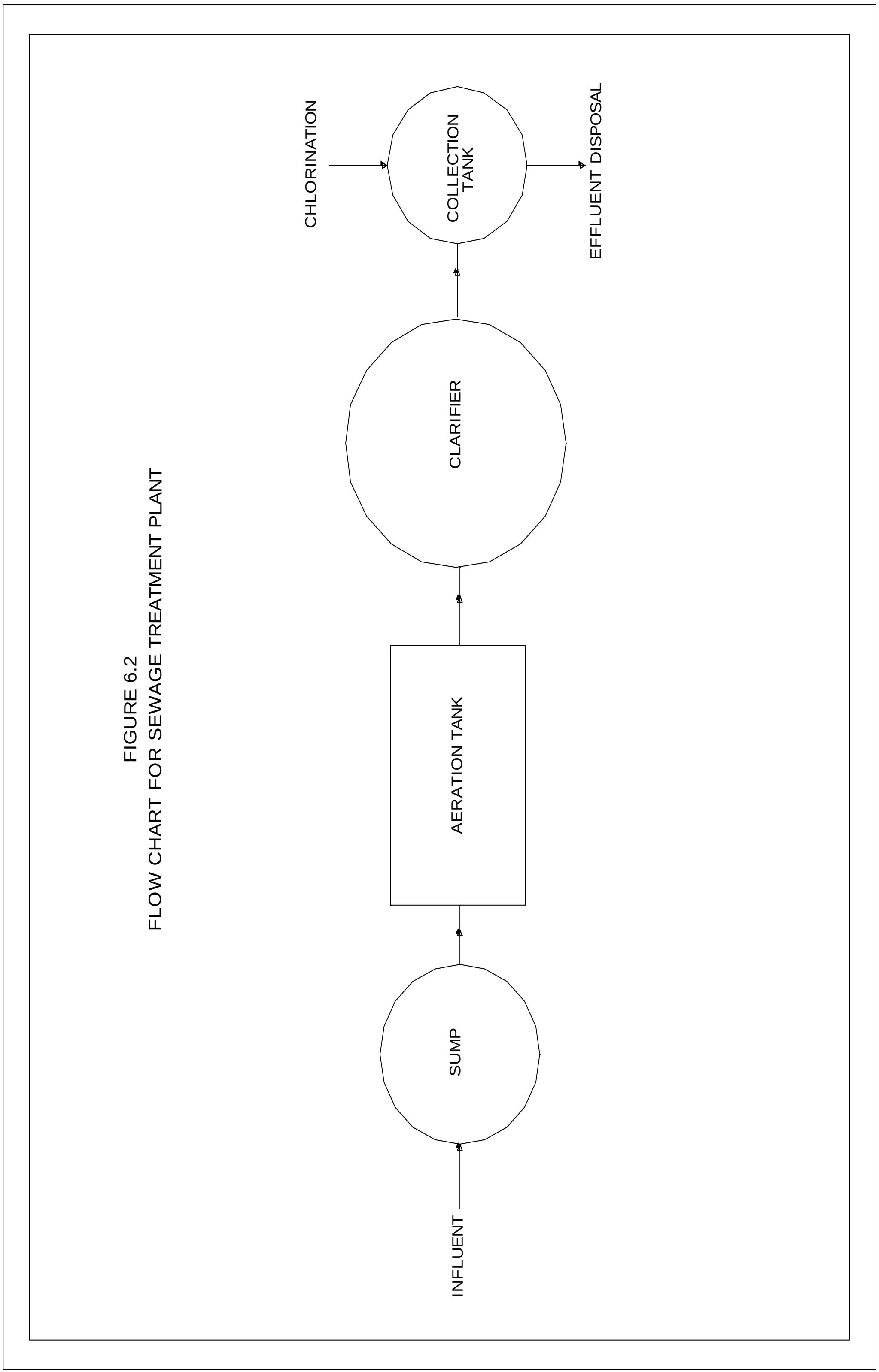


Fig. 9.5 Flow Chart for Sewage Treatment Plant

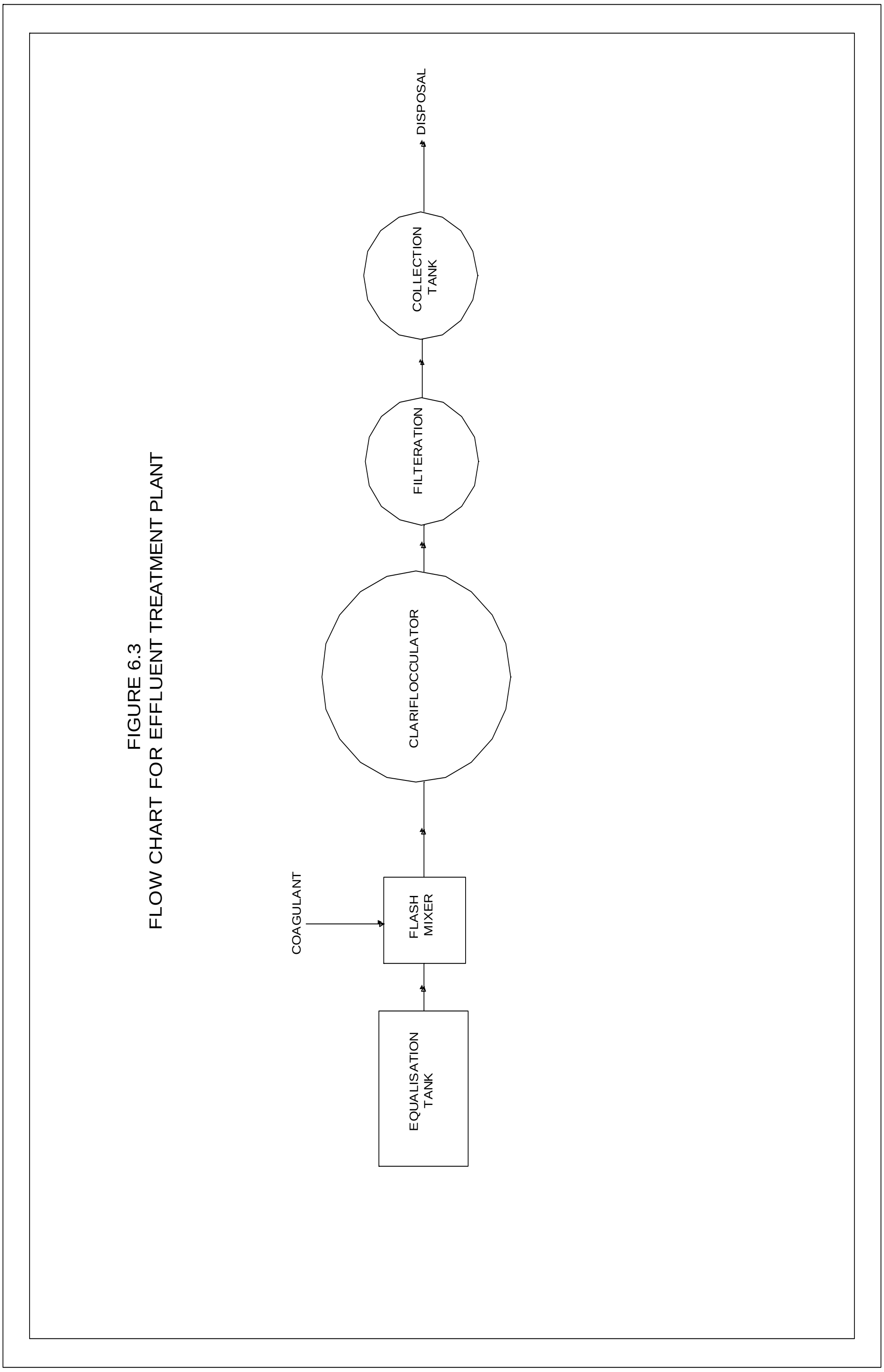


Fig. 9.6 Flow Chart for Effluent Treatment Plant

9.14.19 DISASTER MANAGEMENT

Disaster is an unexpected event due to sudden failure of the system, external threats, internal disturbances, earthquakes, fire and accidents. The first step is to identify the causes which develop/ pose unexpected danger to the structural integrity of Metro overhead rail. The potential causes are excessive load, cracks, failure and malfunctioning of sensing instruments, accident, etc. These need to be looked into with care.

- **Preventive Action**

Once the likelihood of a disaster is suspected, action has to be initiated to prevent a failure. Engineers responsible for preventive action should identify sources of repair equipments, materials, labour and expertise for use during emergency.

- **Reporting Procedures**

The level at which a situation will be termed a disaster shall be specified. This shall include the stage at which the surveillance requirements should be increased both in frequency and details.

The Engineer-in-Chief should notify the officer for the following information:

➢ Exit points for the public,
➢ Safety areas in the tunnel/overhead rail, and
➢ Nearest medical facility

- **Communication System**

An efficient communication system is absolutely essential for the success of any disaster management plan. This has to be worked out in consultation with local authorities. More often, the entire communication system gets disrupted when a disaster occurs. The damage areas need to be clearly identified and provided with temporary and fool proof communication system.

- **Emergency Action Committee**

To ensure coordinates action, an Emergency Action Committee should be constituted. The civic administrator may be the Chairman of this Committee. The committee may comprise of:

➢ Station Manager concerned,
➢ Police Officer of the area,
➢ Mumbai Transport Corporation Representative,
➢ Home Guard representative,
➢ Fire Brigade representative,
➢ Health Department representative,
➢ Department of Information and Publicity, and
➢ Non-Governmental Organization of the area

Emergency Action Committee will prepare the evacuation plan and procedures for implementation based on local needs and facilities available. The plan should include:

- Demarcation of the areas to be evacuated with priorities,
- Safe route to be used, adequacy of transport for evacuation, and traffic control,
- Safe area and shelters,
- Security of property left behind in the evacuated areas,
- Functions and responsibilities of various members of evacuation teams, and
- Setting up of joint control room

All personnel involved in the Emergency Action Plan should be thoroughly familiar with all the elements of the plan and their responsibilities. They should be trained through drills for the Emergency Action Plan. The staff at the site should be trained for problem detection, evaluation and emergency remedial measures. Individual responsibility to handle the segments in emergency plan must be allotted.

Success of an emergency plan depends on public participation, their response to warning notifications and timely action. Public has to be educated on the hazards and key role in disaster mitigation by helping in the planned evacuation and rescue operations.

It is essential to communicate by whom and how a declared emergency will be terminated. There should be proper notification to the public on de-alert signals regarding termination of the emergency. The notification should be clear so that the evacuees know precisely what to do when re-entering or approaching the affected areas.

9.14.20 EMERGENCY MEASURES

The emergency measures are adopted to avoid any failure in the system such as lights, fire, means of escape etc. The aim of Emergency Action Plan is to identify areas, population and structures likely to be affected due to a catastrophic event of accident. The action plan should also include preventive action, notification, warning procedures and co-ordination among various relief authorities. These are discussed in following sections.

- **Emergency Lighting**

  The emergency lights operated on battery power should be provided at each station. The battery system should supply power to at least 25% of the lights at the station, platforms, viaduct for a period of 2 hours.

- **Fire Protection**

  The building materials should be of appropriate fire resistance standard. The fire resistance period should be at least 2 hours for surface or over head structures. Wood shall not be used for any purpose, excluding artificial wood products, which are flame resistant. The materials which have zero surface burning characteristics need to be used. The electrical systems shall be provided with automatic circuit breakers activated by the rise of current as well as activated by over current. The design of a station will include provision for the following:

- Fire prevention measures,
- Fire control measures,

- Fire detection systems,
- Means of escape,
- Access for fireman, and
- Means of fire fighting

A. Fire Prevention and Safety Measures

Fire prevention measures will be designed and implemented to minimize the risk of outbreak of fire by appropriate choice, location and installation of various materials and equipment. In stations planning, potential sources of fire can be reduced by:

i. Fire Prevention

- Use of non-combustible or smoke retardant materials where possible,
- Rolling stock is provided with fire retarding materials, low smoke zero halogen type electric cable is also provide,
- Provision of layout which permits ease of maintenance for equipment and cleaning of the station premises,
- Provision of special storage spaces for combustible materials such as paint and oil,
- Prohibition of smoking in fire prone areas,
- Provision of cigarette and litter bins, and
- Good housekeeping.

ii. Safety

Following provisions will be required from fire safety point of view:

- Automatic sprinkler/detection system to be provided if floor area exceeds 750 sq.m
- One wet riser-cum-down comer per 1000 sqm floor area with static underground storage tank, overhead tanks and pumps of suitable capacity with hydrants, first-aid reel, etc.
- Portable fire non-aqueous extinguishers of Carbon Dioxide, chemical dry powder etc. at suitable places.
- Automatic smokes venting facilities.
- Two separate means of exit shall be provided, if more than 10 persons are working and the area exceeds 1400 sq.m.
- Fire resisting doors shall be provided at appropriate places along the escape routes to prevent spread of fire and smoke.
- The travel distance for fire escape shall not exceed 20 m where escape is available in more than one direction; the distance could be upto 40 m.

B. Fire Alarm and Detection System

A complete fire detection system with equipment complying with the requirements of Mumbai Fire Services shall be provided through out each station and ancillary buildings including entrance passageways, subways and adits etc. to give visual and audible indication of alarm conditions actuated by the operation of break glass contact or fire sensors e.g. detector heads, linear heat detecting cables etc. The system shall be operated from 24 V DC Power sources.

Manually operated call points shall be provided at every hydrant and nose reel points, station head wall, tail wall and other locations. Alarm bells shall be installed in each plant room complex at both platform and concourse level and shall be clearly audible at all points in the room/area.

Beam detector or heat detector shall be installed at roof level, ceiling and floor cavity, whilst linear detecting cables shall be installed in under platform cable ducts and cable shafts. Smoke probe units shall be installed in rooms/compartments. When an alarm point is operated, the fire pump shall start to operate automatically. A station fire control and indicating panel shall be provided an installed in the station controllers room, for the control, indication and monitoring of the whole detection and fire fighting systems. While designing the fire fighting system, Mumbai Fire Services shall be taken into account for linking with the same.

C. Fire Control Measures

Control of the spread of fire and smoke will be achieved by partition of fire risk areas, planning for smoke extraction, and arrangement for smoke containment. Partition is aimed at limiting the extent of a fire. The openings must be capable of being sealed in the event of fire. With the exception of station public areas, a fire compartment will not exceed 1500 m^2. Partition of the public areas in stations is not practicable for operational reasons. The fire resistance period of this separated area should be about 3 hours.

D. Access for Fireman

A secondary access to the station, not used by passengers for evacuation, shall be available to fireman should the need arise. The entry point shall be easily accessible from the road. Access shall be available to all levels of the station. The minimum width of the stairs is 1.0 m and maximum height should not exceed 25 cm.

E. Emergency Door

The rolling stock is provided with emergency doors at both ends of the cab to ensure directed evacuation of passengers in case of any emergency including fire in the train.

9.15 SUMMARY OF ENVIRONMENTAL MANAGEMENT PLAN (EMP)

The environmental impacts stemming out of the proposed project can be mitigated with simple set of measures, dealing with careful planning and designing of the metro alignment and structures. Adequate provision of environmental clauses in work contracts and efficient contract management will eliminate or reduce significantly all possible problems. A common problem encountered during implementation of environmental management plans of such projects is lack of environmental awareness among engineers and managers concerned with day to day construction activities, which can be solved through regular environmental training programs. A set of preliminary EMP is presented in **Table 9.12,** which defines actions to be undertaken during the design stage, pre-construction, construction and operation stage of the project. The effectiveness of environmental considerations will, however, depend on appropriate inclusion of these in the work contracts.

The major concern during the construction stage is that the contractors, due to lack of enforcement, would not practice good environmental sanitation (housekeeping) may intend to get unauthorized use of the easily available natural resources and other available infrastructure like roads and water resources. This would result in degradation of ambient air quality, water resources and land environment around the construction sites and workers camp. Improper management of earthwork and bridge construction activities would disrupt the natural drainage and increase soil erosion. Improper management may result in spillage of explosives into the hands of unsocial elements. Finally the implementation of the mitigation actions requires that the project implementation unit would record an end-of-construction mitigation checklist, before releasing the final payment of any work contract.

Additionally, project authority should prepare and establish Environmental and Health Policy and Procedures as per earlier Phases and that should become an integral part of contract document.

Operational phase mitigation would involve good environmental sanitation (housekeeping) practice at metro establishments including effective solid waste collection and disposal, wastewater disposal, upbringing of plantations and green area. Protection of earth slopes in landslide prone area would be a very important task. During the operation period, the metro operating unit will be required to confirm receipt of the construction period mitigation report through the MMRDA and prepare a follow on timetable of actions.

TABLE 9.12 ENVIRONMENTAL MANAGEMENT ACTION PLAN (EMP)

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
DESIGN PHASE				
Metro Alignment	The proposed corridor alignment was selected to minimise the land disturbance to avoid environmentally sensitive areas.	During Design	DPR and design consultant	MMRDA
Cultural Heritage	Avoided by adjustment of alignment.	During Design	DPR and design consultant	MMRDA
Flood	Bridges shall be well designed	During Design	DPR and design consultant	MMRDA
Inadequate design provision for safety against seismological hazard	Make sure that design provides for safety of structures against worst combination of forces in the probability of an earthquake likely to occur in seismic zone-III.	DPR and detailed design stage	DPR and design consultant	MMRDA
PRE –CONSTRUCTION STAGE				
Water requirement	The requirement of water for construction purpose etc shall be planned and shall be arranged from available and authorized sources in order to avoid digging of Tube wells.	Pre construction stage	Contractor	MMRDA/ EMP implementing agency
Disposal of final treated	Options for final disposal shall be studied and the suitable disposal route	During design stage / and pre	Contractor	MMRDA/ EMP implementing

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
effluent from treatment plant	shall be decided carefully to minimize the impact on receiving bodies. As far as possible zero discharge rules may be adopted.	construction of treatment plant		agency
Batching Plant and Casting Yard	These facilities to be located away from habitation. Consent to Establish and Consent to Operate to be taken from MPCB and to comply with all stipulations.	During Pre-construction Stage	Contractor	MMRDA/EMP implementing agency
CONSTRUCTION PHASE				
Environmental Management and Monitoring	This will include institutional requirements, training, environmental management and monitoring	During and after construction	Contractor	MMRDA/EMP implementing agency
Dust	Water should be sprayed during construction phase, wherever it is required to avoid dust. Vehicles delivering materials should be covered to reduce spills and dust blowing off the load.	During construction	Contractor	MMRDA/EMP implementing agency
Air Pollution	Vehicles and machinery are to be regularly maintained so that emissions conform to National and State AAQ Standards. No vehicle without valid PUC certificate would be allowed at Construction Sites.	Beginning with and continuing throughout construction period	Contractor	MMRDA/EMP implementing agency
Equipment Selection maintenance and operation	Construction plants and equipment will meet acceptable standards for emissions and will be maintained and operated in a manner that ensures that relevant air, noise, and discharge regulations are met.	During construction	Contractor	MMRDA/EMP implementing agency
Noise	Noise standard at processing sites, will be strictly enforced as per GOI noise standards. Workers in vicinity of strong noise will wear earplugs and their working time should be limited as a safety measure. At construction sites within 150m of sensitive receptors construction will be stopped from 22:00 to 06:00. Machinery to be provided noise barriers (Stone walls and plantation) for silence zones including schools and hospitals.	Beginning and through construction	Contractor	MMRDA/EMP implementing agency
Vibration	The vibration level limits at work sites adjacent to the alignment shall conform to the permitted values of peak velocity as given in Environmental Manual	Beginning and through construction	Contractor	MMRDA/EMP implementing agency
WATER				
Contamination from Wastes	All justifiable measures will be taken to prevent the wastewater produced in construction from entering directly into any rivers, drainage and irrigation system	Throughout construction period	Contractor	MMRDA/EMP implementing agency
Wastage of	Measures shall be taken to avoid	Beginning with	Contractor	MMRDA/EMP

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
water	misuse of water. Construction agency shall be instructed accordingly to follow strict procedures while using the water for construction and drinking purpose.	and continuing throughout construction		implementing agency
Sewerage disposal during construction at Service Centres	A minimum distance of any sewage or toilet facility from water sources should be 200 meters.	Throughout construction period	Contractor	MMRDA/EMP implementing agency
Sanitation and Waste Disposal in Construction Camps	Sufficient measures will be taken in the construction camps, i.e. provision of garbage tank and sanitation facilities. Waste in septic tanks will be cleared periodically. Drinking water will meet Indian National Standards. Garbage will be collected in a tank and disposed off daily. Special attention shall be paid to the sanitary condition of camps. Camps will be located at a minimum distance of 200 m from water sources.	Before and during building of construction camps	Contractor	MMRDA/ EMP implementing agency
SOIL				
Quarrying	Quarrying will be carried out at approved and licensed quarries only. All environmental mitigation measures shall be enforced at Quarry site also.	During construction	Contractor	MMRDA/ EMP implementing agency
FLORA AND FAUNA				
Loss of trees and Avenue Plantation	Areas of tree plantation cleared will be replaced according to Compensatory Afforestation Policy under the Forest Conservation Act. Ten trees will be planted against every tree felled as per norms.	During and after completion of construction activities	MCGM	MCGM
SOCIAL				
Loss of Access	Temporary access should be built at the interchange and other roads.	During construction	Contractor	MMRDA/ Traffic department
Traffic jams and congestion	If there are traffic jams during construction, measures should be taken to relieve the congestion with the co-ordination of transportation and traffic police department	During construction	Contractor	MMRDA/ Traffic department
Safety with vehicles, people and livestock and signage	• Safety education and fines. • Allow for adequate traffic flow around construction areas • Provide adequate signage, barriers and flag persons for safety precautions.	During construction	Contractor	MMRDA/ Traffic department

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
	• Communicate to the public through radio, TV & newspaper announcements regarding the scope and timeframe of projects, as well as certain construction activities causing disruptions or access restrictions			
Increase in disease Water-borne Insect-borne Communicable diseases	Make certain that there is good drainage at all construction areas, to avoid creation of stagnant water bodies. Provide adequate sanitation and waste disposal at construction camps. Provide adequate health care for workers and locate camps away from vulnerable groups, if any	During construction At start-up Throughout construction	Contractor	MMRDA/ EMP implementing agency
Location of camps depots and storage areas	Location of camps depots and storage areas shall be as per the contract specifications.	Throughout construction	Contractor	MMRDA/ EMP implementing agency
OPERATION PHASE				
Noise and Vibration	Suitable measures should be considered where warranted. The public shall be educated about the regulations of noise and vibration pollution and its implications.	After completion of construction	MMRDA/EMP implementing agency	MMRDA/ EMP implementing agency
WATER				
Maintenance of Storm Water Drainage System	The urban drainage systems will be periodically checked and cleared so as to ensure adequate storm water flow.	Beginning and end of monsoon	MMRDA/EMP implementing agency	MMRDA/ EMP implementing agency

9.16 ENVIRONMENTAL MONITORING PLAN

9.16.1 PRE-CONSTRUCTION PHASE

The environmental monitoring programme is a vital process of any Environmental Management Plan (EMP) of development project for review of indicators and for taking immediate preventive action. This helps in signalling the potential problems resulting from the proposed project activities and will allow for prompt implementation of corrective measures. Historically, environmental monitoring has been integral part of works of MMRDA towards better environmental management of air, noise, vibration, water quality etc both during construction and in operation. Generation of dust and noise are two main issues during any large construction activity. Degradation of water quality is another. The parameters are monitored in pre-construction, construction and operation phase and are based on the need to evaluate the deviation of environmental conditions from baseline environmental conditions due to construction and operation of the Metro. The environmental monitoring will be required during both construction and operational phases. The following parameters are proposed to be monitored:

- Water Quality,
- Air Quality,
- Noise and Vibration,
- Environmental Sanitation and Waste Disposal
- Ecological Monitoring and Afforestation,
- Workers Health and Safety

Environmental monitoring during pre-construction phase is important to know the baseline data and to predict the adverse impacts during construction and operations phases. Pre-construction phase monitoring has been done for the proposed project for air, noise, water, soil quality and ecology.

9.16.2 CONSTRUCTION PHASE

During construction stage environmental monitoring will be carried out for air quality, noise levels and water quality. Keeping a broad view of the sensitive receptors and also the past experience of Phase I and II and Mumbai Metro, an estimate of locations has been made and are summarized in **Table 9.13.** The number could be modified based on need when the construction actually commences.

- **Water Quality**

  Since water contamination leads to various water related diseases, the project authorities shall establish a procedure for water quality surveillance and ensure safe water for the consumers. The water quality parameters are to be monitored during the entire period of project construction. Monitoring should be carried out by NABL certified laboratory. Water quality should be analyzed following the procedures given in standard methods. Parameters for monitoring will be as per BIS: 10500. The monitoring points could be ground and surface water.

- **Air Quality**

  Air quality should be monitored at the locations of baseline monitoring. The parameter recommended is Particulate Matter (PM_{10}). The contractor will be responsible for carrying out air monitoring during the entire construction phase under the supervision of project authority.

- **Noise and Vibration**

  The noise levels will be monitored at construction sites for entire phase of construction by the site contractor and under the supervision of project authority.

- **Workers Health and Safety**

  Monitoring of health risk issues that might arise throughout the project life time will be done. Epidemiological studies at construction sites and workers camp will be performed to monitor the potential spread of diseases. Regular inspection and medical checkups shall be carried out to workers health and safety monitoring. Any reoccurring incidents such as irritations, rashes, respiratory problems etc shall be recorded and appropriate mitigation measures shall be taken. Contractor will be the responsible person to take care health and safety of workers during the entire period of the construction and project proponent is responsible to review/audit the health and safety measures/plans. The monitoring Schedule for Water Air, noise and ecology are presented in **Table 9.13.**

TABLE 9.13 CONSTRUCTION STAGE MONITORING SCHEDULE

Item	Parameter	Frequency and Duration	Locations
Air	PM_{10}	2×24 hours Twice a month During entire civil construction stage or even later, if directed by MMRDA	13 locations
Water	Groundwater quality (IS 10500:1991)	Once in 6months During entire civil construction stage or even later, if directed by MMRDA	4 locations
Noise	Noise Level (Leq and Lmax)	24hours Once a week During entire civil construction stage or even later, if directed by MMRDA	15 locations
Ecology	Felled and planted trees	Once a year till all trees that were to be planted by Maharashtra Government on behalf of project authority, are planted	All the trees felled and newly planted

9.16.3 OPERATION PHASE

Even though the environmental hazards during the operation phase of the project are minimal, the environmental monitoring will be carried out for air, noise, water, waste water, solid waste and ecology during operation phase of the project. The parameters monitored during operation will be PM_{10} for air, heavy metals for solid waste, pH, TSS, BOD, COD, oil and grease for waste water. However, water quality parameters that will be monitored will be as per BIS 10500. The monitoring schedule is presented in **Table 9.14**. The monitoring program shall be conducted by an external agency certified by NABL under the supervision of MMRDA. Project proponent (MMRDA) is responsible for successful environmental monitoring of the proposed project during operation phase.

TABLE 9.14 OPERATION STAGE MONITORING SCHEDULE

Item	Parameter	Frequency and Duration	Locations
Air	PM_{10}	2×24hours Once a monthFor 3years	5 location
Water	Surface, Groundwater quality (IS 10500:1991)	Once a year For 3years	1+1 location
Noise	Noise Level (Leq)	24hours Once a year For 3years	16 locations (Sensitive Receptors)

The results of Air quality, water quality, waste-water will be submitted to management quarterly during construction phase and half yearly during operation phase.

9.17 ESTABLISHMENT OF AN ENVIRONMENTAL DIVISION

MMRDA already has the setup for environmental Management and the proposed corridor is an extension of already existing operative line, additional set-up for environmental management is not recommended. Existing set up for environmental management can also handle this extension.

9.18 COST ESTIMATES

9.18.1 SUMMARY OF COSTS

All costs involved in Environmental mitigation and management and monitoring has to be put on the account of Mumbai Metro Project corridors. A summary of these is presented in Table 9.15.

Table 9.15 Environmental Costs

S. No.	ITEM	COST Rs. lakh
1.	Rain Water Harvesting at stations and along alignment	213.25
2.	Air, Noise, vibration, Water, Waste Water, Solid waste, during construction and operation	25.00
3.	Ecological monitoring	10.00
4.	Tree Plantation 850trees @ Rs.2000/- per tree	3.42
5.	Water Treatment Plant	120.50
6.	Sewage Treatment Plant	78.00
7.	Effluent Treatment Plant	88.50
8.	Green Belt at Depot	40.00
9.	Rain water harvesting at Depot	35.00
10.	Recycling of treated waste water	41.00
	Total	**654.67**

The compensation for loss of land, fire control, information systems and contractor's obligations has been incorporated in project costs.

The Environmental management plan should be implemented in phases so that optimum benefit could be achieved and should be synchronized with the construction schedules.

Table 9.16 Details of Cost of Resettlement and Rehabilitation (Rs. Lakh)

S. No.	Description	Entitlement	Unit	Quantity	Rate	Amount
1	Acquisition of Permanent land Private Land	Total Replacement Cost of land *	m^2	38441 m^2	0.50	19220.50
2	Solatium	100% as per Act 30 of 2013.	m^2	38441 m^2	0.50	19220.50
3	Acquisition of temporary private land	6% of total land cost per year for 3 years	m^2	-	-	-
4	Acquisition of structures					
4.1	Residential PAPs	Area equivalent to affected area 20.91 m2 free of cost	Per unit	99		**
4.2	Commercial PAPs	Area equivalent to affected area 20.91 m2 free of cost	Per unit	38		**
5.	Subsistence Allowance ***	For a period of one year @Rs.3000/ month	Family	137	0.36	49.32
6.	Shifting Allowance ***	A lump sum shifting allowance of Rs. 50,000/-	No.	99	0.50	49.5

S. No.	Description	Entitlement	Unit	Quantity	Rate	Amount
7.	One time resettlement allowance ***	For All the affected families excluding employees in shops	Per Family	137	0.50	68.5
8	Employees Transportation cost	12 Quarterly passes for differential distance	LS	48		2.00
9.	Independent Evaluation		LS		5.00	5.00
10.	Miscellaneous		LS		5.00	5.00
	Cost of R & R					**38620.32**

* Average rate of land for all the stations

**refers the accommodation is available with MMRDA so additional cost is not given.

*** applicable for only titleholders.

9.19 CONCLUSION

The proposed Metro line is proved to have significant positive effects to the development of Mumbai City. Benefits to the economy, traffic congestion reduction, quick and safety transport, employment opportunities, fuel consumption reduction, and air quality improvement are the obvious positive effects from this Metro line. Besides, the potential adverse environmental impacts on air quality (during construction phase), water environment, noise, solid waste, ecology, population resettlement are also taken into consideration. The current project need to be the categorized as per the policy of Multilateral Funding Agencies. Based on these detailed potential adverse environmental impacts, appropriate mitigation measures have been developed for consideration. The EIA concluded that project impacts from both construction and operation will be minimal, and can be mitigated through the use of prevailing current practices and appropriate technologies. With the implementation of the EMP and the monitoring plan, the Project is not expected to have significant environmental impacts.

Chapter -10

MULTI MODAL TRAFFIC INTEGRATION AT METRO STATIONS

10.1 INTRODUCTION

Swami Samarth Nagar – JVLR – SEEPZ – Kanjur Marg – Vikhroli (EEH) Metro Corridor starts from Swami Samarth Nagar runs eastward via Adarsh Nagar, Jogeshwari (W), JVLR, Shyam Nagar, Mahakali Caves, SEEPZ Village, Milind Nagar, Ram Baug, Pawai, Kanjur Marg and terminates at Vikhroli (EEH). The entire corridor will be elevated and total length is 14.477 km. (Dead-end to dead end).

It will be augmented through enhanced flexibility of criss-cross interchanges to other metro corridors and other modes of public transport. It will reduce the travel time of commuters. While Metro is a high capacity mode of transport, the need for integration with other secondary/intermediate transport mode is getting highlighted more than ever to ensure a seamless journey. This concept is to provide first mile and last mile connectivity to the commuters with their places of stay. With top priority to this issue, MoUD has laid down policy guidelines to include the need and provisioning of all public, IPT and private modes in the DPRs for the Metro Rail Systems. (Ref: MoUD (Urban Transport Wing) Advisory Circular No. K-14011/1/2007-UT-IV dated 30.08.2013).

The share of various modes of secondary/intermediary mode of travel is complex and debatable issue which is dependent on a large number of variables like available road width, penetration in the residential areas, Road condition, distance from the Metro Stations, availability of parking and lay out and availability of circulating areas at the Metro Rail Stations, Business centre or Market & existing traffic densities. These factors relate with each other and evolve with development of new model mix of transport, infrastructure and changes with the passage of time. Even though for a given urban transport scenario, optimal mode share may be determined from computer based models but actual **optimal mode share** is never achievable on the road due to dynamic nature of demand and supply of transport modes.

10.2 PRESENT CONDITION OF TRANSPORT ON CITY ROADS

At present the various modes coming to Metro Stations comprise of State Transport buses, Auto-rickshaws, Private cars, Two Wheelers and Bi-cycles. These can be classified in three groups of transport modes namely Public, IPT and Private.

In public transport group there are large buses of State Transport (50 Seaters) and Charted Buses hired by Schools and private offices. Generally the public transport in Mumbai comprises of the buses which are operated by the Transport Corporation.

Auto-rickshaws are also an important part of public transports at Mumbai. After bus, it is these auto rickshaws which are the most important modes of public transport in Mumbai even though they are little expensive. Auto rickshaws are Intermediate Public Transport (IPT) Modes. Another public transport at Mumbai which can be ranked third among all is the cabs or taxis that run on the streets of Mumbai.
In the personalised transport modes, there are Cars, Two Wheelers and Bicycles of all possible sizes.

A chaotic situation is observed when all the above mentioned transport vehicles are seen jostling to each other for space for moving forward. More pathetic conditions are seen at the Road Intersections.

The solution lies in the showcasing a workable arrangement of co-existence through identification of good points of each mode and then utilise the same to get the attention and embedding it in public psyche.

Because of high traffic and less capacity as well as length of the roads, average distance between two consecutive vehicles becomes very less. Such situation does not permit speed higher than 15-20 km/hr. This indicates that unless there is some solution to reduce this unmanageable mix of the vehicle fleet, real transport integration may not be possible. While no significant increase, the Road length on main & arterial Roads may be anticipated which may relieve the congestive/chaotic/slow moving road traffic, a divergent policy of linking commuters directly through E-Rickshaw using the service/inner road length to supplement the main road traffic will impact the congestion and provide relief to the Metro commuters in reaching out to Metro Stations.

10.3 IMPACT OF BUS/CLUSTERS IN MODE SHARE

Primary reason for using personal vehicle (for buying vehicle) is **to save travel time** during journey. On the other hand, Government has tried to increase number of public buses on the road in many different ways.

Government has tried hard to popularise public buses by subsidising the fare but could not bring higher (and middle) income group to use public bus simply because it is slow and uncomfortable. Therefore objective of achieving optimal mode share remained elusive than reality.

10.4 BALANCING ACT OF METRO

After introduction of Metro Rail System in the city, Traffic and Transportation scenario will significantly change. People will no longer be afraid to travel a much longer distance. With Metro in place, longer distances can be travelled in shortest time with relatively more ease and comfort.

10.5 WAY FORWARD

In view of above deliberations in back ground, along with planning for Metro System in any city, there is a need for providing a transportation system which is seamlessly integrated across all modes and provides first mile as well as last mile connectivity. It is also necessary that various public transportation modes including Inter-mediate Public Transport (IPT) and feeder buses etc. work together in order to facilitate increase in ridership to the Metro/Metro system and provide ease of using Metro system by the public at large.

Therefore, there is a need for doing more scientific study exclusively for this. To achieve this goal, Metro Stations influenced zone need to be defined which can be taken as approximately 5 kms for the motorized traffic and 1.5 km. for pedestrian/cyclists. Detailed Study is required to be done in this influenced zone of a Metro station for following aspects mainly:

i) Availability and review of existing public and IPT facilities, in terms of motorized and non-motorised mode with main consideration of the streets/roads adjoining to the stations and also to examine adequacy of availability of pedestrians/cycle paths in the influenced zone.

ii) Analysis and identification of gaps between supply and demand in terms of feeder facilities and other requirements for better first and last mile connectivity.

iii) Proposal for introduction/enhancement of feeder buses and cycle/pedestrians tracks, bike sharing arrangement for each Metro station to be finalised.

iv) Proposal for better integration of Metro station with other mode of transport, such as relocation of existing bus stop, introduction of new bus stop, bus base etc.

v) Cost of the requirements namely road widening including roads for pedestrian/cycle paths, feeder buses based on the outcome of the study.

The detailed study and requirement for providing first mile as well as last mile connectivity to the Metro users will be carried out separately and the same should be in place before the commercial operation of the Metro services for the benefit of the users as well as for better ridership and the financial viability of the project.

Since, it is envisaged that detailed study for provision of feeder buses, public bike sharing and pedestrianisation in the influence zone of Metro stations will be done and put in place by the time commercial operation of the Metro services, a lump-sum cost of Rs. 2.40crores per station has been considered sufficient and included in the project cost of proposed Metro System. If at any stage more feeder services etc will be required, same can be augmented by concerned city transportation authorities.

Chapter -11

FRIENDLY FEATURES FOR DIFFERENTLY ABLED

11.1 INTRODUCTION

The objective of making this chapter is to create a user-friendly mass transport system in India which can ensure accessibility to persons with disabilities, people travelling with small children or are carrying luggage, as well as people with temporary mobility problems (e.g. a leg in plaster) and the elderly persons.

The design standards for universal access to Public Transport Infrastructure including related facilities and services, information, etc. would benefit people using public transport.

The access standards given here are extracted from Indian Roads Congress Code, IRC 103: 2012, Guidelines for Pedestrian Facilities; Model Building Bye-Laws, 2011 and National Building Code, 2005. Central Public Works Department's (CPWD) "Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons", 1998 and 2013 edition (under revision by MoUD), and international best practices / standards

Further, it has also been attempted to provide guidelines/ standards for alighting and boarding area, approach to station, car parking area, drop-off and pick-up areas, taxi/auto rickshaw stand, bus stand/stop, footpath (sidewalk), kerb ramp, road intersection, median/pedestrian refuge, traffic signals, subway and foot over bridge etc. to achieve a seamless development around Metro stations.

11.2 CONTENT

1. Metro Rail Station
   - Way finding
   - Signage
   - Automated Kiosks
   - Public Dealing Counters
   - Audio-visual Displays
   - Public Telephones
   - Rest Areas/Seating
   - Tactile Paving - Guiding & Warning
   - Doors
   - Steps & Stairs
   - Handrails
   - Ramps

- Lifts/Elevators
- Platform/Stair Lift
- General and Accessible toilets
- Drinking Water Units
- Visual Contrasts
- Emergency Egress/Evacuation

2. Street Design
   - Footpath (Sidewalk)
   - Kerb Ramp
   - Road Intersection
   - Median/Pedestrian Refuge
   - Traffic Signals
   - Subway and Foot Over Bridge

3. Alighting and Boarding Area
   - Approach
   - Car Park
   - Drop-off and Pick-up Areas
   - Taxi/Auto Rickshaw Stand
   - Bus Stand/Stop

11.3 METRO RAIL STATION

1. General
   - Whether over-ground or underground, rail travels is a highly effective mode of transport.
   - Every train should contain fully accessible carriages.
   - Staff should be trained in methods of assistance and be at hand on request.
   - Stations for all rail travel should be fully accessible with extra wide turnstiles where possible alongside wheelchair accessible doorways
   - Staff should be on hand to assist persons with disabilities and elderly to enter or exit through convenient gates.
   - All new railway stations should be designed to be fully accessible.
   - For persons with hearing impairments, an electronic sign board (digital display) should be displayed on each platform at conspicuous location for all announcements made by the railways.
   - For persons with visual impairments audio system announcing the station names and door location should be available.

2. Accessible Metro Rail Cars

   The railway cars should have the following features:
   - Railway car doors should be at least 900 mm wide;
   - The gap between the car doors and the platform should preferably be less than 12 mm;
   - Identification signage should be provided on the doors of wheelchair accessible coach.

- If the car door and the platform cannot be at the same level, then at least one car doors should have apparatus such as a hydraulic lift or pull-out ramp installed in the doorway for wheelchair users.

3. Wheel Chair Space
   - Space for a wheel chair should be available at the side of the door:-
   - The space should be indicated inside and outside the car by using the international symbol of access; and
   - Wheel stoppers and ring-strap or other appropriate safety grip should be provided for wheelchair users.

4. Seats
   - An appropriate number of designated seats for passengers with disabilities and elderly people should be provided near the doors.

5. Aisles
   - Aisles should be at least 900 mm wide.

11.4 INFORMATION SIGNS AND ANNOUNCEMENTS

A map of train routes should be installed. This should be in Braille/raised numbers as well. In each car, there should be an announcement and provision of a visual display of the names of stations route. This display should be in raised numbers with sharp contrast from the background.

11.5 METRO STATION AREA

1. Level Approach
   - Approach route should not have level differences. If the station is not on the same level as the walkway or pathway, it should have a ramp.
   - Walkway surfaces should be non-slip.
   - Approach walkway should have tactile pavements for persons with visual impairments.

2. Station Entrances and Exits
   - These should have a minimum width of 1800mm and is level or ramped.

3. Reservation and Information Counters
   - Should have clear floor space of at least 900 mm x 1200 mm in front of the counters;
   - There should be at least one low counter at a height of 750 mm to 800 mm from the floor with clear knee space of 750 mm high by 900 mm wide by 480 mm deep.
   - At least one of the counters should have an induction loop unit to aid people with hearing impairments; and
   - The counters should have pictographic maps indicating all the services offered at the counter and at least one of the counter staff should be sign language literate.

4. TOILET FACILITIES
   - There should be at least one unisex accessible toilet
   - Ticket Gates

   At least one of the ticket gates should:
   - Be minimum 900 mm wide to allow a wheelchair user through; and
   - Have a continuous line of guiding paver for people with visual impairments.

5. PLATFORMS

   The Platforms should:
   - Have a row of warning paver installed 600mm before the track edge (photo 6);
   - Have non-slip and level flooring;
   - Have seating areas for people with ambulatory disabilities;
   - Be well illuminated lux level 35 to 40;
   - There should be no gap or difference in level between the train entry door and the platform.
   - All platforms should inter-connect by means of an accessible routes or lifts; and provide accessible level entrance to the train coach.

6. WAY FINDING
   - Way finding references should be available at decision points.
   - Colour can be used to identify routes and provide assistance in locating doors, walls and hazards. Proper colour contrast between different elements greatly improves visibility for all users and is critical for persons with low vision. For example, colour contrasting of door frames can assist in locating doors, and likewise floors should be contrasted with walls. In addition, furniture should contrast with walls and floors so as not to create an obstacle.
   - Structural elements such as columns should be colour contrasted or brightly marked so as to be visible to those who may have a visual disability.
   - Generally, patterns on flooring should be avoided or else should be minimal and small to avoid visual confusion.
   - In addition to identifying hazards or warnings, tactile floor surfaces can also be used to inform that there is a change in area (e.g. leaving a corridor and entering a boarding area).
   - Tactile systems should be consistent throughout the building. For example, terminals should not have carpeting in some boarding areas and tile in others as this may create confusion for those who rely on tactile surfaces to guide them to their destination.
   - Good lighting assists those with a visual disability to see better and allows people who have a hearing impairment to lip read easier. However, care should be taken to properly direct lighting and to use matte finishes on floors, walls and signage, so as not to create glare which may create difficulties for all travellers.
   - Blinds can be used to adjust lighting levels in areas where the natural lighting changes significantly throughout the day.

7. SIGNAGE
   - Signs must be clear, concise, and consistent. All travelers need clear information about the purpose and layout of terminals to maintain a sense of direction and independent use of all facilities. Using internationally and nationally established

symbols and pictograms with clear lettering and Braille ensures universal accessibility cutting across regional/cultural and language barriers. A cohesive information and signage system can provide visual (e.g. signs, notice boards), audible (e.g. public address and security systems, induction loops, telephones, and infrared devices), and/ or tactile information (e.g. signs with embossed lettering or Braille)

8. SIGN DESIGN SPECIFICATIONS

- The sign should be in a prominent position.
- The face of the sign should be well-illuminated by natural or artificial light.
- Letters should be simple such as Arial, Helvetica medium, and san serif or similar and numbers should be Arabic.
- The colour of the text should be in a colour that contrasts with the sign board.
- The sign board should also contrast with the wall on which it is mounted.
- The surface of the sign should not be reflective.
- Some signs such as those adjacent to or on a toilet door may be embossed so that they can be read by touch.
- Illuminated signs should not use red text on a dark background.
- Signs should be supplemented by Braille where possible.

Fig. 11.1 - Way finding signage

Fig. 11.2 - International Symbol of Accessibility

9. AUTOMATED KIOSKS

- Automated kiosks should be accessible for wheelchair users.
- Should be clearly marked with international symbol of accessibility.
- Should have Braille buttons and audio announcement system for persons with vision impairments.
- Operations should be easy to understand and operate for persons with learning disabilities, intellectual disabilities, and elderly persons.

10. PUBLIC DEALING COUNTERS

- Ticketing, Information, Check-in, Help desk, Restaurants, Shops, etc. should have public dealing counters.
- Information or help desks should be close to the terminal entrance, and highly visible upon entering the terminal. In addition, they should be clearly identified and accessible to both those who use wheelchairs and those who stand.

- It should provide information in accessible formats, viz. Braille leaflets for persons with vision impairments.
- Ideally, these desks should have a map of the facility that desk attendants can view with passengers, when providing directions.
- Staff manning the counters should know sign language.
- Information desk acoustics should be carefully planned and controlled as a high level of background noise is confusing and disorienting to persons with hearing impairment.
- Lighting should be positioned to illuminate the receptionist/person manning the counter and the desk top without creating glare.
- Lighting should not create shadows over the receptionist staff, obscuring facial detail and making lip reading difficult.
- There should be a hearing enhancement system such as a loop induction unit, the availability of which is clearly indicated with a symbol.
- One of the counters should not be more than 800mm from the floor, with a minimum clear knee space of 650mm high and 280mm- 300mm deep.

11. AUDIO-VISUAL DISPLAYS

- Terminal maps should be placed so that they are readily visible to persons who are standing and persons who use wheelchairs. They should also be accessible to persons with a visual disability (i.e. tactile maps). Other alternatives include electronic navigation systems or audio maps.
- Enable captioning at all times on all televisions and other audio-visual displays that are capable of displaying captions and that are located in any portion of the terminal.
- The captioning must be in high contrast for all information concerning travel safety, ticketing, check-in, delays or cancellations, schedule changes, boarding information, connections, checking baggage, individuals being paged by bus railway or airlines, vehicle changes that affect the travel of persons with disabilities, and emergencies (*e.g.*, fire, bomb threat).

12. REST AREAS/SEATING

- Seating area / benches should be provided along the circulation path at regular intervals so that passengers do not need to walk more than 50 to 60 metres before being able to sit and rest.
- Where seating is provided, designated seating for passengers with disabilities is to be provided at boarding gates and departure areas within viewing distance of communication boards and/or personnel and identified by the symbol of access.
- Public transit operators should provide seating in passenger service areas where there may be long waiting lines or times, including at ticket sales counters, check-in counters, secured screening and during inter-country travel in customs areas and baggage retrieval areas.
- Designated seating should be provided for at boarding gates and departure areas within viewing distance of communication boards, and within hearing range of audio announcements as well. Such seating areas should be identified by the symbol of accessibility and shelter should be provided where this seating is outdoors.

- In outdoor settings, seating should be provided along with the planned hawker spaces.
- At waiting lounges for persons with disabilities chairs should have armrests and backrest.

13. TACTILE PAVING- GUIDING & WARNING

(a) Tactile Guiding Paver (Line-Type)

It is recommended to install a row of tactile guidance paver along the entire length of the proposed accessible route for visual impaired persons. Care must be taken to ensure that there are no obstacles, such as wall, pillar, uneven surfaces, Soffit (underside /open area under the stairs, along the route traversed by the guidance paver. Also, there should be clear headroom of at least 2.1 meters height above the tactile guidance paver, free of protruding objects such as overhanging advertisement panel and signage, along the entire length of the walk.

(b) Tactile Warning Paver (Dot-Type)

Indicate an approaching potential hazard or a change in direction of the walkway, and serve as a warning of the approaching danger to persons with visual impairments, preparing them to tread cautiously and expect obstacles along the travel path, traffic intersections, doorways, stairs, etc. They are used to screen off obstacles, drop-offs or other hazards, to discourage movement in an incorrect direction, and to warn of a corner or junction. Two rows of tactile warning paver should be installed across the entire width of the designated accessible passenger pathway at appropriate places such as before intersections, terminal entrances, obstacles such as signage, and each time the walkway changes direction.

14. PLACES TO INSTALL WARNING PAVER

- In front of an area where traffic is present.
- In front of an entrance/exit to and from a staircase or multi-level crossing facility.
- Entrances/exits at public transport terminals or boarding areas.

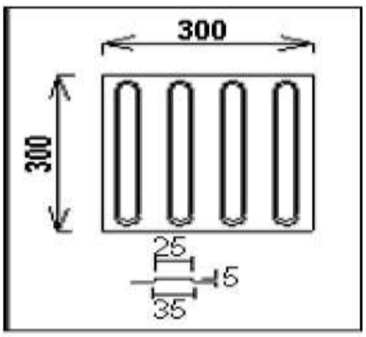


Fig. 11.3 - Guiding paver

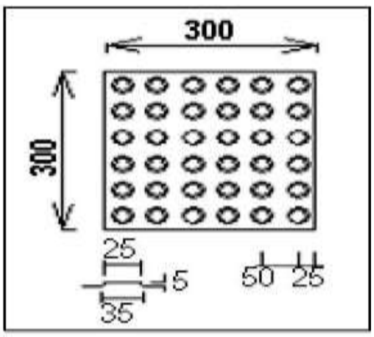


Fig. 11.4 - Warning paver

15. DOORS

Whatever the type of entrance door, it must be wide enough to accommodate passenger traffic comfortably.

- The recommended minimum clear opening width of an internal door is 900mm minimum.
- Where doors comprise two leaves (i.e. double doors), each leaf should be 900mm min. wide, so that persons carrying large items and people using wheelchairs do not have to open both leaves.
- Manual doors should incorporate kick plates 300-400mm high to withstand impact of wheelchair footrest (this is especially important where doors are glazed).

  - Also be fitted with vision panels at least between 900mm and 1500mm from floor level.
  - Be color contrasted with the surrounding wall and should not be heavier than 22N to open.
  - Lever handles and push type mechanisms are recommended. When a sliding door is fully open, handles should be usable from both sides.

- Where revolving doors or turnstiles are used, an alternative wheelchair-
- Accessible entrance must also be provided.
- A distance of 400mm should be provided beyond the leading edge of door to enable a wheelchair user to maneuver and to reach the handle.
- To ensure maximum clarity for persons with visual impairments, the entrance should be easily distinguishable from its surroundings by the effective use of landscaping, signage, colour (preferably yellow/orange), tonal contrast and tactile surfacing.
- Door hardware should be positioned between 900-1000mm above floor (figure 28).
- Operable devices such as handles, pulls, latches and locks should:
  - Be operable by one hand
  - Not require fine finger control, tight grasping, pinching or twisting to operate

- Glazed doors and fixed glazed areas should be made visible by use of a clear, colour and tone contrasted warning or decorative feature that is effective from both inside and outside and under any lighting conditions, e.g. a logo, of minimum dimensions 150mm by 150mm (though not necessarily square), set at eye level.

16. STEPS & STAIRS

- Steps should be uniform with the tread not less than 300mm and the risers 150mm.
- The risers should not be open.
- The steps should have an unobstructed width of 1200mm minimum.
- All steps should be fitted with a permanent colour and tone contrasting at the step edge, extending the full width of the step, reaching a minimum depth of 50mm on both tread and riser.
- Have continuous handrails on both sides including the wall (if any) at two levels
- Warning paver to be placed 300mm at the beginning and at the end of all stairs.
- Nosing to be avoided.
- The staircase should be adequately and uniformly illuminated during day and night (when in use). The level of illumination should preferably fall between 100-150 lux.
- The rise of a flight between landings must be no more than 1200mm.
- There should be no more than 12 risers in one flight run.
- The stair covering and nosing should be slip-resistant, non-reflective, firmly-fixed and easy to maintain.
- Soffit (underside /open area under the stairs) of the stairs should be enclosed or protected.

17. HANDRAILS

- Handrails should be circular in section with a diameter of 38-45mm and formed from materials which provide good grip such as timber, nylon or powder coating, matt finish metal finishes.
- The handrail should contrast in colour (preferably yellow/orange) with surrounding surfaces.
- At least 50mm clear of the surface to which they are attached and should be supported on brackets which do not obstruct continuous hand contact with the handrail.
- The handrail should be positioned at two levels- 760mm and 900mm above the pitch-line of a flight of stairs.
- Handrail at foot of the flight of stairs should extend 300mm beyond the stairs in the line of travel and returning to the wall or floor or rounded off, with a positive end that does not project into the route of travel.

18. RAMPS

- Ramps gradient should ideally be 1 in 20 and no greater than 1 in 12.
- Width of the ramp should not be less than 1200mm and preferred width is 1800mm.
- The steeper the gradient, the shorter the length of ramp between landings.
- On long ramps, a horizontal resting space should be provided every 6 meters.

- Surface materials should be slip-resistant, non-reflective, firmly-fixed and easily maintained
- The edge of the ramp should have an edge protection with a minimum height of 100mm.
- Landings every 750mm of vertical rise.
- A tapping or lower rail should be positioned so that its bottom edge is no higher than 200mm above ground level.
- Handrails on the ramps should be on both sides at two levels: upper at 900mm and lower at 760mm; both end to be rounded and grouted; extend 300 mm beyond top and bottom of ramp .
- A row of tactile warning paver should be placed 300mm beginning and end of each run.
- Landings should be provided at regular intervals as indicated in the table (Table 11.1).

Table 11.1 - Specifications for Ramps

Level difference	Minimum Gradient of Ramp	Ramp Width	Handrail on both sides	Comments
≥ 150 mm ≤ 300 mm	1:12	1200 mm	√	
≥ 300 mm ≤ 750 mm	1:12	1500 mm	√	Landings every 5 meters of ramp run.
≥ 750 mm ≤ 3000mm	1:15	1800 mm	√	Landings every 9 meters of ramp run.
≥ 3000 mm	1:20	1800 mm	√	Landings every 9 meters of ramp run.

19. LIFTS/ELEVATORS

- A carefully designed lift makes a huge contribution to the accessibility of a multi-storied terminal building for persons with disabilities.
- Lift locations should be clearly signposted from the main pedestrian route and recognizable through design and location.
- The colour and tone of the lift doors should contrast with the surrounding wall finish to assist in their location. Lift doors with metallic finishes such as steel grey and silver should be avoided as they are difficult to identify by persons with low vision.
- The lift lobby shall be of an inside measurement of 1800mm X 2000mm or more. A clear landing area in front of the lift doors of minimum dimensions 1500mm x 1500mm should be provided.
- By making the landing area distinguishable by floor surface and contrast, it will aid location and recognition of core areas. This could comprise a change in floor finish from thin carpet to vinyl/PVC, or cement/mosaic floor to carpet.
- Changes in floor finish must be flushed. There should be no level difference between lift door and the floor surface at each level; the gap if unavoidable should not be more than 12mm.
- The floor level/location should be indicated on the wall adjacent to or just above the call buttons, and opposite the lift doors where possible.

20. Lift Dimensions

- Provisions of at least one lift shall be made for people using wheelchairs with the following car dimensions:
  - Clear internal depth -1500 mm minimum
  - Clear internal width - 1500 mm minimum
  - Entrance door width - 900 mm minimum

21. LIFT CONTROLS

- The lift call button should be wall-mounted adjacent to the lift and should contrast with wall finish, either by using a contrasting panel, or a contrasting border around the button panel.
- The call buttons should be located within the range 800-1000mm above floor finish.
- Buttons should not be touch sensitive, but should require a light positive pressure and should ideally be large enough to be operable by the palm of the hand if required.
- The control buttons inside the lift should be positioned on the side wall rather than front wall to allow access from the back and front of the lift car, by mobility aid users like wheelchair users.
- The control buttons should contrast with their surroundings and illuminate when pressed and should incorporate highly visible tactile embossed (NOT engraved) characters and in Braille.
- Time of closing of an automatic door should be more than 5 seconds and the closing speed should not exceed 25 meters per second. There should be a provision of censor enabled closing.
- In larger lifts, controls should be positioned on both side walls, at least 400mm from front wall and between 800-1000mm above floor level.

22. CAR DESIGN

- Internal walls should have a non-reflective, matt finish in a colour and tone contrasting with the floor, which should also have a matt, non-slip finish.
- Use of reflective materials such as metal (stainless steel for example) can be problematic in creating sufficient contrast with control buttons, emergency telephone cabinet, etc. for persons with low vision and the use of such materials should be avoided wherever possible.
- A mirror (750mm above floor level) on the rear wall can be useful to persons using wheelchairs and other mobility aids should they need to reverse safely out of the lift car or view the floor numbers.
- Internal lighting should provide a level of illumination of minimum 100 lux (approximately 50-75 lux at floor level), uniformly distributed, avoiding the use of spotlights or down lighters.
- A grab bar should be provided along both sides and the back wall, 900mm above floor level.
- Handrails should be of tubular or oval cross section, in order to be easily gripped and capable of providing support.
- Handrails should be positioned so that there is a clear space behind the handrail to allow it to be grasped i.e. knuckle space should be 50mm.

11.6 INFORMATION SYSTEMS

- Lifts should have both visual and audible floor level indicators
- Audible systems are also usually capable of incorporating additional messages, such as door closing, or, in the case of an emergency, reassurance (with manual over-ride allowing communication with lift occupants).
- Announcement system should be of 50 decibel.
- The display could be digital or segmented LED, or an appropriate alternative. A yellow or light green on black display is preferred to a red on black display as it is easier to read.

11.7 GENERAL ACCESSIBLE TOILETS

1. SIGNAGES
   - All signage of general toilets should be in bold and contrasting colors.
   - For persons with low vision and vision impairments: male pictogram in triangle and female pictogram in circle, marked on plates along with Braille & raised alphabets, to be mounted on wall next to door near the latch side, at a height between 1400mm-1600mm.
   - Warning strip/ thin rubber door mat to be provided 300mm before and after the toilet entrance.
   - Tactile paver to be provided for urinals, WC and washbasins for persons with vision impairments.

2. ACCESSIBLE TOILETS
   - Should have the international symbol of accessibility displayed outside for wheelchair access.
   - The toilet door should be an outward opening door or two way opening or a sliding type and should provide a clear opening width of at least 900mm.
   - It should have a horizontal pull-bar, at least 600mm long, on the inside of the door, located so that it is 130mm from the hinged side of the door and at a height of 1000mm.

3. WC COMPARTMENT DIMENSIONS
   - The dimensions of a unisex toilet are critical in ensuring access. The compartment should be at least 2200mm and 2000mm. This will allow use by both manual and motorized wheelchair users.
   - Layout of the fixtures in the toilet should be such that a clearing maneuvering space of 1500mm x 1500mm in front of the WC and washbasin.

4. WATER CLOSET (WC) FITTINGS
   - Top of the WC seat should be 450-480mm above finished floor level, preferably be of wall hung or corbel type as it provides additional space at the toe level.
   - An unobstructed space 900mm wide should be provided to one side of the WC for transfer, together with a clear space 1200mm deep in front of the WC.
   - WC should be centred 500mm away from the side wall, with the front edge of the pan 750mm away from the back wall. Have a back support. The WC with

a back support should not incorporate a lid, since this can hinder transfer.
- L-shape grab bar at the adjacent wall and on the transfer side (open side) swing up grab bar shall be provided.
- The cistern should have a lever flush mechanism, located on the transfer side and not on the wall side and not more than 1000mm from the floor.

5. GRAB BARS
   - Grab bars should be manufactured from a material which contrasts with the wall finish (or use dark tiles behind light colored rails), be warm to touch and provide good grip.
   - It is essential that all grab rails are adequately fixed, since considerable pressure will be placed on the rail during maneuvering. Grab bars should sustain weight of 200kgs minimum.
   - A hinged type moveable grab bar should be installed adjacent to the WC on the transfer side. This rail can incorporate a toilet tissue holder. A distance of 320mm from the centre line of the WC between heights of 200-250mm from the top of the WC seat. It should extend 100-150mm beyond the front of the WC.
   - A fixed wall-mounted L- shape grab bar (600mm long horizontal and 700mm long vertical) on the wall side should be provided. It should be placed at a height of 200-250mm above the WC seat level.

6. WASHBASINS
   - Hand washbasins should be fitted on cantilevered brackets fixed to the wall.
   - The basin should be fixed no higher than 750mm above the finished floor level.
   - Be of dimensions 520mm and 410mm, mounted such that the top edge is between 800- 900mm from the floor; have a knee space of at least 760mm wide by 200mm deep by 650-680mm high.
   - The position of the basin should not restrict access to the WC i.e. it should be located 900mm away from the WC.
   - A lever operated mixer tap fitted on the side of the basin closest to the WC is useful as it allows hot and cold water to be used from a seated position on the WC.
   - The hand drying facilities should be located close to the hand washbasin between 1000-1200mm.
   - Lever type handles for taps are recommended.
   - Mirror’s bottom edge to be 1000mm from the floor and may be inclined at an angle.

7. FIXTURES AND FITTINGS

- Contrast between fittings and fixtures and wall or floor finishes will assist in their location. For example, using contrasting fittings, or dark tiles behind white hand washbasins and urinals, contrasting soap dispensers and toilet roll holders.
- Contrast between critical surfaces, e.g. floors, walls and ceilings helps to define the dimensions of the room.
- Towel rails, rings and handrails should be securely fixed to the walls and positioned at 800-1000mm from the floor.

- The mirror should be tilted at an angle of 300 for better visibility by wheelchair users.
- It should have lower edge at 1000mm above floor finish and top edge around 1800mm above floor finish.
- Hooks should be available at both lower-1200mm and standard heights-1400mm, projecting not more than 40mm from the wall.
- Where possible, be equipped with a shelf of dimensions 400mm x 200mm fixed at a height of between 900mm and 1000mm from the floor.
- Light fittings should illuminate the user's face without being visible in the mirror. For this reason, most units which have an integral light are unsatisfactory.
- Large, easy to operate switches are recommended, contrasting with background to assist location, at a maximum height of 1000mm above floor finish.
- All toilet facilities should incorporate visual fire alarms.
- Alarms must be located so that assistance can be summoned both when on the toilet pan i.e. at 900mm height and lying on the floor i.e. at 300mm, from floor surface. Alarms should be located close to the side wall nearest the toilet pan, 750mm away from rear wall and at 900mm and 200mm above floor finish

8. SIGNAGE OF ACCESSIBLE TOILETS

- All unisex accessible toilets to have access symbol in contrast colours. A distinct audio sound (beeper/clapper) may be installed above the entrance door for identification of the toilets.

Fig. 11.5 - Signage for accessible washroom

9. ACCESSIBLE URINAL

   - At least one of the urinals should have grab bars to support ambulant persons with disabilities (for example, people using mobility aids like crutches).
   - A stall-type urinal is recommended.
   - Urinals shall be stall-type or wall-hung, with an elongated rim at a maximum of 430mm above the finish floor. This is usable by children, short stature persons and wheelchair users.
   - Urinal shields (that do not extend beyond the front edge of the urinal rim) should be provided with 735mm clearance between them.
   - Grab bars to be installed on each side, and in the front, of the urinal.
   - The front bar is to provide chest support; the sidebars are for the user to hold on to while standing.

11.8 DRINKING WATER UNITS

- Drinking water fountains or water coolers shall have up front spouts and control.
- Drinking water fountains or water coolers shall be hand-operated or hand and foot-operated.

- Conventional floor mounted water coolers may be convenient to individuals in wheelchairs if a small fountain is mounted on the side of the cooler 800mm above the floor.
- Fully recessed drinking water fountains are not recommended.
- Leg and knee space to be provided with basin to avoid spilling of water. This allows both front and parallel access to taps for persons using mobility aids like wheel chair, crutches etc.

11.9 VISUAL CONTRASTS

- Visual contrasts means adequate contrast created by difference of at least 30 LRV (Light Reflectance Value) of the two surfaces/ objects and it helps everyone especially persons with vision impairments.
- Visual contrast should be provided between:
  - Critical Surfaces (walls, ceiling and floor),
  - Signage and background sign frame/ wall,
  - Step edges and risers/ treads on steps,
  - Handrails and background walls,
  - Doors and surrounding walls,
  - Switches/ sockets and background wall,
  - Toilet fixtures and critical surfaces in toilet.

- Barriers and hazards should be highlighted by incorporating colours and luminance contrast.

11.10 EMERGENCY EGRESS/EVACUATION

- Placement (accessibility) and visibility of such devices is very important. The following is to be considered for the installation of such alarm devices; fire alarm boxes, emergency call buttons and lit panels should be installed between heights of 800mm and 1000mm from the furnished floor surface. These should be adequately contrasted from the background wall and should be labelled with raised letters and should also be in Braille.
- A pre-recorded message, alerting an emergency to the control room or reception should be installed in the telephone and this should be accessible by a 'hotkey' on the phone keypad. This 'hotkey' should be distinct from the rest of the keypad.

11.11 ALERTING SYSTEMS

- In emergency situations, it is critical that people are quickly alerted to the situation at hand, for persons with disability the following needs to be considered.
- Consider having audible alarms with 'voice instructions' that can help guide them to the nearest emergency exit. As an alternative to the pre-recorded messages, these alarms may be connected to the central control room for on-the-spot broadcasts.
- Non-auditory alarms (visual or sensory) to alert persons with hearing impairments should be installed at visible locations in all areas that the passengers may use (including toilet areas, etc).

Non-auditory alarms include:

- Flashing beacons
- Vibrating pillows and vibrating beds.
- Pagers or mobile phones that give out a vibrating alarm along with a flashing light (these may be issued to persons with vision or hearing impairments at the time of check-in or boarding the vehicle.)

11.12 WRITTEN EVACUATION PROCEDURE

A written evacuation procedure that details the egress plan for people with disability should be installed behind the entrance door in the accessible rest rooms. The evacuation procedure should be detailed in large print letters that contrast strongly against the background. Where possible, it should also incorporate raised letters and Braille. The evacuation route should be displayed on a high contrast tactile map for benefit of persons with vision impairments.

11.13 EMERGENCY EVACUATION ROUTE

- Designate routes that are at least 1200mm wide, to ensure that a person using a wheelchair and a non-disabled person are able to pass each other along the route. The route should be free of any steps or sudden changes in level and should be kept free from obstacles such as furniture, coolers, AC units and flower pots.

- Use Exit signage along the route. Orientation and direction signs should be installed frequently along the evacuation route and these should preferably be internally illuminated. The exit door signage should also be internally illuminated.

- A ‘way guidance lighting system’ consisting of low mounted LED strips to outline the exit route (with frequent illuminated direction indicators along the route) should be installed along the entire length of the evacuation route. Way guidance systems allow persons with vision impairments to walk significantly faster than traditional overhead emergency lighting. Moreover, emergency exit lights in green color and directional signals mounted near the floor have been found to be useful for all people in cases where a lot of smoke is present.

11.14 WAY GUIDENCE SYSTEM

- Luminance on the floor should be 1lux minimum provided on along the centre line of the route and on stairs.

- Install clear illuminated sign above exit and also directional signage along the route.

- The directional exit signs with arrows indicating the way to the escape route should be provided at a height of 500mm from the floor level on the wall and should be internally illuminated by electric light connected to corridor circuits.

11.15 Fire Resistant Doors

- Fire resistant doors and doors used along the emergency evacuation route are generally heavy and the force required to open these is much higher than 25 Newton, making it difficult for people with disability to negotiate these doors independently. There are, however, magnetic and other types of door holders available that can be connected to fire alarms so that they will hold the doors open normally but will release the doors when the fire alarm is activated.

11.16 STREET DESIGN

(a) Footpath (Sidewalk)

Footpaths should be regarded as a transportation system which is connected and continuous, just like roadways and railways. They should not be sporadically placed where ever convenient, but instead should be provided consistently between all major attractions, trip generators, and other locations where people walk.

Footpath should

- Be along the entire length of the road;
- Have height of a standard public step riser i.e. 150 mm maximum;
- Be at least 1800 mm wide;
- Have non-slip surface;
- Have tactile guiding paver for persons with visual impairments;
- Preferably have well defined edges of paths and routes by use of different colours and textures;
- Have no obstacles or projections along the pathway. If this is unavoidable, there should be clear headroom of at least 2200 mm from the floor level;
- The minimum 1.8m (width) x 2.2m (Height) Walking Zone should be clear of all obstructions – both horizontally and vertically.

Footpath should have:

- Have kerb ramps where ever a person is expected to walk into or off the pathway; and
- Have tactile warning paver installed next to all entry and exit points from the footpath.

(b) Kerb Ramp

- Kerb should be dropped, to be flush with walk way, at a gradient no greater than 1:10 on both sides of necessary and convenient crossing points. Width should not be less than 1200mm. If width (X) is less than 1200mm, then slope of the flared side shall not exceed 1:12.
- Floor tactile paving- Guiding & Warning paver shall be provided to guide persons with vision impairment so that a person with vision impairment does not accidentally walk onto the road.
- Finishes shall have non-slip surface with a texture traversable by a wheel chair.

(c) Road Intersections

- Pedestrian crossings should be equipped with traffic control signal.
- Traffic islands to reduce the length of the crossing are recommended for the safety of all road users.
- Warning pavers should be provided to indicate the position of pedestrian crossings for the benefit of people with visual impairments.
- Table tops (raised road level to the sidewalk height) are helpful in reducing the speed of traffic approaching the intersection.

(d) Median/Pedestrian Refuge

Raised islands in crossings should:

- Cut through and level with the street; or
- Have kerb ramps on both the sides and have a level area of not less than 1500 mm long in the middle; and
- A colored tactile marking strip at least 600 mm wide should mark the beginning and end of a median/ pedestrian refuge to guide pedestrian with visual impairments to its location.

11.17 Traffic Signals

- Pedestrian traffic lights should be provided with clearly audible signals for the benefit of pedestrians with visual impairments;
- Acoustic devices should be installed on a pole at the point of origin of crossing and not at the point of destination;
- The installation of two adjacent acoustic devices such as beepers is not recommended in order to avoid disorientation;
- The time interval allowed for crossing should be programmed according to the slowest crossing persons; and
- Acoustical signals encourage safer crossing behavior among children as well.

11.18 Subway and Foot Over Bridge

Subways and foot over bridges should be accessible for people with disabilities. This may be achieved by:

- Provision of signage at strategic location;
- Provision of slope ramps or lifts at both the ends to enable wheelchair accessibility ;
- Ensuring that the walkway is at least 1500 mm wide;
- Provision of tactile guiding and warning paver along the length of the walkway;
- Keeping the walkway; free from any obstructions and projections; and
- Providing for seats for people with ambulatory disabilities at regular intervals along the walkway and at landings.

11.19 ALIGHTING AND BOARDING AREAS

- All areas and services provided in the Mass Rapid Transit System (Metro/subway), bus terminuses, etc. that are open to the public should be accessible.

11.19.1 APPROACH

- Passenger walkways, including crossings to the bus stops, taxi stands, terminal / station building, etc. should be accessible to persons with disabilities.
- Uneven surfaces should be repaired and anything that encroaches on corridors or paths of travel should be removed to avoid creating new barriers. Any obstructions or areas requiring maintenance should be white cane detectable1.
- Access path from plot entry and surface parking to terminal entrance shall have even surface without any steps.
- Slope, if any, shall not have gradient greater than 5%. The walkway should not have a gradient exceeding 1:20. It also refers to cross slope.
- Texture change in walk ways adjacent to seating by means of tactile warning paver should be provided for persons with vision impairment.
- Avoid gratings in walks.

11.19.2 CAR PARK

(A) SIGNAGE

- International symbol of accessibility (wheelchair sign) should be displayed at approaches and entrances to car parks to indicate the provision of accessible parking lot for persons with disabilities within the vicinity.
- Directional signs shall be displayed at points where there is a change of direction to direct persons with disabilities to the accessible parking lot.
- Where the location of the accessible parking lot is not obvious or is distant from the approach viewpoints, the directional signs shall be placed along the route leading to the accessible parking lot.
- Accessible parking lot should be identifiable by the International Symbol of Accessibility. The signs should not be obscured by a vehicle parked in the designated lot.
- Vertical signs shall be provided, to make it easily visible, the sign should be at a minimum height of 2100 mm.

(B) SYMBOL

International Symbol of Accessibility should be clearly marked on the accessible parking lot for drivers/riders with disabilities only.

- A square with dimensions of at least 1000 mm but not exceeding 1500 mm in length;
- Be located at the centre of the lot; and
- The colour of the symbol should be white on a blue background.

(C) CAR PARK ENTRANCE

The car park entrance should have a height clearance of at least 2400 mm.

LOCATION

- Accessible parking lots that serve a building should be located nearest to an accessible entrance and / or lift lobby within 30 meters. In case the access is through lift, the parking shall be located within 30 meters.
- The accessible route of 1200 mm width is required for wheelchair users to pass behind vehicle that may be backing out.

(D) ACCESSIBLE CAR PARKING LOT

The accessible car parking lot should:

- Have minimum dimensions 5000 mm × 3600 mm;
- Have a firm, level surface without aeration slabs;
- Wherever possible, be sheltered;
- Where there are two accessible parking bays adjoining each other, then the 1200 mm side transfer bay may be shared by the two parking bays. The transfer zones, both on the side and the rear should have yellow and while cross-hatch road markings;
- Two accessible parking lots shall be provided for every 25 no of car spaces.

(E) DROP OFF AND PICK UP AREAS

- Designated drop-off and pick-up spaces, to be clearly marked with international symbol of accessibility.
- Kerbs wherever provided, should have kerb ramps.

Chapter-12

SECURITY MEASURES FOR A METRO RAIL SYSTEM

12.1 INTRODUCTION

Metro Rail System is emerging as the most favoured mode of urban transportation system. The inherent characteristics of Metro Rail System make it an ideal target for terrorists and miscreants. Metro Rail System is typically open and dynamic systems which carry thousands of commuters. Moreover the high cost of infrastructure, its economic importance, being the life line of city high news value, fear & panic and human casualties poses greater threat to its security. Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally. Security differs from safety which addresses problems caused accidentally. Security problems or threats are caused by people whose actions aim to undermine or disturb the public transport system and/or to harm passengers or staff. These threats range from daily operational security problems such as disorder, vandalism and assault to the terrorist threat.

12.2 NECESSITY OF SECURITY

It is well known that public transportation is increasingly important for urban areas to prosper in the face of challenges such as reducing congestion and pollution. Therefore, security places an important role in helping public transport system to become the mode of choice. Therefore, excellence in security is a prerequisite for Metro Rail System for increasing its market share. Metro Rail System administration must ensure that security model must keep pace rapid expansion of the Metro Rail System and changing security scenario.

12.3 THREE PILLARS OF SECURITY

Security means protection of physical. Human and intellectual assets either from criminal interference, removal of destruction by terrorists or criminals or incidental to technological failures or natural hazardous events. There are three important pillars of security as mentioned under:

(i) The human factor;
(ii) Procedures;
(iii) Technology

Staff engaging with the passengers creates a sense of re-assurance which cannot fully be achieved by technology. For human factor to be more effective staff has to be qualified, trained, well equipped and motivated. They should be trained, drilled and tested. The security risk assessment is the first step for understanding the needs and prioritizing resources. The organization of security should be clear and consistent. Security incidents, especially major ones, often happen without warning. Emergency and contingency plans must be developed communicated and drilled in advance.

There are number of technologies which can be used to enhance security e.g. surveillance systems. The objectives of the security systems are to differ i.e., making planning or execution of on attack too difficult, detect the planned evidence before it occurs deny the access after in plan of attack has been made and to mitigate i.e. lessen the impact severity as the attack by appropriate digits.

12.4 PHASES OF SECURITY

There are three phases of security as under:

(i) Prevention

These are the measures which can prevent a security incidence from taking place. These can be identified by conducting a risk assessment and gathering intelligence. Prevention begins with the daily operational security -problems.

Uncared for dirty, damaged property is a breeding ground for more serious crime.

(ii) Preparedness

Plans must be prepared to respond to incidents, mitigate the impact. Train staff accordingly and carry out exercises. The results of the risk assessment give a basis for such plans.

(iii) Recovery

Transport system must have laid down procedures/instructions for the quick recovery of normal service after an incident. Recovery is important for the financial health of the operation, but it also sends a clear message to public, it reassures passengers and gives them confidence to continue using the system. Communication is key to the quick restoration after such incidents. Restoration should also include an evaluation process for the lessons learnt.

12.5 RESPONSIBILITIES AND PARTNERSHIPS

Security is a sovereign function and hence is the responsibility of the state. Security in public requires clear governance. Responsibility should be clearly defined. In the present scenario, this is the responsibility of the Government of Maharashtra to ensure secured travelling to the public including Metro Rail System.

12.6 PROPOSED PROVISIONS FOR SECURITY SYSTEM

1. CCTV coverage of all Metro Rail System stations. With a provision of monitoring in the Station Security Room as well as at a Centralized Security Control Room with video wall, computer with access to internet TV with data connection, printer

and telephone connection (Land Line and EPBX) for proper functioning, cluster viewing for stations. Cost of this is included in Telecom estimate.

2. Minimum one Baggage Scanners on all entry points (1 per AFC array). Additional requirement of baggage scanners at heavily crowed stations i.e at interchange may also be required. Cost of one baggage scanner is Rs. 15.0 Lacs approximately, on 2013 prices.

3. Multi-zone Door Frame Metal Detector (DFMD) minimum three per entry (2 per AFC array). The number can increase in view of the footfall at over crowed stations. Cost of one Multi-zone DFMD is Rs 2.15 Lacs approximately.

4. Hand held Metal Detector (HHMD) as per requirement of security agency, minimum two per entry, which varies from station to station with at least 1.5 per DFMD installed at the station. Cost of one HHMD is Rs 6000/- approximately at 2012 prices.

5. Bomb Detection Equipments with modified vehicle as per requirement of security agency. One BDS team per 25 - 30 station will be required at par with present criteria of DMRC. Cost 1.25 crores including vehicle.

6. Bomb Blanket at least one per station and Depots. Cost is Rs. 50,000/- per bomb blanket.

7. Wireless Sets (Static and Hand Held) as per requirement of security agency.

8. Dragon light at least one per station and vital installation.

9. Mobile phones, land lines and EPBX phone connections for senior security officers and control room etc.

10. Dog Squads (Sniffer Dog), at least one dog for 4 Metro Rail System stations which is at par with current arrangement of Delhi Metro. Cost of one trained sniffer dog is Rs 1.25 Lacs approximately. Dog Kennels along with provision for dog handlers and MI room will also be provided by Metro Rail System train depot administration including land at suitable places line wise.

11. Bullet proof Morcha one per security check point (i.e. AFC array) and entry gate of Metro Rail System train depot administration Metro Rail System station.

12. Bullet proof jackets and helmets for QRTs and riot control equipments including space at nominated stations. One QRT Team looks after 5-6 Metro Rail System stations as per present arrangement. One QRT consist of 5 personnel and perform duty in three shifts.

13. Furniture to security agency for each security room, and checking point at every entry point at stations. Scale is one office table with three chairs for security room and office of GO and one steel top table with two chairs for checking point.

14. Ladies frisking booth - 1 per security check point (AFC Array)
    Wooden Ramp - 1 per DFMD for security check points.

15. Wall mounted/ pedestal fan at security check point, ladies frisking booth and bullet proof Morcha, as per requirement.

16. Physical barriers for anti-scaling at Ramp area, low height of via duct by providing iron grill of appropriate height & design/concertina wire.

17. Adequate number of ropes. Queue managers, cordoning tapes, dragon search lights for contingency.

18. Iron grill at station entrance staircases, proper segregation of paid and unpaid by providing appropriate design grills etc.

19. Proper design of emergency staircase and Fireman entry to prevent unauthorized entry.

20. The provision procurement of all the above hardware is included in the cost of Stations.

Chapter -13

DISASTER MANAGEMENT MEASURE

13.1 INTRODUCTION

“Disaster is a crisis that results in massive damage to life and property, uproots the physical and psychological fabric of the affected communities and outstrips the capacity of the local community to cope with the situation.” Disasters are those situations which cause acute distress to passengers, employees and outsiders and may even be caused by external factors. As per the disaster management act, 2005 "disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area”. As per World Health Organization (WHO):

“Any occurrence that causes damage, economic disruption, loss of human life and deterioration of health and services on a scale sufficient to warrant an extra ordinary response from outside the affected community or area.”

A disaster is a tragic event, be it natural or manmade, which brings sudden and immense agony to humanity and disrupts normal life. It causes large scale human suffering due to loss of life, loss of livelihood, damages to property and persons and also brings untold hardships. It may also cause destruction to infrastructure, buildings, communication channels essential services, etc.

13.2 NEED FOR DISASTER MANAGEMENT MEASURES

The effect of any disaster spread over in operational area of Metro Rail System is likely to be substantial as Mumbai Metro will be dealing with thousands of passengers daily. Disaster brings about sudden and immense misery to humanity and disrupts normal human life in its established social and economic patterns. It has the potential to cause large scale human suffering due to loss of life, loss of livelihood, damage to property, injury and hardship. It may also cause destruction or damage to infrastructure, buildings and communication channels of Metro Rail System. Therefore there is an urgent need to provide for an efficient disaster management plan.

13.3 OBJECTIVES

The main objectives of this Disaster Management Measures are as follows:

- Save life and alleviate suffering.
- Provide help to stranded passengers and arrange their prompt evacuation.

- Instill a sense of security amongst all concerned by providing accurate information.
- Protect Metro Rail property.
- Expedite restoration of train operation.
- Lay down the actions required to be taken by staff in the event of a disaster in VMRT in order to ensure handling of crisis situation in coordinated manner.
- To ensure that all officials who are responsible to deal with the situation are thoroughly conversant with their duties and responsibilities in advance. It is important that these officials and workers are adequately trained in anticipation to avoid any kind of confusion and chaos at the time of the actual situation and to enable them to discharge their responsibilities with alertness and promptness.

13.4 LIST OF SERIOUS INCIDENTS REQUIRING USE OF PROVISIONS OF THE DISASTER MANAGEMENT MEASURES

Medium Metro specific disasters can be classified into two broad categories e.g.: Man-made and Natural.

- **Man Made Disaster**
  1. Terrorist attack
  2. Bomb threat/ Bomb blast
  3. Hostage
  4. Release of Chemical or biological gas in trains, stations or tunnels
  5. Fire in Metro buildings, underground/ elevated infrastructures, power stations, train depots etc.
  6. Train accident and train collision/derailment of a passenger carrying train.
  7. Sabotage
  8. Stampede

- **Natural Disaster**
  1. Earthquakes
  2. Floods

13.5 PROVISIONS UNDER DISASTER MANAGEMENT ACT, 2005

A. The National Disaster Management Authority (NDMA) Establishment of National Disaster Management Authority:-

(1) With effect from such date as the Central Government may, by notification in the Official Gazette appoint in this behalf, there shall be established for the purposes of this Act (The Disaster Management Act, 2005), an authority to be known as the National Disaster Management Authority.

(2) The National Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the Central

Government and, unless the rules otherwise provide, the National Authority shall consist of the following:-

(a)The Prime Minister of India, who shall be the Chairperson of the National Authority, ex officio;
(b) Other members, not exceeding nine, to be nominated by the Chairperson of the National Authority.

(3) The Chairperson of the National Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the National Authority.

(4) The term of office and conditions of service of members of the National Authority shall be such as may be prescribed.

B. State Disaster Management Authority

Establishment of State Disaster Management Authority:-

(1) Every State Government shall, as soon as may be after the issue of the notification under sub-section (1) of section 3, by notification in the Official Gazette, establish a State Disaster Management Authority for the State with such name as may be specified in the notification of the State Government.

(2) A State Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the State Government and, unless the rules otherwise provide, the State Authority shall consist of the following members, namely:-

(a) The Chief Minister of the State, who shall be Chairperson, ex officio;
(b) Other members, not exceeding eight, to be nominated by the Chairperson of the State Authority;
(c) The Chairperson of the State Executive Committee, ex officio.

(3) The Chairperson of the State Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the State Authority.

(4) The Chairperson of the State Executive Committee shall be the Chief Executive Officer of the State Authority, ex officio: Provided that in the case of a Union territory having Legislative Assembly, except the Union territory of Delhi, the Chief Minister shall be the Chairperson of the Authority established under this section and in case of other Union territories, the Lieutenant Governor or the Administrator shall be the Chairperson of that Authority: Provided further that the Lieutenant Governor of the Union territory of Delhi shall be the Chairperson and the Chief Minister thereof shall be the Vice-Chairperson of the State Authority.

(5) The term of office and conditions of service of members of the State Authority shall be such as may be prescribed.

C. Command & Control at the National, State & District Level

The mechanism to deal with natural as well as manmade crisis already exists and that it has a four tier structure as stated below:-

(1) National Crisis Management Committee (NCMC) under the chairmanship of Cabinet Secretary
(2) Crisis Management Group (CMG) under the chairmanship of Union Home Secretary.
(3) State Level Committee under the chairmanship of Chief Secretary.
(4) District Level Committee under the Chairmanship of District Magistrate.

All agencies of the Government at the National, State and district levels will function in accordance with the guidelines and directions given by these committees.

D. Plans by Different Authorities at District Level and their Implementation

Every office of the Government of India and of the State Government at the district level and the local authorities shall, subject to the supervision of the District Authority:-

(a) Prepare a disaster management plan setting out the following, namely:-

(i) Provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
(ii) Provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
(iii) The response plans and procedures, in the event of, any threatening disaster situation or disaster;

(b) Coordinate the preparation and the implementation of its plan with those of the other organizations at the district level including local authority, communities and other stakeholders;

(c) Regularly review and update the plan; and

(d) Submit a copy of its disaster management plan and of any amendment thereto, to the District Authority.

13.6 PROVISIONS AT METRO STATIONS/OTHER INSTALLATIONS

To prevent emergency situations and to handle effectively in case ‘one arises’ there needs to be following provisions for an effective system which can timely detect the threats and help suppress the same.

(A) FIRE DETECTION AND SUPPRESSION SYSTEM
(B) SMOKE MANAGEMENT
(C) ENVIRONMENTAL CONTROL SYSTEM (ECS)
(D) TRACK-WAY EXHAUST SYSTEM (TES)
(E) STATION POWER SUPPLY SYSTEM
(F) DG SETS& UPS
(G) LIGHTING SYSTEM
(H) STATION AREA LIGHTS
(I) SEEPAGE SYSTEM
(J) WATER SUPPLY AND DRAINAGE SYSTEM
(K) SEWAGE SYSTEM
(L) ANY OTHER SYSTEM DEEMED NECESSARY

The above list is suggestive not exhaustive actual provisioning has to be done based on site conditions and other external and internal factors.

13.7 PREPAREDNESS FOR DISASTER MANAGEMENT

Being a technological complex system worked by new set of staff, with a learning curve to improve and stabilize with time, intensive mock drills for the staff concerned is very essential to train them to become fully conversant with the action required to be taken while handling emergencies.

They also need to be trained in appropriate communication skills while addressing passengers during incident management to assure them about their wellbeing seeking their cooperation.
Since learning can only be perfected by ‘doing’ the following Mock Drills is considered essential:

a. Fire Drill
b. Rescue of a disabled train
c. Detrainment of passengers between stations
d. Passenger evacuation from station
e. Drill for use of rescue & relief train
f. Hot line telephone communication with state disaster management authority.

13.8 COMMUNICATION WITH STATE DISASTER MANAGEMENT CELL

Operation Control Centre will have a hotline connection with the State Disaster Management cell so as to avoid any time loss in communication of the information.

Chapter –14

COST ESTIMATES

14.1 INTRODUCTION

Project Cost estimates for the Mumbai Metro Corridor No. 06 : Swami Samarth Nagar to Vikhroli (EEH) has been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction etc. at October 2016 price level.

While preparing the cost estimates, various items have generally been grouped under three major heads on the basis of:-

(i) Route km. Length of alignment
(ii) No. of units of that item and
(iii) Item being an independent entity.

All items related with alignment, permanent way, OHE, signaling and telecommunication, have been estimated on rate per route km basis. The cost of elevated stations includes civil work for station structures, architectural finishes, platform, roofing, etc. Provisions for electrical and mechanical works, air conditioning, lifts, escalators, etc. have been worked out separately. These rates do not include cost of permanent way, O.H.E., power supply, signaling and telecommunication, automatic fare collection (AFC) installations, for which separate provisions have been made in the cost estimates. Similarly, for other items like Rolling stock, Traction & Power, etc. costs have been summed up separately. 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.

In order to arrive at realistic cost of various items, costs have been assessed on the basis of accepted/completion rates in various contracts, awarded for similar works by DMRC in Phase-III. A suitable escalation factor has been applied to bring these costs to October 2016price level. In addition the rates of Civil works have been escalated by 10% to compensate the higher costs in Mumbai compared to Delhi. Taxes & Duties such as Customs Duty, Excise Duty, VAT, Service Tax, Octroi, etc. wherever applicable, have been worked out on the basis of prevailing rates and included in the cost estimates separately.

The overall Capital Cost for Swami Samarth Nagar to Vikhroli (EEH) Metro Corridor of Mumbai at October 2016 price level works out to **Rs. 4631 Crores** excluding applicable Taxes & Duties of **Rs. 936 crores** as tabulated hereunder.

Table 14.1 – Details of Capital Cost

Sr. No.	Name of the corridor	Capital Cost (Rs. Crore)	Taxes & Duties (Rs. Crore)	Total (Rs. Crore)
1.	Swami Samarth Nagar to Vikhroli (EEH)	4631	936	5567

Details and methodology of arriving at these costs are discussed in paras hereinafter.

14.2 CIVIL ENGINEERING WORKS

14.2.1 Land

Land requirements have been kept to the barest minimum and worked out on area basis. Acquisition of private land has been minimized as far as possible. Elevated alignment is proposed within the Right of way as far as possible. The land acquisition is required to be done mainly for exit and entries and also for running section at few locations where alignment runs outside the ROW.

Cost of Govt. land is based on the rate presently being charged by the concerned authorities. Private land for MRTS project shall be acquired by MMRDA/ Maharashtra State Government and compensation shall be paid as per Land Acquisition Act 2013 (MUTP Act), MMRDA Act. The average rate of private land has been worked out to be Rs.100 Crore per hectare on the basis of latest information available. Similarly average rate for govt. land has been taken 20 Crore per hectare to work out the cost of land.

Provision for Rehabilitation and Resettlement is made separately.

In addition to the lands required permanently, some areas of land (mainly Govt.) are proposed to be taken over temporarily for construction depots. Ground rent charges @ 5% per year for a period of 4 years have been provided for in project cost estimates.

Details of the land with costs have been shown in corridor cost estimate.

14.2.2 Formation and Alignment

Elevated section: Entire alignment is proposed with elevated viaduct and the rates adopted are based on the completion cost for these works of Phase-II and ongoing Phase-III works, duly updated to October 2016 price level and enhanced by 10% for the higher cost at Mumbai as compared to Delhi. A lump sum provision of Rs 60 crore has been made for special spans, extra height of Piers, etc.

14.2.3 Stations

Elevated Stations: Rates adopted for elevated stations cover works of station structures, platforms, architectural finishes, covering, etc. Provisions for Electrical and Mechanical works have been made separately. Also provisions for Lifts and Escalators, Viaduct, P-way, O.H.E., Signalling & Telecommunication works, Automatic fare collection installations, etc. have been summed up in the cost estimates.

Mainly three types of stations are proposed for elevated alignment & rates are proposed accordingly.

Type A: Wayside station
Type B: Wayside with Signalling
Type C: Terminal Station

Rates for stations have also been arrived based on Delhi metro Phase-III accepted rates added by 10% more for higher cost at Mumbai compared to Delhi

14.2.4 Permanent way

For elevated alignment ballastless track and for depot, ballasted track is proposed except for washing lines, repair lines etc. Rates adopted are based on similar works done in Phase-II and ongoing Phase-III works duly updated to October 2016 price level.

14.3 DEPOT

Depot at Kanjur Marg has been planned for this corridor.

14.4 UTILITY DIVERSIONS, ENVIRONMENTAL PROTECTION, MISCELLANEOUS OTHER WORKS

Provisions have been made to cover the cost of utility diversions, miscellaneous road works involved, road diversions, road signages etc. and environmental protection works on route km basis, based on the experience gained from the works done in Phase- III of Delhi Metro.

14.5 REHABILITATION AND RESETTLEMENT

Provisions have been made on fair assessment basis, to cover cost of relocation of Jhuggies, shops, residential Houses on private land etc.

Provisions for barracks and security equipment for CISF and Staff Quarters for O&M Wing have been made in the cost estimates on the basis of average cost involved per km length in the recent past.

14.6 TRACTION AND POWER SUPPLY

Provisions have been made to cover the cost of O.H.E., Auxiliary sub stations, receiving substations, service connection charges, SCADA and miscellaneous items, on route km basis separately for elevated and at-grade section (Depot Connection).

Provisions towards cost of lifts, escalators for elevated stations have been made in the cost estimates. Rates provided are based on cost of similar works done in Phase-II and ongoing Phase-III works duly updated to October 2016 price level.

14.7 SIGNALLING AND TELECOMMUNICATION WORKS

Rates adopted are based on the completion cost of similar works for Delhi Metro under Phase-II and ongoing Phase-III works. These rates include escalation during manufacturing and supply of equipment and their installation at site.

14.8 AUTOMATIC FARE COLLECTION

Adopted rates are based on accepted rates for similar work of Phase-II and ongoing Phase-III works duly updated to October 2016 price level.

14.9 ROLLING STOCK

Adopted rates are based on awarded rates of similar works of Phase-II and ongoing Phase-III works duly updated to October 2016 price level considering likely indigenization.

14.10 SECURITY

A lump sum provision for providing security infrastructure in the station premises has been made on running kilometre basis. Adopted rates are as taken in phase III DPR suitably escalated to current price level.

14.11 MULTIMODAL TRAFFIC INTEGRATION

A lump sum provision of Rs. 2.47 Crore per station has been made to have seamless integration of metro stations with other modes of transport. It is envisaged that in case this money is not sufficient for this purpose the deficient part of money will borne by the Urban Local Body (ULB) in whose area station is located.

14.12 GENERAL CHARGES AND CONTINGENCES

Provision @ 7% has been made towards general charges on all items, except cost of land, which also includes the charges towards Detailed Design Charges (DDC), etc. Provision for contingencies @ 3 % has been made on all items including general charges.

14.13 CAPITAL COST ESTIMATES

14.13.1 Swami Samarth Nagar to Vikhroli (EEH) Metro Rail Corridor

The overall Capital Cost for the Swami Samarth Nagar to Vikhroli (EEH) Metro Corridor of Mumbai at October 2016 price level works out to **Rs. 4631 Crores** excluding applicable Taxes & Duties of **Rs. 936 crores** as tabulated hereunder.

Table 14.2 - Capital Cost Estimate

Total length = 14.477 km (Entirely Elevated)

Total Station (All Elevated) =13

October 2016 level

S. No.	Item	Unit	Rate	Qty.	Amount (Rs. in Cr.)
				Without taxes	
1.0	**Land and R & R incl. Hutments etc.**				
1.1	Permanent				
a	Government	ha	20.00	18.79	375.80
b	Private	ha	100.00	3.84	384.00
1.2	Temporary Land (@5% pa for 4 years)	ha	4.00	6.60	26.40
1.3	**R & R incl. Hutments etc.**	R. Km.	3.99	14.48	57.78
	Subtotal (1)				**843.98**
2.0	**Alignment and Formation**				
2.1	Elevated section including station length (Including Cost of Rain Water Harvesting)	R. Km.	41.96	14.48	607.58
2.2	Depot entry connection	R. Km.	41.96	0.70	29.37
2.3	Special Spans, Extra height of Piers, etc.	LS			60.00
	Subtotal (2)				**696.95**
3.0	**Station Buildings**				
3.1	Elevated stations(including finishes)	Each			
a	Type (A)* - civil works	Each	33.06	6	198.36
b	Type (A)*- EM works including lifts and escalators	Each	9.16	6	54.96
c	Type (B)** -civil works	Each	32.37	5	161.85
d	Type (B)**-EM works including lifts and escalators	Each	9.16	5	45.80
e	Type (C)# -civil works	Each	36.88	2	73.76
f	Type (c)# -EM works including lifts and escalators	Each	9.16	2	18.32
3.2	Providing half height platform Screen Doors (PSD) at all Stations	Each	2.61	26	67.86
3.3	OCC bldg.				
a	civil works	LS			35.00
b	EM works etc	LS			15.00
	Subtotal (3)				**670.91**
4.0	**Depot**	LS			
4.1	Depot				
a	Civil works	LS			88.00
b	EM works etc	LS			132.00
	Subtotal (4)				**220.00**
5.0	**P-Way**				
5.1	Ballast less track	R. Km.	9.13	15.18	138.59
5.2	Ballasted track for Depot	R. Km.	5.02	5.00	25.10
	Subtotal (5)				**163.69**
6.0	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**				
6.1	Elevated section	R.Km.	10.82	15.18	164.25
	Subtotal (6)				**164.25**
7.0	**Signalling and Telecom.**				
7.1	Sig. & Telecom.	R. Km.	16.47	15.18	250.01
7.2	Automatic fare collection	Stn.			
	a) Elevated stations	Each	5.85	13	76.05

S. No.	Item	Unit	Rate	Qty.	Amount (Rs. in Cr.)
				Without taxes	
	Subtotal (7)				**326.06**
8.0	**Misc. Utilities, road works, other civil works such as median stn. signages Environmental protection**	R. Km.			
a	Civil works **(4.79 cr/km)** + EM works **(3.72 cr/km)**	R. Km.	8.51	15.18	129.18
b	Diversion/Shifting of overhead HT lines	LS			5.00
	Subtotal (8)				**134.18**
9.0	**Rolling Stock (3.2 m wide Coaches)**	Each	10.00	96	960.00
	Subtotal (9)				**960.00**
10.0	**Capital expenditure on security**				
a	Civil works	R.Km.	0.07	15.18	1.06
b	EM works etc	R.Km.	0.31	15.18	4.71
	Subtotal (10)				**5.77**
11.0	**Staff quarter for O & M**				
a	Civil works	R.Km.	1.85	15.18	28.08
b	EM works etc	R.Km.	0.47	15.18	7.13
	Sub Total (11)				**35.22**
12.0	**Capital expenditure on Multimodal Traffic Integration**				
a	Capital expenditure on Multimodal Integration	Each	2.47	13	32.11
	Sub Total (12)				**32.11**
13.0	**Total of all items except Land**				**3466.92**
14.0	**General Charges incl. Design charges @ 7 % on all items except land**				**242.68**
15.0	**Total of all items including G. Charges except land**				**3709.61**
16.0	**Contingencies @ 3 %**				**111.29**
17.0	**Gross Total**				**3820.89**
	Cost without land			**=**	**3821**
	Cost with land including contingencies on land			**=**	**4631**

* **Type (A): Way side station**

** **Type (B): Way side station with signalling**

\# **Type (C): Terminal station**

Table 14.3 - Details of Taxes and Duties

Customs duty =23.4155%

Excise duty = 12.50 %

VAT = **12.5%**

Octroi = **4%**

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties				Octroi	Total taxes & duties (Cr.)
			custom duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	Service Tax (Cr.)		
1	**Alignment & Formation**							
	Elevated, at grade & entry to Depot	696.95		60.98	68.61	26.14	15.16	**170.88**
2	**Station Buildings**							
	Elevated station - civil works	433.97		37.97	42.72	16.27	9.44	**106.40**
	Elevated station-EM works	119.08	5.58	10.12	11.39	4.47	3.77	**35.32**
	OCC bldg-civil works	35.00		3.06	3.45	1.31	0.76	**8.58**
	OCC bldg-EM works	15.00	0.70	1.28	1.43	0.56	0.48	**4.45**
3	**Depot**							
	Civil works	88.00	6.18	5.39	6.06	3.30	1.99	**22.93**
	EM works	132.00	6.18	11.22	12.62	4.95	4.18	**39.16**
4	**P-Way**	163.69	30.66	3.48	3.91	6.14	5.54	**49.73**
5	**Traction & power supply**							
	Traction and power supply	164.25	15.38	10.47	11.78	3.70	5.32	**46.65**
6	**S and T Works**							
	S & T	250.01	46.83	6.25	7.03	5.63	8.49	**74.23**
	AFC	76.05	13.36	2.38	2.67	1.71	2.57	**22.69**
	PSD	67.86	12.71	1.70	1.43	1.53	2.30	**19.67**
7	**R & R hutments**	57.78			3.61		1.16	**4.77**
8	**Misc.**							
	Civil works	153.86		13.46	15.15	5.77	3.35	**37.73**
	EM works	53.41		5.68	6.38	2.00	1.65	**15.72**
9	**Rolling stock**	960.00	197.81	9.36	10.53	21.60	37.35	**276.65**
	Total	**3466.92**	**335.41**	**182.80**	**208.78**	**105.07**	**103.51**	**935.56**
	Total taxes & Duties							**936**

Chapter-15

FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

15.1 INTRODUCTION

The Mumbai Metro Rail Project from Swami Samarth Nagar to Vikhroli (EEH) is proposed to be constructed at an estimated cost of Rs. 5254.00 Crore with central taxes and land cost. The route length of the proposed metro rail system and estimated cost at October-2016 price level without central taxes, with central taxes and with all taxes are placed in table 15.1 as under:

Table 15.1 Cost Details

Sr. No.	Name of Corridor	Distance (KMs)	Estimated cost without taxes (Rs/Crore)	Estimated cost with Central taxes & land cost (Rs/Crore)	Estimated cost with all taxes, Octroi & land cost (Rs/Crore)
1	Swami Samarth Nagar to Vikhroli (EEH)	14.477	4927.00	5254.00	5567.00

The estimated cost at October-2016 price level includes an amount of Rs.5.77 Crore as one-time charges of security personal towards cost of weapons, barricades, and hand held and door detector machine. However, the recurring cost towards salary and allowances of security personal have not taken in to account in the FIRR calculation since providing required security at metro stations shall be the responsibility of state police.

15.2 COSTS

15.2.1 Investment Cost

15.2.1.1 For the purpose of calculating the Financial Internal Rate of Return (FIRR), the completion cost with central and state taxes has been calculated by taking escalation factor @6% per annum. The taxes and duties consist of Custom Duty (CD), Excise Duty (ED), Service tax, State Value Added Tax (VAT) and Octroi levied by the Municipal Corporation (BMC). Mumbai Metro project is eligible for availing concessional project import duty under chapter 98.01 of the Custom Tariff Act. The effective CD works out to 23.4155% (Basic CD (5%), Countervail Duty (CVD) + Additional Custom Duty (ACD)) on the imported portions, ED @ 12.50%, VAT @ 12.50% on indigenously manufactured items, and Octroi @ 4% on supply items have been considered for working out the estimated taxes and duties. With effect from 01.03.2016, exemption from the service tax on works contract services for metro and mono rail projects have been withdrawn in the union budget 2016. Therefore service tax @15% on the taxable service portion of the works contract is applicable on the new contracts to be awarded on or after 01.03.2016. Accordingly service tax @ 15% on the service portion has been assumed in the FIRR calculation. It has been assumed that Maharashtra State Government will either exempt or reimburse or interest free subordinate debt of the local taxes (Sate VAT, Octroi etc.) and provide the land worth Rs. 945 crore on completion cost basis free of cost or shall provide Interest Free Subordinate Debt. The Interest Free Subordinate Debt is repayable in 5 equal instalments after repayment of Multilateral/Overseas Development Assistance Loan. The impact of proposed GST Act has not been considered in the FIRR calculation.

Particulars	Estimated Tax at Oct-2016 level (Rs./Crore)	Estimated Tax at Completion cost level (Rs./Crore)
Custom Duty	335.41	410.60
Excise Duty	182.80	223.78
Service Tax	105.07	128.62
State VAT	208.78	453.00
Octroi	103.51	
Total	**935.57**	**1216.00**

It is assumed that the construction work will start on 01.04.2017 and is expected to be completed on 31.03.2021 with Revenue Opening Date (ROD) as 01.04.2021 for the corridor. The total completion costs duly escalated and shown in the table 15.2 have been taken as the initial investment. The cash flow of investments separately is placed in Table –15.2 as below.

Table 15.2 Year – wise Investment (Completion Cost including cost of land and all taxes & duties)

Figures in Rs. Crore

Financial Year	Estimated Cost including cost of land and all taxes & duties at Sept. 2016 Price Level	Completion Cost including cost of land cost and all taxes & duties
2017-18	525.00	545.00
2018-19	995.00	1098.00
2019-20	1229.00	1434.00
2020-21	1410.00	1742.00
2021-22	940.00	1226.00
2022-23	468.00	646.00
Total	**5567.00**	**6691.00**

15.2.1.2 Although the construction is expected to get over by 31st March 2021, the cash flow spill over up to March 2023 on account of payment normally required to be made to the various contractors up to that period necessitated by contractual clauses.

15.2.1.3 The cost of Land of Rs. 945 crore included in the above completion cost will be provided free of cost by the Maharashtra Government.

15.2.2 Additional Investment

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @5% PA is placed in table 15.3 as under: -

Table 15.3 Additional Investment towards Rolling Stock

(Rs/Crore)

Financial Year	No. of Cars	Amount
2031-32	12	321.00
TOTAL	**12**	**321.00**

15.2.3 Operation & Maintenance (O&M) Costs

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

The requirement of staff has been assumed @ 30 persons per kilometre based on DMRC's current practice. The escalation factor used for staff costs is 9% per annum to provide for both escalation and growth in salaries. The impact towards IDA Wage revision due with effect from 01.01.2017 has not been considered in FIRR calculation.

The cost of other expenses is based on the actual O & M unit cost for the Delhi Metro Phase-II project. The prevailing rate of electricity in Mumbai is Rs. 8.46 per unit which has been used for all calculations. The O&M cost (excluding staff cost) has been obtained by providing an escalation of 6.00% per annum. The O&M costs have been tabulated in Table 15.4 as below:

Table 15.4 Operation and Maintenance Costs

Rs. In Crore

YEAR			Staff	Maintenance etc	Energy	Total
2021	-	2022	28.00	21.72	69.95	119.66
2022	-	2023	30.52	23.02	74.14	127.68
2023	-	2024	33.27	24.40	78.59	136.26
2024	-	2025	36.26	25.86	83.31	145.43
2025	-	2026	39.52	27.42	88.31	155.25
2026	-	2027	43.08	29.06	93.61	165.75
2027	-	2028	46.96	30.80	99.22	176.99
2028	-	2029	51.19	32.65	105.18	189.01
2029	-	2030	55.79	34.61	111.49	201.89
2030	-	2031	60.81	36.69	118.18	215.68
2031	-	2032	66.29	38.89	155.89	261.07
2032	-	2033	72.25	41.22	165.24	278.72
2033	-	2034	78.75	43.70	175.16	297.61
2034	-	2035	85.84	46.32	185.67	317.83

YEAR			Staff	Maintenance etc	Energy	Total
2035	-	2036	93.57	49.10	196.81	339.47
2036	-	2037	101.99	52.04	208.62	362.65
2037	-	2038	111.17	55.17	221.13	387.47
2038	-	2039	121.17	58.47	234.40	414.05
2039	-	2040	132.08	61.98	248.46	442.53
2040	-	2041	143.97	65.70	263.37	473.04
2041	-	2042	156.92	69.64	279.17	505.74
2042	-	2043	171.05	73.82	295.93	540.80
2043	-	2044	186.44	78.25	313.68	578.37
2044	-	2045	203.22	82.95	332.50	618.67
2045	-	2046	221.51	87.92	352.45	661.89
2046	-	2047	241.45	93.20	373.60	708.25
2047	-	2048	263.18	98.79	396.01	757.98

15.2.4 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.

15.2.5 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, it is expected that only 50% of the Signalling and Telecom and 25% of electrical works would require replacement after 20 years.

15.3 REVENUES

The Revenue of Mumbai Metro mainly consists of fare box collection and other incomes from property development, advertisement, parking etc.

15.3.1 Fare box

The Fare box collection is the product of projected ridership per day and applicable fare structure based on trip distribution at different distance zones.

15.3.2 Traffic

15.3.2.1 (a). The projected ridership figures years as provided by MMRDA are as indicated in table 15.5 below: -

Table 15.5 Projected Ridership

Financial Year	Trips per day (lakhs)
2021-22	6.50
2031-32	7.69

(b). The growth rate for traffic is assumed @1.70% Per Annum till 2031-32 and @ 0.80% per annum thereafter.

15.3.2.2 Trip Distribution

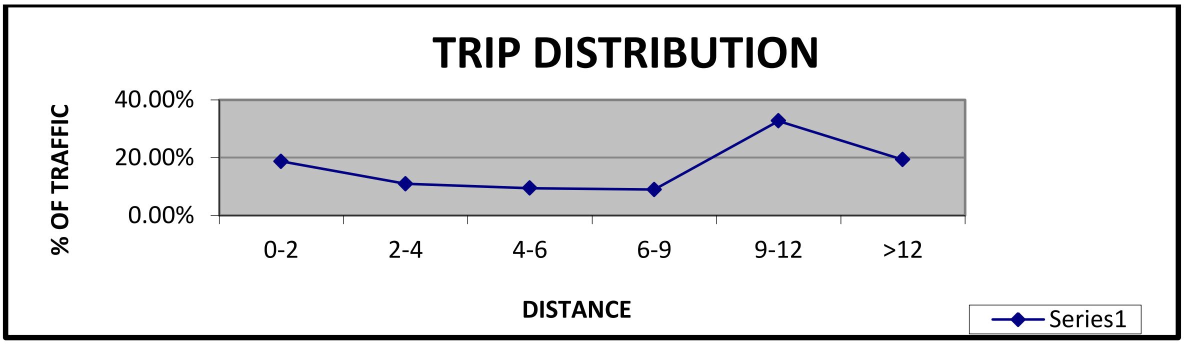
The trip distribution data provided by MMRDA based on the traffic study conducted by them for the year 2021-22 is shown in Table 15.6 below: -

Table 15.6 Trip Distribution

Distance in km	Percent distribution
0-2	18.68%
2-4	10.93%
4-6	9.47%
6-9	8.96%
9-12	32.66%
12-15	19.30%
Total	**100.00%**

The graphic presentation of the same is placed below in Figure-15.1.

Figure 15.1 –Trip Distribution



Fare Structure

The fare structure for the FY 2021-22 has been assumed based on the details provided by MMRDA. Considering the increase in the Consumer Price Index (CPI) and input costs of operation since then, the fare structure has been escalated by using @12.00% once in every two years. The fare structure for the FY 2021-22 as per the proposed fare slabs is shown in the table 15.7 below:

Table 15.7 Fare Structure in 2021-22

Sr. No.	Distance	Proposed Fare
1	0-2	11
2	2-4	13
3	4-6	16
4	6-9	20
5	9-12	22
6	>12	24

The above fare structure has been taken as furnished by MMRDA with the approval GOM. DMRC proposed that the under mentioned fare structure in a multiple of Rs. 10 be adopted at the time of commissioning of this Line to have convenience in making use of ticket vending machine and eliminate the problems of non-availability of changes for tendering changes to the passengers.

Table 15.8

Year 2021-22	
SLAB	**FARE (Rs)**
0-3 Kms	10.00
3-12 Kms	20.00
12-18 Kms	30.00
18 Kms and More	40.00

15.3.2.3 Other Sources of Revenues

Other revenues from Property Development and advertisement have been assumed @ 10% of the fare box revenues during the first five years of operations and thereafter @ 20% 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 corporate, film shootings and special events on metro premises.

15.4 FINANCIAL INTERNAL RATE OF RETURN (FIRR)

15.4.1 The Financial Internal Rate of Return (FIRR) obtained costs for 30 years business model including construction period is 8.46%. The FIRR with all taxes & duties including land cost is produced in Table 15.9:-

Table 15.9 – FIRR with all Taxes & Duties including land cost

Figs in cr. (Rs.)

Year			Outflow					Cash Flow			
			Completion Cost	Additional Cost	Running Expenses	Replacement costs	Total Costs	Fare Box Revenue	PD & ADVT	Total Revenue	IRR
2017	-	2018	545				545			0	-545
2018	-	2019	1098				1098			0	-1098
2019	-	2020	1434				1434			0	-1434
2020	-	2021	1742				1742			0	-1742
2021	-	2022	1226		120		1346	411	41	452	-894
2022	-	2023	646	0	128		774	418	42	460	-314
2023	-	2024	0	0	136		136	479	48	527	391
2024	-	2025	0	0	145		145	486	49	535	390
2025	-	2026	0	0	155		155	554	55	609	454
2026	-	2027	0	0	166		166	564	113	677	511
2027	-	2028	0	0	177		177	637	127	764	587
2028	-	2029	0	0	189		189	647	129	776	587
2029	-	2030	0	0	202		202	741	148	889	687
2030	-	2031	0	0	216		216	753	151	904	688
2031	-	2032	0	321	261		582	855	171	1026	444
2032	-	2033	0	0	279		279	862	172	1034	755
2033	-	2034	0	0	298		298	972	194	1166	868
2034	-	2035	0	0	318		318	980	196	1176	858
2035	-	2036	0	0	339		339	1111	222	1333	994
2036	-	2037	0	0	363		363	1120	224	1344	981
2037	-	2038	0	0	387		387	1258	252	1510	1123

2038	-	2039	0	0	414		414	1268	254	1522	1108
2039	-	2040	0	0	443		443	1441	288	1729	1286
2040	-	2041	0	0	473		473	1452	290	1742	1269
2041	-	2042	0	0	506		506	1635	327	1962	1456
2042	-	2043	0	0	541	732	1273	1648	330	1978	705
2043	-	2044	0	0	578	768	1346	1864	373	2237	891
2044	-	2045	0	0	619	0	619	1879	376	2255	1636
2045	-	2046	0	0	662	0	662	2126	425	2551	1889
2046	-	2047	0	0	708	0	708	2143	429	2572	1864
Total			**6691**	**321**	**8823**	**1500**	**17335**	**28304**	**5426**	**33730**	**8.46%**

The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in Table 15.10 below : -

Table 15.10 – FIRR Sensitivity Analysis

Capital Cost with Central Taxes but without land cost			
10% increase in capital cost	**20% increase in capital cost**	**10% decrease in capital cost**	**20% decrease in capital cost**
7.70%	7.01%	9.34%	10.36%
REVENUE			
20% decrease in Fare Box revenue	**10% decrease in Fare Box revenue**	**10% increase in Fare Box revenue**	**20% increase in Fare Box revenue**
5.84%	7.23%	9.58%	10.61%
O&M COSTS			
10% increase in O&M cost		**10% decrease in O&M cost**	
8.15%		8.76%	

These sensitivities have been carried out independently for each factor.

15.5 FINANCING OPTIONS

Objectives of Funding: - The objective of funding metro rail systems is not necessarily enabling the availability of funds for construction but coupled with the objective of financial closure are other concerns, which are of no less importance: -

- Ensuring low project cost
- Ensuring debt funds at low rates of interest
- Creating self sustainable system in the long run by
  - Low infrastructure maintenance costs
  - Longer life span
  - Setting fares which minimise dependence on subsidies
- Recovering returns from both direct and indirect beneficiaries

Rail based mass transit systems are characterised by heavy capital investments coupled with long gestation period leading to low financial rates of return although the economic benefits to the society are immense. Such systems generate externalities, which do not get captured in monetary terms and, therefore, do not flow back to the system. However, experience all over the world reveals that both construction and operations of metro are highly subsidised. Government involvement in the funding of metro systems is a foregone conclusion. Singapore had a 100% capital contribution from the government, Hong Kong 78% for the first three lines and 66% for the later 2 lines. The Phase-I, Phase-II as well as Phase-III of Delhi MRTS project, Chennai, Bengaluru, Mumbai Line-3, Nagpur, Lucknow Metro projects are funded with a mixture of equity and debt (ODA) by GOI & concerned state governments.

15.5.1 Alternative Models Of Financing

The financing option shall depend upon selection of the dedicated agency created to implement the project. The prominent models are: -

(i) Special Purpose Vehicle under the State Government Control (Delhi Metro Rail Corporation (DMRC) / Bangalore Metro Rail Corporation (BMRC)

(ii) Built, Operate & Transfer (BOT), and

SPV (DMRC/CMRL/BMRC) Model: - MMRDA is already implementing Line No. 2, 7 and 4 of Mumbai Metro Rail Project. This line also can be implemented by them.

ODA/Multilateral funding/JICA Loan: - Overseas Development assistance from Japan International Cooperation Agency (JICA) may be availed of for the Mumbai metro rail projects with interest @ 1.40%PA (excluding onetime front end fee @0.20% on the sanctioned loan) by GOI and lend it to the SPV on back to back basis. The loan is repayable in 30 years including moratorium period of 10 years. The loan is being provided by JICA to GOI which in turn releases the same to SPV under a Pass Through Assistance (PTA) mechanism. Normally, JICA funds for underground civil including track works, Electrical, Signalling &Telecom and Rolling Stock only. Since the loan will be in Japanese Yen, fluctuation in exchange rate at the time of repayment shall be borne by the Central Government and Government of Maharashtra in proportion to which their share holding. Alternatively, JICA can release the loan to the SPV for which a sovereign guarantee will be required from Central Government. Foreign exchange variation in such eventuality will be borne either by the SPV or GOM. In either case loan shall be repaid by SPV from the income streams of metro operations.

Modified JICA Loan: The union cabinet chaired by the PM has given its approval for modification of existing guidelines of the policy on bilateral official development assistance for Development Corporation from with bilateral partners. As per the discussions with JICA officials, JICA may extend only the modified step loan for the new projects in India at an interest rate of 0.30% per annum. The tenure of the loan is 40 years with 10 years moratorium period. JICA shall fund the project to the extent of 85% of the cost of the project excluding the cost of the land, cost of Rehabilitation and Resettlement and taxes and duties. In case JICA agree to fund the project, the full loan i.e., Rs. 3175 crore shall be funded by JICA. In that case there will be no need to borrow from Market Borrowing. The loan can also be availed from AFD, KFW, EIB etc whose interest rate is linked with six monthly LIOBOR.

Loan from Asian Development Bank (ADB)/World Bank: - The Loan shall be available from ADB/World Bank, but as per the experience it's processing and approval normally takes 8-12 months. The interest rate is linked with prevailing 6 monthly LIBOR. These bilateral funding institutions also charge some margin ranging from 200 basis points to 300 basis points. Loan from these institutions may delay the implementation of the project resulting in avoidable increase in the completion cost due to time taken during finalization of loan agreement. Recently, Bangalore Metro availed ADB loan; however loan is yet to be disburse.

Loan from Bank and Financial Institutions: - Funds can be arranged from domestic Financial Institutions like India Infrastructure Finance Company Limited (IIFCL), India Development Financing Corporation (IDFC), Life Insurance Corporation of India (LIC), IDBI Bank, ICICI Bank Ltd etc. These institutions are increasingly engaged to fund infrastructure projects subject to their commercial viability against guarantee from GOI. There are many models available under which the funds can be arranged by these financial institutions with or without syndicating with other commercial banks. IIFCL e.g. fund 20% of the project cost and arrange balance through the syndication of commercial banks with a lead banker among the consortium of bankers. The loan can be given for a period of 20-30 years with interest rate ranging from 9.50% to 12% PA. IIFCL can also provide 100% funding against GOI guarantee. They arrange ECB to the extent of foreign currency requirement at very competitive rate. The funding arrangement may require the central government guarantee as well. Since the rate of interest of these financial institutions is much higher than the interest rates of soft loan provided by JICA considering the exchange rate variation will be to GOI & GOM account, GOI and GOM shall have to bear the interest difference and provide suitable subsidy to the SPV to make the project financially sustainable.

The funding pattern under this model (SPV) is placed in table 15.11 as under: -

Table 15.11 Funding pattern under SPV model (with central taxes and land)

(Rs./Crore)

Particulars	With Taxes & Duties	
	Amount	% of contribution
Equity By GOI	677.50	12.80%
Equity By GOM	677.50	12.80%
SD for CT by GOM	381.50	7.21%
SD for CT by GOI	381.50	7.21%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	3175.00	59.98%
Total	5293.00	100.00%
SD for Land by GOM	945.00	
SD for State Taxed by GOM	453.00	
Total	6691.00	
PTA for Interest During Construction @1.40% (*)	25.00	
Grand Total	6716.00	

(*) In the case of loan @12% from domestic borrowings, the IDC works out to Rs.163 crore.

BOT Model: - In this model, the private firm will be responsible for financing, designing, building, operating and maintaining of the entire project. The contribution of Government of Maharashtra will be limited to cost of land only. Such a project become eligible for Viability Gap Funding (VGF) upto 20% from the Central Government provided the state government also contribute same or more amount towards the project. The metro being a social sector project not much private parties are available to bid for such a project. Besides quite expectedly the private operator may demand assured rate of return in the range of 16% to 18% or a comfort of guaranteed ridership.

The funding pattern assumed under this model excluding the cost of land is placed in table 15.12 tabulated as under: -

Table 15.12 Funding pattern under BOT – Combined (16% EIRR)
(With central taxes and without land cost)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% Of contribution
VGF by GOI	1059.00	20.01%
VGF by GOM	1139.00	20.57%
Equity by Concessionaire	1032.00	19.80%
Concessionaire's debt @12% PA	2063.00	39.63%
Total	5293.00	100.01%
Land Free by GOM	945.00	
State Taxes Free by GOM	453.00	
Total	6691.00	
IDC	319.00	
Total	7010.00	

15.6 RECOMMENDATIONS

The FIRR of the corridor with all taxes and land cost is 8.46%. The pre-tax Equity FIRR to the BOT operator worked out to 16% with total VGF of Rs. 3143.00 crore. In addition to the above, the state government may have to exempt or reimburse state states amounting to Rs.453 crore.

The total fund contribution of GOI & GOM under various alternatives is tabulated in table 15.13 excluding state taxes.

Table 15.13

Rs. In crore

Particulars	SPV Model	BOT Model
GOI	1059.00	1059.00
GOM	2004.00	2084.00
Total	**3063.00**	**3143.00**

In addition to the above, the state government may either have to exempt or reimburse or interest free subordinate debt of state taxes amounting to Rs.453 crore.

Considering the difference in the contribution of funds under SPV owned by GOI & GOM vis-a-vis BOT model, it is recommended to implement the project under SPV model (completely Government Funded) as per the funding pattern given in Table 15.11.

The detailed cash flow statements under various alternatives are enclosed as per detail given below:-

Option	Table No.
SPV Model with JICA Loan	15.14
SPV Model with Market Borrowings	15.15
BOT Model	15.16

The funding pattern assumed under SPV model with JICA Loan / Market Borrowing and BOT model is depicted in the pie chart i.e., Figure 15.2 & 15.3 as under: -

Figure 15.2
Funding pattern under SPV Model

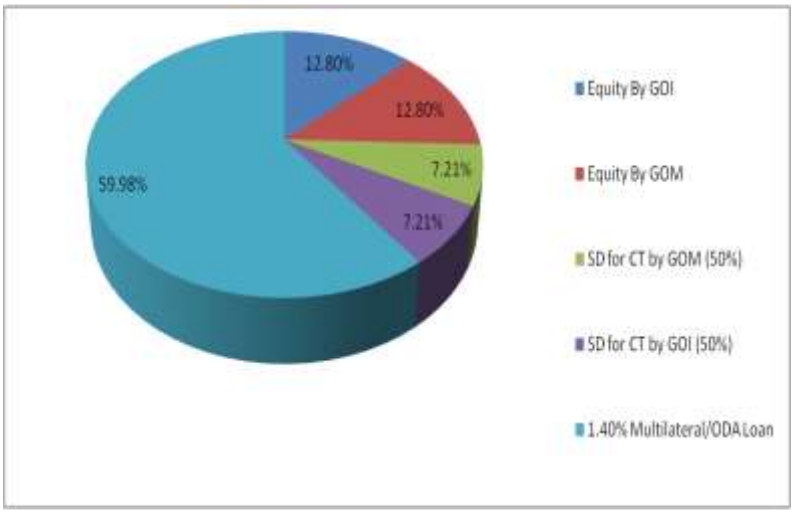


Figure 15.3
Funding pattern under BOT Model

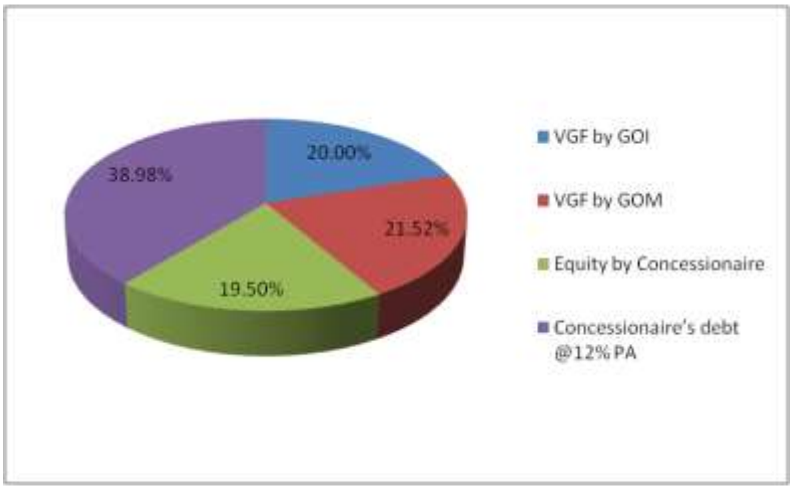


Table 15.14

Mumbai Metro (Swamy Samarth Nagar to Vikhroli (EEH) Corridor

CAPITAL COST-FIXED	5567	MB	0%	0.00%
CAPITAL COST - CURRENT	6691	Multilateral Loan	1.40%	100.00%
DOMESTIC FUNDING - BASE CASE		Front end Fee (one time)	0.20%	
		Tenure of JICA Loan	10+30 Years	

MB	0%	0.00%	0.00%
Multilateral Loan	1.40%	100.00%	1.40%
Front end Fee (one time)	0.20%		1.40%
Tenure of JICA Loan	10+30 Years		

	Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Total Revenue	Net Cash Flow for IRR	Equity from GOI & GOM	Availability of cash	Cumulative cash	Cum. Loan	Loan	Repayment of Loan	IDC	Cumulative loan incl. IDC	Interest	Profit before Tax	Cash Balance	Cumulative Cash
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2017 - 2018	545					545			0	-545	636	91	91	0	0	0	0	0				
2	2018 - 2019	1098					1098			0	-1098	959	-139	-48	48	48	0	0	48				
3	2019 - 2020	1434					1434			0	-1434	977	-457	-505	505	457	0	10	515				
4	2020 - 2021	1742					1742			0	-1742	643	-1099	-1604	1604	1099	0	15	1629				
5	2021 - 2022	1226		120	201		1346	411	41	452	-894	301	-925	-2529	2529	925	0		2554	29	102	303	303
6	2022 - 2023	646	0	128	201		774	418	42	460	-314	0	-646	-3175	3175	646	0		3200	40	91	292	594
7	2023 - 2024	0	0	136	201		136	479	48	527	391		0	-3175	3175	0	0		3200	45	145	346	941
8	2024 - 2025	0	0	145	201		145	486	49	535	390		0	0	0	0	0		3200	45	144	345	1286
9	2025 - 2026	0	0	155	201		155	554	55	609	454		0	0	0	0	0		3200	45	208	409	1695
10	2026 - 2027	0	0	166	201		166	564	113	677	511		0	0	0	0	0		3200	45	265	466	2161
11	2027 - 2028	0	0	177	201		177	637	127	764	587		0	0	0	0	107		3093	45	341	436	2597
12	2028 - 2029	0	0	189	201		189	647	129	776	587		0	0	0	0	107		2987	43	343	437	3034
13	2029 - 2030	0	0	202	201		202	741	148	889	687		0	0	0	0	107		2880	42	444	539	3572
14	2030 - 2031	0	0	216	201		216	753	151	904	688		0	0	0	0	107		2773	40	447	541	4113
15	2031 - 2032	0	321	261	211		582	855	171	1026	444		0	0	0	0	107		2667	39	515	299	4412
16	2032 - 2033	0	0	279	211		279	862	172	1034	755		0	0	0	0	107		2560	37	507	611	5023
17	2033 - 2034	0	0	298	211		298	972	194	1166	868		0	0	0	0	107		2453	36	621	725	5748
18	2034 - 2035	0	0	318	211		318	980	196	1176	858		0	0	0	0	107		2347	34	613	717	6465
19	2035 - 2036	0	0	339	211		339	1111	222	1333	994		0	0	0	0	107		2240	33	750	854	7320
20	2036 - 2037	0	0	363	211		363	1120	224	1344	981		0	0	0	0	107		2133	31	739	843	8163
21	2037 - 2038	0	0	387	211		387	1258	252	1510	1123		0	0	0	0	107		2027	30	882	986	9149
22	2038 - 2039	0	0	414	211		414	1268	254	1522	1108		0	0	0	0	107		1920	28	869	973	10122
23	2039 - 2040	0	0	443	211		443	1441	288	1729	1286		0	0	0	0	107		1813	27	1048	1152	11275
24	2040 - 2041	0	0	473	211		473	1452	290	1742	1269		0	0	0	0	107		1707	25	1033	1137	12412
25	2041 - 2042	0	0	506	211		506	1635	327	1962	1456		0	0	0	0	107		1600	24	1221	1325	13737
26	2042 - 2043	0	0	541	233	732	1273	1648	330	1978	705		0	0	0	0	107		1493	22	1182	576	14313
27	2043 - 2044	0	0	578	256	768	1346	1864	373	2237	891		0	0	0	0	107		1387	21	1382	763	15076
28	2044 - 2045	0	0	619	256	0	619	1879	376	2255	1636		0	0	0	0	107		1280	19	1361	1510	16586
29	2045 - 2046	0	0	662	256	0	662	2126	425	2551	1889		0	0	0	0	107		1173	18	1615	1764	18351
30	2046 - 2047	0	0	708	256	0	708	2143	429	2572	1864		0	0	0	0	107		1067	16	1592	1741	20092
		6691	321	8823	5588	1500	17335	28304	5426	33730	8.46%	3516				3175	2133	25		861	18458	20092	
											16395												

Table 15.15

Mumbai Metro Swamy Samarth Nagar to Vikhroli (EEH) Corridor

CAPITAL COST-FIXED 5567

CAPITAL COST - CURRENT 6691

MARKET BORROWING 12.00%

DOMESTIC FUNDING - BASE CASE

	Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Total Revenue	Net Cash Flow for IRR	Equity from GOI & GOM	Availability of cash	Cumulative cash	Cum. Loan	Loan	Repayment of Loan	IDC	Cumulative loan incl. IDC	Interest	Profit before Tax	Cash Balance	Cumulative Cash
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2017 - 2018	545					545			0	-545	636	91	91	0	0	0	0	0				
2	2018 - 2019	1098					1098			0	-1098	959	-139	-48	48	48	0	3	51				
3	2019 - 2020	1434					1434			0	-1434	977	-457	-505	505	457	0	33	541				
4	2020 - 2021	1742					1742			0	-1742	643	-1099	-1604	1604	1099	0	127	1767				
5	2021 - 2022	1226		120	206		1346	411	41	452	-894	301	-925	-2529	2529	925	0		2692	268	-142	64	64
6	2022 - 2023	646	0	128	206		774	418	42	460	-314	0	-646	-3175	3175	646	334		3004	362	-236	-364	-299
7	2023 - 2024	0	0	136	206		136	479	48	527	391		0	-3175	3175	0	334		2670	360	-175	-303	-603
8	2024 - 2025	0	0	145	206		145	486	49	535	390		0	0	0	0	334		2336	320	-136	-264	-867
9	2025 - 2026	0	0	155	206		155	554	55	609	454		0	0	0	0	334		2002	280	-32	-160	-1028
10	2026 - 2027	0	0	166	206		166	564	113	677	511		0	0	0	0	334		1668	240	65	-63	-1091
11	2027 - 2028	0	0	177	206		177	637	127	764	587		0	0	0	0	334		1334	200	181	53	-1038
12	2028 - 2029	0	0	189	206		189	647	129	776	587		0	0	0	0	334		1000	160	221	93	-945
13	2029 - 2030	0	0	202	206		202	741	148	889	687		0	0	0	0	334		666	120	361	233	-712
14	2030 - 2031	0	0	216	206		216	753	151	904	688		0	0	0	0	334		332	80	402	274	-438
15	2031 - 2032	0	321	261	216		582	855	171	1026	444		0	0	0	0	332		0	40	509	72	-366
16	2032 - 2033	0	0	279	216		279	862	172	1034	755		0	0	0	0	0		0	0	539	755	389
17	2033 - 2034	0	0	298	216		298	972	194	1166	868		0	0	0	0	0		0	0	652	868	1257
18	2034 - 2035	0	0	318	216		318	980	196	1176	858		0	0	0	0	0		0	0	642	858	2115
19	2035 - 2036	0	0	339	216		339	1111	222	1333	994		0	0	0	0	0		0	0	778	994	3109
20	2036 - 2037	0	0	363	216		363	1120	224	1344	981		0	0	0	0	0		0	0	765	981	4090
21	2037 - 2038	0	0	387	216		387	1258	252	1510	1123		0	0	0	0	0		0	0	907	1123	5213
22	2038 - 2039	0	0	414	216		414	1268	254	1522	1108		0	0	0	0	0		0	0	892	1108	6321
23	2039 - 2040	0	0	443	216		443	1441	288	1729	1286		0	0	0	0	0		0	0	1070	1286	7607
24	2040 - 2041	0	0	473	216		473	1452	290	1742	1269		0	0	0	0	0		0	0	1053	1269	8876
25	2041 - 2042	0	0	506	216		506	1635	327	1962	1456		0	0	0	0	0		0	0	1240	1456	10332
26	2042 - 2043	0	0	541	238	732	1273	1648	330	1978	705		0	0	0	0	0		0	0	1199	705	11037
27	2043 - 2044	0	0	578	261	768	1346	1864	373	2237	891		0	0	0	0	0		0	0	1398	891	11928
28	2044 - 2045	0	0	619	261	0	619	1879	376	2255	1636		0	0	0	0	0		0	0	1375	1636	13564
29	2045 - 2046	0	0	662	261	0	662	2126	425	2551	1889		0	0	0	0	0		0	0	1628	1889	15453
30	2046 - 2047	0	0	708	261	0	708	2143	429	2572	1864		0	0	0	0	0		0	0	1603	1864	17317
		6691	**321**	**8823**	**5718**	**1500**	**17335**	**28304**	**5426**	**33730**	**8.46%**	**3516**				**3175**	**3338**	**163**		**2431**	**16758**	**17317**	
											16395												

Table 15.16

Mumbai Metro Swamy Samarth Nagar to Vikhroli (EEH) Corridor

CAPITAL COST-FIXED 5567 12.00%

CAPITAL COST - CURRENT 3095

DOMESTIC FUNDING - BASE CASE

	Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Total Revenue	Net Cash Flow for IRR	Concessioner Equity	Availability of cash	Cumulative cash	Cum. Loan	Loan	Repayment of Loan	IDC	Cumulative loan incl. IDC	Interest	Profit before Tax	Cash Balance	Cumulative Cash	Return on Equity (EIRR) Pre-Tax
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	2017 - 2018	247					247			0	-247	258	11	11	0	0	0	0	0					-258
2	2018 - 2019	743					743			0	-743	258	-485	-474	474	474	0	28	502					-258
3	2019 - 2020	969					969			0	-969	258	-711	-1185	1185	711	0	100	1313					-258
4	2020 - 2021	1080					1080			0	-1080	258	-822	-2006	2006	822	0	191	2325					-258
5	2021 - 2022	34		120	102		154	411	41	452	299		-34	-2040	2040	34	0		2359	279	-49	53	53	53
6	2022 - 2023	23	0	128	102		151	418	42	460	309		-23	-2063	2063	23	238		2144	283	-53	-189	-136	-189
7	2023 - 2024	0	0	136	102		136	479	48	527	391		0	-2063	2063	0	238		1906	257	32	-104	-240	-104
8	2024 - 2025	0	0	145	102		145	486	49	535	390		0	0	0	0	238		1668	229	59	-77	-317	-77
9	2025 - 2026	0	0	155	102		155	554	55	609	454		0	0	0	0	238		1430	200	152	16	-301	16
10	2026 - 2027	0	0	166	102		166	564	113	677	511		0	0	0	0	238		1192	172	237	101	-200	101
11	2027 - 2028	0	0	177	102		177	637	127	764	587		0	0	0	0	238		954	143	342	206	6	206
12	2028 - 2029	0	0	189	102		189	647	129	776	587		0	0	0	0	238		716	114	371	235	241	235
13	2029 - 2030	0	0	202	102		202	741	148	889	687		0	0	0	0	238		478	86	499	363	604	363
14	2030 - 2031	0	0	216	102		216	753	151	904	688		0	0	0	0	238		240	57	529	393	996	393
15	2031 - 2032	0	321	261	112		582	855	171	1026	444		0	0	0	0	240		0	29	624	175	1172	175
16	2032 - 2033	0	0	279	112		279	862	172	1034	755		0	0	0	0	0		0	0	643	755	1927	755
17	2033 - 2034	0	0	298	112		298	972	194	1166	868		0	0	0	0	0		0	0	756	868	2795	868
18	2034 - 2035	0	0	318	112		318	980	196	1176	858		0	0	0	0	0		0	0	746	858	3653	858
19	2035 - 2036	0	0	339	112		339	1111	222	1333	994		0	0	0	0	0		0	0	882	994	4647	994
20	2036 - 2037	0	0	363	112		363	1120	224	1344	981		0	0	0	0	0		0	0	869	981	5628	981
21	2037 - 2038	0	0	387	112		387	1258	252	1510	1123		0	0	0	0	0		0	0	1011	1123	6751	1123
22	2038 - 2039	0	0	414	112		414	1268	254	1522	1108		0	0	0	0	0		0	0	996	1108	7859	1108
23	2039 - 2040	0	0	443	112		443	1441	288	1729	1286		0	0	0	0	0		0	0	1174	1286	9145	1286
24	2040 - 2041	0	0	473	112		473	1452	290	1742	1269		0	0	0	0	0		0	0	1157	1269	10414	1269
25	2041 - 2042	0	0	506	112		506	1635	327	1962	1456		0	0	0	0	0		0	0	1344	1456	11870	1456
26	2042 - 2043	0	0	541	134	732	1273	1648	330	1978	705		0	0	0	0	0		0	0	1303	705	12575	705
27	2043 - 2044	0	0	578	157	768	1346	1864	373	2237	891		0	0	0	0	0		0	0	1502	891	13466	891
28	2044 - 2045	0	0	619	157	0	619	1879	376	2255	1636		0	0	0	0	0		0	0	1479	1636	15102	1636
29	2045 - 2046	0	0	662	157	0	662	2126	425	2551	1889		0	0	0	0	0		0	0	1732	1889	16991	1889
30	2046 - 2047	0	0	708	157	0	708	2143	429	2572	1864		0	0	0	0	0		0	0	1707	1864	18855	1864
		3095	321	8823	3014	1500	13739	28304	5426	33730	15.13%	1032				2063	2382	319		1849	20044	18855		16.10%
											19991													

Chapter - 16

ECONOMIC APPRAISAL

16.1 INTRODUCTION

Economic benefits are social and environmental benefits which are quantified and then converted into money cost and discounted against the cost of construction and maintenance for deriving Economic Internal Rate of Return (EIRR). When actual revenue earned from fare collection, advertisement and property development are discounted against construction and maintenance cost, interest (to be paid) and depreciation cost, Financial Internal rate of Return (FIRR) is obtained. Therefore, EIRR is viewed from socio-economic angle while FIRR is an indicator of pure financial profitability and viability of any project.

Economic appraisal of a project starts from quantification of measurable economic benefits in economic money values, which are basically the savings of resource cost due to introduction of the metro line. Economic savings are derived from the difference of the cost of the same benefit components under 'with' and 'without' metro line.

In highway construction projects, 'without' is taken as "base case" and 'with' implies 'alternative case'. In 'alternative case' a portion of traffic on the road is diverted to a new road which is estimated first. Then the difference between maintenance & construction cost for 'base case' and for 'alternative case' which is known as relative road agency cost (RAC) is derived. Difference between road user cost for 'base case' and of 'alternative case' is also derived which is known as relative road user cost (RUC). Difference between RAC and RUC calculated for each year generates net benefit stream. Economic indicators (EIRR, BC Ratio, NPV) are the obtained.

In metro projects, same principal is followed but procedure is slightly different. Here, diverted traffic is nothing but the passengers shifted from road based modes to metro. Travel time saving is the difference between time which would be taking on metro and road based transports for same distance. Fuel cost saving is the difference between the cost of the fuel burnt on road based modes by the shifted passengers and the energy cost of running the metro rail which is a part of the maintenance cost. Thus benefits are directly obtained by correlating with them with the passenger km (ridership and average trip length is multiplied to get passenger km). As is done in highway projects, net benefit is obtained by subtracting the cost of the project (incurred for construction (capital) and maintenance (recurring) costs for the metro line) from the benefits derived from pass km savings in each year. The net benefit value which would be negative during initial years becomes positive as years pass. Internal rate of return and benefit cost ratio are derived from the stream.

The sources from where economic savings occur are identified first. Although there are many kinds of primary, secondary and tertiary benefits, only the quantifiable components can be taken to measure the benefits. These components are quantified by linking with the number of passengers shifted and the passenger km saved by the trips which are shifted from road/rail based modes to metro. It may be observed that first three (no 3-5, given in **Table 16.1**) are direct benefits due to shifting of trips to metro, but other secondary benefit components are due to decongestion effect on the road, reduction of emission, accident, saving of fuel and time by remaining road passengers and road maintenance cost.

Cost components are first estimated applying market values then distributed year wise after applying escalation factors. This is commonly known as completion cost. Tax components are added while arriving at completion cost. For financial analysis these exercises are necessary, but for economic analysis all additional cost components from the asset values are to be removed.

Values of Benefit components are mostly economic values except fuel and vehicle maintenance cost which are estimated from market cost. Economic factors which are used for each component are also given in table 16.1. Overall economic value of benefit components is 88% of the estimated value.

Table 16.1: Cost/Benefit Components due *to* Metro

	Cost/Benefit Components	Economic Factors
1	Construction Cost	100%
2	Maintenance Cost	100%
3	Annual Time Cost Saved by Metro Passengers	100%
4	Annual Fuel Cost Saved by Metro Passengers	80%
5	Annual Vehicle Operating Cost Saved by Metro Passengers	80%
6	Emission Saving Cost	80%
7	Accident Cost	100%
8	Annual Time Cost Saved by Road Passengers	100%
9	Annual Fuel Cost Saved by Road Passengers	80%
10	Annual Infra Structure Maintenance Cost	80%

16.2 VALUES ADOPTED FOR SOME IMPORTANT VARIABLES

Benefit components are converted (by applying appropriate unit cost) to money values (Rs.). Derivation procedures of some of the values used for economic analysis are shown in table 16.2.

Table 16.2: **Values adopted for some important variables**

	Values	Important variables
1	Rs. 0.81/min (2014 value)	Weighted value of Travel Time is derived[1] from the paid cost of travel minus respective vehicle operation cost for every mode used (table 16.7).
2	Market rate of fuel cost	Adopted value of Petrol, Diesel and CNG.(table 16.3 bottom row)
3	Table 16.3	Vehicle Operating Cost per km (Derived from Life Cycle Cost of different passenger vehicles)
4	Table 16.4	Emission (gm/km as per CPCB and UK Norms) Emission Saving Cost (adopted for Indian conditions in Rs/ton).
5	Table 16.5	Accident Rate (No of fatal and all accidents per one Cr.KM). Accident costs are derived from earning in remaining life and published papers.
6	12.85%	Passenger km – Vehicle km conversion factor derived from House Hold Survey and Modal Split survey within study area
7	Graph 16.1	Fuel Consumption of vehicles at a given speed is derived from Road User Cost Study Model (CRRI-2010)
8	Rs. 0.5/vehicle km	Infra Structure Maintenance Cost is derived from published values on annual expenditure on roads and traffic and annual vehicle km
9	21.94 min	Weighted average Journey Time Saved for average trip length (km) journey after Shifting (Derived from modal split -Table 16.7 and speed and delay survey)
10	25 kmph	Average Journey Speed (Speed and delay Survey)

Table 16.3: **Vehicle Operating *Cost (VOC) in Rs.***

Per Vehicle KM	Bus	4 Wh (Large)	4 Wh (Small)	2 Wh (MC)	2 Wh (SC)	3 Wh (Auto)	Mini Bus
Maintenance Cost	4.84	3.78	2.22	0.93	0.88	2.40	2.99
Capital Cost	4.81	4.27	1.87	0.29	0.19	1.20	2.57
Vehicle Maintenance Cost including overhead	10.61	8.85	4.50	1.34	1.18	3.96	6.12
Fuel Cost	9.38	5.02	3.11	1.07	1.07	3.09	4.75
VOC (with fuel)	19.99	13.87	7.61	2.41	2.25	7.05	10.87

As there is substantial number of trips by local train (EMU), VOC cost of train is derived from energy (electricity) consumed which is about Rs. 175.5 per train km carrying 3000 passenger and running @33 km per hour. Energy charges is taken as Rs. 8 per KWH.

[1] Workers value of time is Rs. 1.38 and non workers value of time is Rs.0.61. 70% are work and business related trips and 30% of non work trips (source: traffic study report) Assuming workers will be metro users, same value of time is taken. For 2021 it will be Rs.2.08

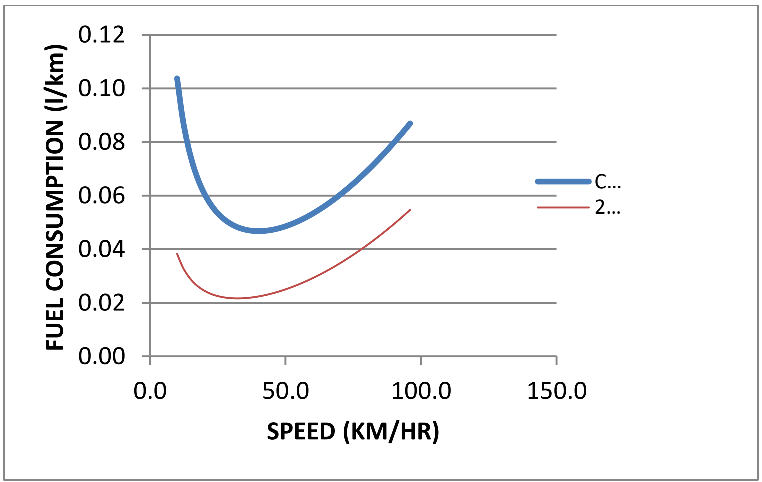
Table 16.4: Vehicle Emission 2011-2021(CPCB) and Cost in Rs.

VEHICLE	CO	HC	NOX	PM	CO	CO2
BUS	3.72	0.16	6.53	0.24	3.72	787.72
2W-2 STROKE	1.4	1.32	0.08	0.05	1.4	24.99
2W-4 STROKE	1.4	0.7	0.3	0.05	1.4	28.58
MINI BUS	2.48	0.83	8.26	0.58	2.48	358.98
4W-SMALL	1.39	0.15	0.12	0.02	1.39	139.51
4W-LARGE	0.58	0.05	0.45	0.05	0.58	156.55
TATA MAGIC	1.24	0.17	0.58	0.17	1.24	160
3W	2.45	0.75	0.12	0.08	2.45	77.89
Cost	RS. 100000 PER TON					500

Table 16.5: Accident Rate and Cost in Rs

Expected Accident Rate in the year 2021	/Cr. Vehicle KM	Average Cost in lakh Rs
All Types except Fatal.	1.82	2.30
Fatal Accident.	0.22	10.26

Figure 16.1 Fuel Consumption/against speed graph for Car and two wheeler



Traffic demand estimates used for economic analysis are given in table 16.6 and 16.7.

Table 16.6: Summary of the Ridership

Particulars	2021	2031	2041
Trips/day	650690	769698	833539
Average Trip length (km)	7.79	7.79	7.79
Passenger km	5067834	5994716	6491931
Passenger km/km	350061	414086	448431

Source: Traffic Study Report

In this area, public transport system is good (passenger - train 71.60%, Bus 19.58%). Personalised mode passenger (car, and two wheelers)-trips are 6.61% and IPT modes are carrying 2.20% passengers. Vehicular trips made by Public modes are 13.45% and 18.84% by IPT modes and 67.71% are private transport. *(Source:*

Comprehensive Transportation Study for Mumbai Metropolitan Region, April 2008, Lea Associates- derived from table 3-2). and the mode share is shown in table 16.7.

Table 16.7 Mode Share in the Study Area

MODAL SPLIT	VEH (ROAD)	PASS (ROAD)	VEH (SHIFT)	PASS (SHIFT)
Car(S)	11.61%	1.47%	11.7%	3.74%
Car(M)	17.41%	2.20%	17.5%	5.61%
2W	38.69%	2.94%	38.8%	7.49%
Bus(CNG)	7.99%	15.67%	8.0%	39.92%
MB(CNG)	4.99%	3.92%	5.0%	9.98%
Train	0.47%	71.60%	0.1%	27.64%
3W CNG	15.39%	1.71%	15.4%	4.37%
Taxi	3.45%	0.49%	3.5%	1.25%

Estimated shift to metro is 10.58%. Mode share of shifted to metro passengers are obtained by assuming that 5% train passenger will shift to metro and from other modes it will be 33%

16.3 ECONOMIC BENEFIT STREAM

Economic benefits are quantified first with reference to the passenger km saved by the passengers shifting to metro and then unit costs (market values) of benefits (or savings) are multiplied and economic factors are applied. Names of benefit components may be seen in table 16.8 below (headings) where benefit stream values are given. For creating benefit stream, quantified values are interpolated or extrapolated from the values directly obtained from horizon year values.

Values of economic indicators (EIRR, NPV, BCR), are derived from the cost and benefit stream. All Benefit component values (economic) accrued between the years 2021-2047 are shown in **figure 16.2** which shows that benefits are mainly coming from saving of travel time by metro and road passengers (71.53%), fuel saving cost (13.96%), vehicle maintenance cost (11.90%) and Environmental benefit from emission reduction, accident reduction and road maintenance cost (together) is 2.60%.

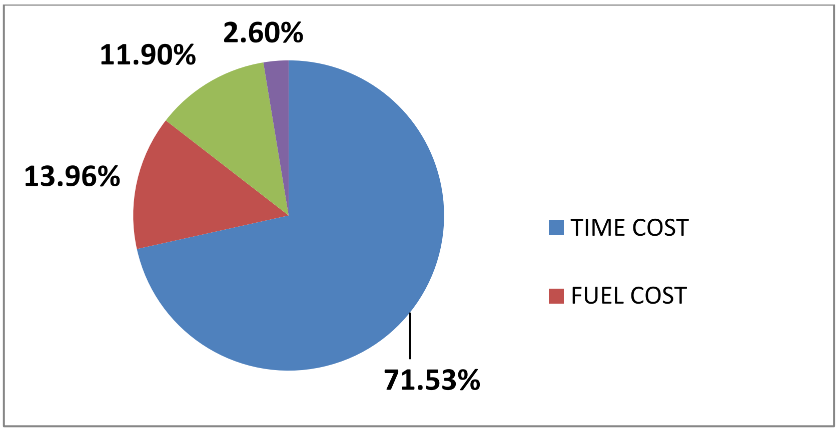


Figure 16.2 Percent of Benefits

Table 16.8 Component wise Stream of Economic Benefit Value

From	To	Annual Time Cost Saved by Metro Passengers in Cr. Rs.	Annual Fuel Cost Saved by Metro Passengers in Cr. Rs.	Annual Vehicle Maintenance Cost Saved by Metro Passengers in Cr. Rs.	Emission Saving Cost in Cr. Rs.	Accident Cost in Cr. Rs.	Annual Time Cost Saved by Road Passengers in Cr. Rs.	Annual Fuel Cost Saved by Road Passengers in Cr. Rs.	Annual Infra Structure Maintenance Cost	Total Benefits without Discount
2021	2022	738	147	139	25	7	15	1	11	1083
2022	2023	815	162	152	28	7	17	1	11	1193
2023	2024	900	178	166	27	8	20	1	11	1311
2024	2025	993	196	182	26	9	22	1	12	1440
2025	2026	1097	215	199	29	9	22	1	12	1584
2026	2027	1211	237	217	31	10	24	2	12	1744
2027	2028	1337	260	237	34	11	27	2	13	1921
2028	2029	1476	286	259	37	12	30	2	13	2116
2029	2030	1630	313	284	41	13	33	2	13	2330
2030	2031	1800	344	310	45	15	37	3	14	2567
2031	2032	1970	374	336	48	16	41	3	14	2802
2032	2033	2156	408	364	52	17	46	3	14	3060
2033	2034	2359	481	430	62	19	59	4	16	3430
2034	2035	2582	525	466	67	20	65	5	16	3746
2035	2036	2826	568	505	73	22	71	5	16	4086
2036	2037	3093	620	548	79	24	78	6	17	4463
2037	2038	3385	669	593	85	26	85	6	17	4867
2038	2039	3764	742	653	94	28	94	7	17	5401
2039	2040	4082	806	701	101	30	102	8	18	5848
2040	2041	4427	876	753	108	33	110	8	18	6333
2041	2042	4800	952	809	116	35	119	9	18	6858
2042	2043	5206	1034	868	125	38	129	10	18	7427
2043	2044	5645	1123	932	134	40	139	11	18	8043
2044	2045	6122	1220	1001	144	43	151	12	18	8710
2045	2046	6639	1325	1074	154	47	163	13	18	9433
2046	2047	7199	1439	1153	166	50	176	14	19	10216

16.4 METRO CONSTRUCTION COST

Total cost of metro construction (**Completion cost**) is derived after considering cost of all major component such as Relocation and Rehabilitation (RR), Civil construction for underground and elevated portions, Stations and Depots, Track laying, Signalling and telecommunication, Power traction line, Rolling stock, Man power etc. (**Recurring cost**) includes energy cost, maintenance cost, and operation cost. These costs are inclusive of all taxes and yearly escalation cost applied on fixed cost (2016). Analysis period is taken from 2017-18 to 2046-47 out of which 4 years (2017-2021) are marked as construction period. During the years 2031-32 and in 2042-44, additional capital will again be required for rolling stock and major maintenance and replacement. Operation is expected to start in 2021-22 (5th Year).

To obtain economic cost, escalation factors (7.5%) are removed from the completion cost. Tax is removed from fixed cost which is 15.96%. Cost stream generated for both options are shown in **Table 16.9.**

Table 16.9: Completion and Economic Cost stream

		Completion Cost		Economic Cost	
Year	Year	Capital Cost	Recurring Cost	Capital Cost	Recurring Cost
Start	Ending	Cr. Rs.	Cr. Rs	Cr. Rs.	Cr. Rs
2017	2018	545	0	401	0
2018	2019	1098	0	809	0
2019	2020	1434	0	1056	0
2020	2021	1742	0	1283	0
2021	2022	1226	120	903	88
2022	2023	646	128	476	94
2023	2024	0	136	0	100
2024	2025	0	145	0	107
2025	2026	0	155	0	114
2026	2027	0	166	0	122
2027	2028	0	177	0	130
2028	2029	0	189	0	139
2029	2030	0	202	0	149
2030	2031	0	216	0	159
2031	2032	321	261	236	192
2032	2033	0	279	0	205
2033	2034	0	298	0	219
2034	2035	0	318	0	234
2035	2036	0	339	0	250
2036	2037	0	363	0	267
2037	2038	0	387	0	285
2038	2039	0	414	0	305
2039	2040	0	443	0	326
2040	2041	0	473	0	348
2041	2042	0	506	0	373
2042	2043	732	541	539	398
2043	2044	768	578	566	426
2044	2045	0	619	0	456
2045	2046	0	662	0	487
2046	2047	0	708	0	521

16.5 ECONOMIC PERFORMANCE INDICATORS

After generating the cost and benefit stream table, values of economic indicators are derived and are given in **table 16.10**. Project period is 2017-2047, On the basis of COMPLETION cost, EIRR is found to be **21.92%** and B/C ratio as **6.46** and with 12 % discount, EIRR is **8.86%** and B/C ratio is **2.19**. NPV without discount is Rs **94677** Cr. and with 12% discount rate, NPV is Rs. **7665** Cr. On the basis of ECONOMIC cost, EIRR is 26.93% B/C Ratio is 8.78 and NPV is 99248, both shows that the project is economically viable.

Table 16.10: Economic Indicator Values (2046-47)

Swami Samarth Nagar – Vikhroli (EEH)	(Completion Cost Basis)		(Economic Cost Basis)	
Economic Indicators	Without Discount	With Discount (12%)	Without Discount	With Discount (12%)
Cumulative cost (Cr.)	17335	6436	12765	4739
Cumulative benefit(Cr.)	112012	14101	112012	14101
Benefit Cost Ratio	6.46	2.19	8.78	2.98
NPV(Cr.)	94677	7665	99248	9362
EIRR	21.92%	8.86%	26.93%	13.33%

16.6 SENSITIVITY ANALYSIS

Sensitivity of EIRR and B/C ratios both with and without discount was carried out and the output is given in the **table 16.11**. 2046-47 is taken for the year of comparison.

Table 16.11 Sensitivity of EIRR (Completion Cost)

SENSITIVITY		WITHOUT DISCOUNT			WITH DISCOUNT		
TRAFFIC	COST	EIRR	B/C	COST	EIRR	B/C	COST
0%	0%	21.92%	6.46	17335	8.86%	2.19	6436
-10%	0%	20.39%	5.82	17335	7.49%	1.97	6436
-20%	0%	18.76%	5.17	17335	6.03%	1.75	6436
0%	10%	20.53%	5.87	19069	7.61%	1.99	7080
0%	20%	19.31%	5.38	20802	6.53%	1.83	7723
-10%	10%	19.06%	5.29	19069	6.31%	1.79	7080
-20%	20%	16.41%	4.31	20802	3.93%	1.46	7723

Sensitivity analysis shows that economic indicator values namely EIRR is within the limit of acceptance as also the B/C ratios. If cost is increased by more than 20% or traffic is decreased by 20%, economic return reduces to 16.41%.

16.7 QUANTIFIED BENEFITS

Benefits which are shown in previous tables are money value of the benefits. These benefits are estimated first and the converted into money value. For brevity, only 5 year estimates are shown in **table 16.12** (Reduction of Vehicle gas Emission) and in **table 16.13** (Reduction of Fuel, Time of Travel, Vehicle on Road etc).

Table 16.12 Environmental Benefits Quantified

Tons/Year	2021	2022	2023	2024	2025
CO	747.85	760.52	773.40	715.58	655.57
HC	498.28	506.72	515.31	300.84	78.96
NOX	859.59	874.15	888.95	909.30	930.08
PM	79.67	81.02	82.39	65.38	47.77
SO2	4.07	4.14	4.21	3.95	3.67
CO2	103766	105524	107311	109129	110977
Total Emission Saved	105956	107750	109575	111124	112693

From **Table 16.13**, it may be seen that in 2021, due to shifting, metro passengers time saving will be 7.81 Cr. (10 million) hour, fuel saving by metro passengers will be 45.00 thousand tons. Amount of travel in terms of passenger km reduced due to shifting to Metro Rail is equivalent to reduction of 14454 vehicles from the road. About 6 fatal accidents and 43 other accidents may be avoided. Hence it is expected that there will be some improvement of the overall ambience of the area.

Table 16.13 Travel Benefits Quantified

Quantified Benefits in Horizon Years	2021	2022	2023	2024	2025
Annual Time Saved by Metro Passengers in Cr. Hr.	8.29	8.51	8.74	8.98	9.22
Annual Fuel Saved by Metro Passengers in thousand Tons.	20.66	21.25	21.76	22.35	22.90
Daily vehicles reduced (off the road)	7813	7946	8080	8217	8356
CO2 reduced in thousand tons	103.77	105.52	107.31	109.13	110.98
Other gases reduced in thousand tons	2.19	2.23	2.26	2.00	1.72
Reduced No of Fatal Accidents in Year	5.82	5.92	6.02	6.12	6.22
Reduced No of Other Accidents in year	41.77	42.47	43.19	43.92	44.67
Annual Vehicle km Reduced in Cr. Km.	26.14	26.58	27.03	27.49	27.96

Chapter - 17

IMPLEMENTATION

17.1 INTRODUCTION

Mumbai Metro Corridor No. 06, Swami Samarth Nagar to Vikhroli (EEH) is 14.477 km long with 13 stations. The entire corridor is elevated.

Estimated Cost of the project at October 2016 price level is Rs. 5567.00 crores inclusive of all taxes & duties and land cost. Completion cost with all taxes & duties and land cost and escalation at 6.0% p.a. is estimated to be Rs. 6691 Crores.

It is recommended that Government of India will fund the central taxes and duties to the extent of 50% through grant by subordinate debt. The State Government will also contribute 50% of the Central taxes and duties.

17.2 POSSIBLE MODELS FOR FINANCING A METRO PROJECT

1. A Build, Operate & Transfer (BOT)
2. A Private Public Partnership (PPP) and
3. Fully through Government funding i.e. Government mobilizing all the funds required for the project through equity, grants or loans borrowed by the Government.

Possibilities, implications of the 3 models mentioned above are discussed below:

1. BOT model:

Under this model the project is handed to a Consortium for a specified period of time, selected through competitive bidding. The consortium will bring in all the funds required for the project, appoints consultants for design, planning and project implementation, execute the project fully and then operate and maintain the same during concession period. All the revenues from the project, fare box collections as well as non-fare box collections will go to the Consortium and in all the concession period the project is handed over to the Consortium. Here the Government responsibility is only to make available the required land and right of way and monitor the quality of services and safety standards. Building the system to the specified safety standards and obtaining the safety certificate from the competent authority will be the responsibility of the BOT operator. In this model the Government has no financial liability and all the risks are carried by the BOT operator. The Government may or may not stipulate the fares to be levied.

2. PPP model:

There are essentially two variants under this model.

Variant 1:- Here the Government funds the fixed infrastructure cost such as land and basic civil structures and private investor funds all the systems such as rolling stock, signalling, power supply, traction, track, fare collection system and E&M works including station architectural design. An example for this is Delhi Metro Airport line. Under this arrangement, the Government's investment will be about 40 to 45% of the total cost and the PPP Operator funds the remaining cost. The operator is selected again on competent bidding with viability gap funding who operates and maintains the system to the specified service safety levels. All the Revenues will accrue to the Operator in all the concession period till the project is handed over to the owner. Ridership for this is taken by the Operator fully or shared between the operator and the owner.

Variant 2:- Under this the Government acquires the required land and offers to the concessionaire free of cost. The private partner funds all the rest of the project, operates and maintains the system taking all the revenues and risks. His expected losses are made good through a viability Gap Funding (VGF), by the Government arrived at based on competitive bidding. At the end of concession period the system reverts to the owner. Under the PPP model, Sweeteners are sometime offered to the operator in the form of lands for commercial exploitation. Private management generally ensures better efficiency in the execution and operation of the system compared to a Government agency.

When the project is taken up on BOT or PPP model the total cost of the project generally gets hiked up by the Concessionaire adding the availing additional costs.

1. As bulk of the funds will be through borrowings. Interest during construction period will get added on to the projects costs.
2. The funds are available to a private party to which borrowing costs compared to the Government and additional funding cost will get factor to the cost of the project.
3. When a private party executes the project the refunds of the taxes and duties of the two Governments may not be possible. This alone will increase the cost of project by 18 to 20%.
4. Metro projects by themselves will not be financially viable. Commercial exploitation of surplus lands and identified Governments lands along the route has to be necessary to augment the Capex as well as revenue earnings. Making available normal land free to the Concessionaire for commercial exploitation will lead to public criticism and often end up in scandals.

Nowhere in the country a complete BOT or PPP model has so far found successful or attractive for the main reason that the fare levels have to be kept low and affordable to the common citizens.

3. Fully through Government funding:-

Here, the Government takes full responsibility for funding the project either from its own resources or through borrowings. For convenience and speedy execution a Special Purpose Vehicle is set up and given the mandate to execute the project. The Operation and maintenance of the system can be either directly by the SPV or they can engage an operator for the purpose. Usually a debt equity ratio of 2:1 is followed but there can be variations depending upon the tender's terms and the Government's ability to provide funds. The government's own investment will be in the form, of share holdings in the SPV and borrowings can be either from a Consortium of local banks or from infrastructure funding organizations such as IIFCL, IDBI, etc. or through an external bilateral loan from institutions such as ADB, World Bank, JICA etc. All the loans will need Governmental guarantee to reduce the borrowing cost. The Government can also assist the SPV with interest free subordinate loans. The SPV will have responsibility to service and pay back the loan and if SPV fails the responsibility will then devolve on the Government.

17.3 THE RECOMMENDED FINANCIAL MODEL FOR SWAMI SAMARTH NAGAR – VIKHROLI (EEH) CORRIDOR

World over Metro projects cannot be financially viable and depend upon generous concessions and subsidies. The financial internal rate of return for this corridor is **8.46%.**

The only Metro which has been implemented on BOT model so far is the Rapid Metro in Gurgaon. Financially this Metro has been a total failure since the revenues are not able to meet even the interest payment on the loans raised.

Out of the 3 PPP models in the country, Delhi Airport Line has been a total failure since the Concessionaire has voluntarily withdrawn with claims through arbitration. In the case of Bombay Metro Line No.1 which is only 11 Kms length had taken more than 6 years for completion and the cost had gone up 2 times. Concessionaire is representing to government for allowing him to charge very high fare in spite of very good ridership leading to loading the public financially.

In the case of the Hyderabad Metro the PPP Concessionaire withdrew from the project and another Concessionaire namely L&T is implementing the project. The financial performance of this project is yet to be assessed as even one section of the project is still not opened for traffic. Considering the global scenario and the experience in our own country DMRC does not recommend either the BOT model or PPP route for implementing the Swami Samarth Nagar – Vikhroli (EEH) Corridor.

It is therefore recommended that the project is implemented fully as a Government initiative. By this route the project can be completed at the shortest time and at the lowest cost. This is important because then only ticket can be priced low, affordable to the common citizens and make the system truly a popular public transport.

17.4 INSTITUTIONAL ARRANGEMENTS

The State Govt. of Maharashtra will have to approve the implementation of the project by Mumbai Metropolitan Region Development Authority (MMRDA).

17.5 IMPLEMENTATION STRATEGY

When the project is taken up as a Government initiative there are two ways the projects can be implemented. One is MMRDA handling the project directly with the help of General Consultants (G.C.). Further bilateral lending agencies generally insist of international consultants to engage as G.C. for assisting for the implementation of the project. International G.C. is required for planning, design, drawing up specifications, preparation of tender documents, finalization of contract and supervision of the project during execution. To engage the G.C. globally tenders would be necessary. For finalizing such a global contract and positioning the Consultants itself takes about 9 to 12 months. G.C. will generally cost about 3½ to 4% of the project cost. Even if G.C. is engaged, still MMRDA will need a fairly big organisation to oversee the G.C. work. It will be difficult for MMRDA to mobilize required technical persons with experience and knowledge and the establishment cost of MMRDA itself would be about another 3½ to 4%. Thus about 7 to 8% of the project cost will be spent on total establishment alone.

The 2nd option is MMRDA for this project can be a very small lean and efficient organization responsible for land acquisition and mobilization of funds. The entire Metro project can be entrusted on turnkey basis and on deposit terms to an experienced organization such as DMRC who has the experience and track record and competency of technical manpower. DMRC is implementing on similar basis Jaipur Metro for Rajasthan Government and Kochi Metro for Kerala Government and Greater Noida Metro project for the Greater Noida Authority. Similarly Dahisar (E) to D.N. Nagar Corridor (Line-2A) is handed over to DMRC on a turnkey basis for implementation. The same way the Swami Samarth Nagar to Vikhroli (EEH) Corridor can be handed over to DMRC on a turnkey basis for implementation. DMRC generally charges 6% of the project cost for the total turnkey implementation. This will be the cheapest and quickest way of completing the project in time.

17.6 CONTRACT PACKAGES FOR IMPLEMENTATION OF THE PROJECT

The project may be implemented in eight packages as under.

Package –1: Starting from chainage -0.8225 km (Dead End of Swami Samarth Nagar Station) and upto SEEPZ Village Station (Including) proposed metro station.

Package – 2: Starting SEEPZ Village station (excluding) upto Vikhroli (EEH) Dead end.

Package - 3: Detailed design consultant for corridor including Depot.

Package - 4: Construction of boundary wall for depot, earth work filling and construction of workshop, inspection bay, stabling lines etc.

Package – 5: System Contracts: Supply and installation of traction power system (3^{rd} bay) including sub-station.

Package - 6: Supply and installation of signaling system (CBTC)

Package - 7: Supply and installation of AFC System.

Package - 8: Supply and commissioning of rolling stock.

Any other small package may be decided at the time of implementation of the Project.

17.7 IMPLEMENTATION SCHEDULE

A suggested project implementation schedule for Project Implementation on Turnkey Basis (Deposit Terms) is given in Table 17.1

Table 17.1 Project Implementation on Turnkey basis (Deposit Terms)

Sl. No.	Item of Work	Completion Date
1	Submission of Final DPR to State Govt.	D
2	Approval of DPR by State Government	D+15 days
3	Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+30 days
4.	Sanction of Project by GOI	D+60 days
5.	Appoint an agency on deposit terms	D+30 days
6.	Implementation of the project	D+46 months
7.	Testing and Commissioning	D+47 months
8.	CMRS Sanction	D+48 months
9.	ROD	D+48 months

17.8 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

MMRDA. It is reliably learnt that for the 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.

17.9 CONCESSION 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. With reasonable fare 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. 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.

As in the case of Delhi Metro, the State Government should exempt/reimburse the Maharashtra Value Added Tax (VAT) to this Metro project. It should also exempt the following:

As per the present policy 50% of the Central Taxes will be paid by GOI as subordinate Debt and balance 50% will be paid by the concerned State Government. Maharashtra State Government may pursue the Central government to extend the same benefit to MMRC.

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 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.

It is recommended that 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.

17.10 LEGAL COVER FOR MUMBAI METRO

Implementation of proposed Metro Corridor may be done under “The Metro Railways (Amendment) Act 2009”. The copies of the Gazette notification and the amendment are put up enclosure to this chapter.

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रजिस्ट्री सं॰ डी॰ एल॰-33004/99

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(मैट्रो रेल प्रकोष्ठ)

अधिसूचना

नई दिल्ली, 7 सितम्बर, 2009

का.आ. 2279(अ).—केन्द्रीय सरकार, मैट्रो रेल (संशोधन) अधिनियम, 2009 (2009 का 34) की धारा 1 की उप-धारा (2) द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए, 7 सितम्बर, 2009 को उस तारीख के रूप में नियत करती है, जिसको उक्त अधिनियम के उपबंध प्रवृत्त होंगे।

[फा.सं. के-14011/40/2003-एमआरटीएस/मैट्रो]

विमल कुजूर, अवर सचिव

MINISTRY OF URBAN DEVELOPMENT

(Metro Rail Cell)

NOTIFICATION

New Delhi, the 7th September, 2009

S.O. 2279(E).—In exercise of the powers conferred by sub-section (2) of Section 1 of the Metro Railways (Amendment) Act, 2009 (34 of 2009) the Central Government hereby appoints the Seventh September, 2009 as the date on which the provisions of the said Act, shall come into force.

[F. No. K-14011/40/2003-MRTS/Metro]

BIMAL KUJUR, Under Secy.

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इस भाग में भिन्न पृष्ठ संख्या दी जाती है जिससे कि यह अलग संकलन के रूप में रखा जा सके।
Separate paging is given to this Part in order that it may be filed as a separate compilation.

MINISTRY OF LAW AND JUSTICE
(Legislative Department)

New Delhi, the 27th August, 2009/Bhadra 5, 1931 (Saka)

The following Act of Parliament received the assent of the President on the 26th August, 2009, and is hereby published for general information:—

THE METRO RAILWAYS (AMENDMENT) ACT, 2009

No. 34 OF 2009

[26th August, 2009.]

An Act further to amend the Metro Railways (Construction of Works) Act, 1978 and to amend the Delhi Metro Railway (Operation and Maintenance) Act, 2002.

BE it enacted by Parliament in the Sixtieth Year of the Republic of India as follows:—

CHAPTER I

PRELIMINARY

1. (1) This Act may be called the Metro Railways (Amendment) Act, 2009. Short title and commencement.

(2) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint.

CHAPTER II

AMENDMENT TO THE METRO RAILWAYS (CONSTRUCTION OF WORKS) ACT, 1978

Amendment of section 1.

2. In the Metro Railways (Construction of Works) Act, 1978 (hereafter in this Chapter referred to as the Metro Railways Act), in section 1, in sub-section (*3*), for the portion beginning with the words "such other metropolitan city" and ending with the words "to that city accordingly", the following shall be substituted, namely:— 33 of 1978.

"the National Capital Region, such other metropolitan city and metropolitan area, after consultation with the State Government, and with effect from such date as may be specified in that notification and thereupon the provisions of this Act shall apply to the National Capital Region, such metropolitan city or metropolitan area accordingly.".

Substitution of words "metropolitan city" by words "metropolitan city, metropolitan area and National Capital Region".

3. In the Metro Railways Act, for the words "metropolitan city" occurring in clause (*h*) of sub-section (*1*) of section 2, clause (*c*) of sub-section (*1*) of section 4 and clause (*a*) of sub-section (*1*) of section 32, the words "metropolitan city, metropolitan area and the National Capital Region" shall be substituted.

Amendment of section 2.

4. In section 2 of the Metro Railways Act, in sub-section (*1*),—

(*i*) after clause (*h*), the following clause shall be inserted, namely:—

'(*ha*) "metropolitan area" shall have the meaning assigned to it in clause (*c*) of article 243P of the Constitution;';

(*ii*) after clause (*o*), the following clause shall be inserted, namely:—

'(*oa*) "National Capital Region" means the National Capital Region as defined in clause (*f*) of section 2 of the National Capital Region Planning Board Act, 1985;'. 2 of 1985

CHAPTER III

AMENDMENT TO THE DELHI METRO RAILWAY (OPERATION AND MAINTENANCE) ACT, 2002

Substitution of references to "metropolitan city of Delhi" by references to "National Capital Region and any other metropolitan area"

5. Throughout the Delhi Metro Railway (Operation and Maintenance) Act, 2002 (hereafter in this Chapter referred to as the Delhi Metro Railway Act), for the words "metropolitan city of Delhi" wherever they occur, the words "the National Capital Region, metropolitan city and metropolitan area" shall be substituted. 60 of 2002.

Amendment of section 1.

6. In section 1 of the Delhi Metro Railway Act, for sub-sections (*1*) and (*2*), the following sub-sections shall be substituted, namely:—

"(*1*) This Act may be called the Metro Railways (Operation and Maintenance) Act, 2002.

(*2*) It extends in the first instance to the National Capital Region and the Central Government may, by notification, after consultation with the State Government, extend this Act to such other metropolitan area and metropolitan city, except the metropolitan city of Calcutta, and with effect from such date as may be specified in that notification and thereupon the provisions of this Act shall apply to that metropolitan area or metropolitan city accordingly.".

7. In section 2 of the Delhi Metro Railway Act, in sub-section (*1*),— Amendment of section 2.

(*i*) for clause (*a*), the following clauses shall be substituted, namely:—

'(*a*) "Central Government", in relation to technical planning and safety of metro railways, means the Ministry of the Government of India dealing with Railways;

(*aa*) "Claims Commissioner" means a Claims Commissioner appointed under section 48;';

(*ii*) for clause (*h*), the following clauses shall be substituted, namely:—

'(*h*) "metropolitan area" shall have the meaning assigned to it in clause (*c*) of article 243P of the Constitution;

(*ha*) "metropolitan city" means the metropolitan city of Bombay, Calcutta, Delhi or Madras;';

(*iii*) after clause (*k*), the following clause shall be inserted, namely:—

2 of 1985. '(*ka*) "National Capital Region" means the National Capital Region as defined in clause (*f*) of section 2 of the National Capital Region Planning Board Act, 1985;'.

8. In section 6 of the Delhi Metro Railway Act, in sub-section (*2*), after clause (*b*), the following clauses shall be inserted, namely:— Amendment of section 6.

"(*ba*) develop any metro railway land for commercial use;

(*bb*) provide for carriage of passengers by integrated transport services or any other mode of transport;".

9. Section 7 of the Delhi Metro Railway Act shall be renumbered as sub-section (*1*) thereof and after sub-section (*1*) as so renumbered, the following sub-section shall be inserted, namely:— Amendment of section 7.

24 of 1989. "(*2*) The Commissioner shall function under the administrative control of the Chief Commissioner of Railway Safety appointed under section 5 of the Railways Act, 1989.".

10. For section 12 of the Delhi Metro Railway Act, the following section shall be substituted, namely:— Substitution of new section for section 12.

"12. The Chief Commissioner of Railway Safety shall, for each financial year, prepare in such form, and within such time, as may be prescribed, an annual report giving a full account of the activities of the Commissioners during the financial year immediately preceding the financial year in which such report is prepared and forward copies thereof to the Central Government.". Annual report.

11. In section 13 of the Delhi Metro Railway Act, for the word "Commissioner", the words "Chief Commissioner of Railway Safety" shall be substituted. Amendment of section 13.

12. In section 23 of the Delhi Metro Railway Act, in sub-section (*1*), for the words "Hindi and English", the words "Hindi, English and official language of the State in which such station is located" shall be substituted. Amendment of section 23.

13. In section 26 of the Delhi Metro Railway Act, in sub-section (*1*), the words "a small" shall be omitted. Amendment of section 26.

14. In section 34 of the Delhi Metro Railway Act, for sub-section (*4*), the following sub-section shall be substituted, namely:— Amendment of section 34.

"(4) The Central Government and the State Government shall nominate one member each to the Fare Fixation Committee:

Provided that a person who is or has been an Additional Secretary to the Government of India or holds or has held an equivalent post in the Central Government or the State Government shall be qualified to be nominated as a member.".

Amendment of section 38.

15. In section 38 of the Delhi Metro Railway Act, in sub-section (2), for the words "Government of the National Capital Territory of Delhi", the words "State Government" shall be substituted.

Amendment of section 85.

16. In section 85 of the Delhi Metro Railway Act,—

(i) in sub-section (1), for the words "Government of the National Capital Territory of Delhi", the words "State Government" shall be substituted;

(ii) in sub-section (2), for the words "Government of the National Capital Territory of Delhi in the Delhi Gazette", the words "State Government" shall be substituted.

T.K. VISWANATHAN,
Secretary to the Govt. of India.

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Chapter – 18

CONCLUSIONS AND RECOMMENDATIONS

18.1 Mumbai is the Commercial Capital of India and it's fast growth especially in the suburbs is causing heavy stress on all infrastructure, especially the Transport. Being a linear city, the existing suburban rail services are very effective and the modal split in favour of public transport is about 70% as per Comprehensive Mobility Pan (CMP) 2015 prepared by M/s. Lee Associates for MCGM, which is very high. Since the existing transport infrastructure has been heavily loaded, it has been observed that the population of private vehicles 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. It is proposed to take a new Metro Rail Corridor from Swami Samarth Nagar to Vikhroli (EEH) immediately for implementation.

Metro Projects are highly capital intensive on account of the high costs involved. Due to the need to maintain a fare structure within the affordable reach of ordinary citizens, metro projects are ordinarily not financially viable. However considering the economic gain to the society and the fact that city with a population of more than ten million cannot survive without an efficient Metro System, implementation of Metro System and this particular corridor is strongly recommended.

The proposal of this corridor is technically feasible but involves acquisition of land as well as rehabilitation of some hutments and shops. This is a socio-economic problem and has to be tackled for execution of the project.

Estimated Cost of the project at October 2016 price level is 5567.00 Crore with all the taxes and duties and completion cost at 6.0% p.a. escalation is estimated to be Rs.6691Crores including all the taxes and duties.

18.2 The project has many positive environmental impacts like reduction in traffic congestion, saving in travel time, reduction in air and noise pollution, lesser fuel consumption, lesser road accidents etc., with a few negative impacts (especially during implementation phase of the project) for which Environmental Management Plan has been suggested.

18.3 After examining the various options for execution the project, it has been recommended that the project should be got executed through a SPV on DMRC funding pattern.

18.4 The fare structure has been prepared based on prevailing fare structure in different PT/IPT modes as indicated in the Finance Chapter. Subsequently, for the purpose of assessing returns from the project, the fares have been revised every second year with an escalation of 12% every two years.

18.5 As in the case of Delhi Metro, the State Government should exempt/reimburse the Maharashtra Value Added Tax (VAT) and Octroi etc. to MMRDA. It should also exempt the following:

- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

18.6 As per the present policy 50% of the Central Taxes will be paid by GOI as subordinate Debt and balance 50% will be paid by the concerned State Government. Maharashtra State Government may pursue the Central Government to extend the same benefit to MMRDA.

18.7 Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR)

While the Financial Internal Rate of Return (FIRR) for the project has been assessed as **8.46%.** The Economic Internal Rate of Return (EIRR) works out to **21.92%.**

18.8 Meanwhile the State Government should freeze all future developments along the proposed route of Swami Samarth Nagar to Vikhroli (EEH) Metro to avoid in-fructuous expenditure.

18.9 It is recommended the State Govt. should set up a non-lapsable, non-fungible Transit Fund to fund the project out of revenues from:

- Increased FAR along the Metro corridors.
- A Metro cess on the sale of petrol and diesel in the State.
- Levy of additional charges on the registration of vehicles.
- Levy of additional cess on the Property Tax.
- A onetime green cess on existing vehicles.
- Property development on Government land.

Appendix

MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY
मुंबई महानगर प्रदेश विकास प्राधिकरण

No. T&C/ METRO LINE-6/2016/423

9th Dec, 2016
13

To,

S.D. Sharma
Director Business Development, DMRC
25, Ashoka Road
New Delhi- 110001

Sub: Metro Line 6 (Swami Samarth Nagar- Jogeshwari – Vikhorli) DPR – Remarks to be incorporated in Final DPR

Dear Sir,

With reference to above, the Draft Detailed Project Report (DPR) for Metro Line -6 (Swami Samarth Nagar- Jogeshwari – Vikhorli) corridors was received on 16-11-2016. Please find enclosed herewith detailed remarks for Metro Line 6 DPR for your reference.

In view of above, you are requested to incorporate the above said remarks and submitted the Final DPR within 3 days.

Thanking you,

Yours faithfully,

13.12.16.

(M.S Devaru)
Superintending Engineer
MMRDA

As encl

Bandra - Kurla Complex, Bandra (East), Mumbai - 400 051.
EPABX : 2659 0001 - 04 / 2659 4000 • FAX : 2659 1264 • WEB SITE : https://mmrda.maharashtra.gov.in

MMRDA's Comments & DMRC's Responses on Swami Samarth Nagar – JVLR – SEEPZ – Kanjur Marg - Vikhroli (EEH) Metro Corridor

Sr. No	Reference	Remarks	DMRC's Response
1.		Correct spelling of Swamy to Swami	Names and spellings of stations are as per Email received from MMRDA on 20/10/2016. However spelling of Swamy has been changed to Swami in Final DPR.
2.	Table 2.8 Page 59	Ridership, trip distribution table and OD Matrix for 13 stations as provided by MMRDA have not been reflected in the DPR for 2021 and 2031. Update all references of ridership accordingly.	OD matrix supplied by MMRDA was for 14 stations including Milind Nagar Station. Boarding alighting on Milind Nagar was distributed to SEEPZ Village and Saki Vihar Road Staton by 50% each as this station was not considered at DPR stage. Rider ship has been verified again and was found as per the OD matrix supplied.
3.	4.6.5 Page 130	Executive Summary mentions RSS one at JVLR and another at Depot but para 4.6.5 mentions one at JVLR and another at Kanjur Marg Station, Pl clarify and suitable update accordingly.	The Train Depot for this Line is located at Kanjur Marg and as such the mention of Depot in Executive Summary and mention of Kanjur Marg at Para 4.6.5 is synonymous.
4.	5.1 Page 161	The length of the proposed corridor from Swamy Samarth Nagar, Station in the West to Vikhroli (EEH) Station in the East is approximately 14.4 km between the two terminal stations.	Centre line to centre line distance between the terminal stations is 13.204 km, whereas dead end to dead end distance is 14.477 km.
5.	5.3 Page 179 And 180	Jogeshwari (W), Shayam Nager and Kanjur Marg Stations are not typical stations. Please provide typical sections of the same DPR. Also provide details regarding why Kanjur Marg station is 6 levels and Swami Samarth Nagar and Adarsh Nagar are 3 levels.	Sections for Jogeshwari (W) are provided vide Station Planning drawing number 99/MUM/JVLR/JOG/A/0201 Sections for Shyam Nagar are provided vide Station Planning drawing number 99/MUM/JVLR/SHN/A/0201 Sections for Kanjur Marg are provided vide station planning drawing number 99/MUM/JVLR/KJM/A/0201 Kanjur Marg platform is at a height of 27.052m from ground level, and is an off-road portal station. Due to this height, the station is a 6-level station. Swami Samartha Nagar platform is at a height of 14.385m and is a typical cantilevered station. Hence it is a 3-level station. Adarsha Nagar station is designed as a 3-level station to minimise land acquisition as the height for the same is available above the proposed flyover.
6.	9.1.1 Page 229	The Rapid Environmental Assessment (REA) checklist has screened the project proposed for ADB funding considering the aspects of project settings, potential environmental impacts including climate change and disaster risk.	Same categorization is not applicable to all funding agencies. The para has been modified as follow; *"The proposed project do not passes through any Wildlife Sanctuary, National Park, or any other environmentally sensitive or protected areas.*

Sr. No	Reference	Remarks	DMRC's Response
		Therefore, the project has been classified as category 'A' and requires Environmental Impact Assessment (EIA) Report as per ADB's SPS Replace ADB with multilateral funding agency. Check if the same categorization is done by all funding agencies.	*The proposed project is between Swami Samarth Nagar - Vikhroli (EEH) is proposed on the centre of the road. As per the checklist of Multilateral Funding Agencies, the Environmental Assessment may be required to be done for the project considering the aspects of project siting, potential environmental impacts including climate change and disaster risk. Although, the proposed project will bring in many benefits to the area, there is potential for environmental impacts on the above ground structures due to vibration construction and operation of the metro. Depending upon the categorization of project, Environmental Impact Assessment (EIA) Report may be required as per the policy of Multilateral Funding Agencies."* May require Environmental Impact Assessment (EIA) report as per the policy of Multilateral Funding Agencies.
7.	9.1.2 Page 231	MMRDA propose to apply for loan to seek financial support from ADB Replace ADB with Multilateral Funding Agencies.	ADB replaced with Multilateral Funding Agencies.
8.	9.13 C Page 257	In compliance to the ADB Safeguard and Disclosure policies, this report will be disclosed in the websites of MMRDA and ADB at least 120 days report will be prepared by the MMRDA will be disclosed in the websites of MMRDA and ADB. Replace ADB with multilateral funding agency. Is the same process followed by all funding agencies?	Same process is not followed by all Funding Agencies. The para has been modified as follows; *"In compliance to the policy of Multilateral Funding Agencies, this report may be required to be disclosed in the websites of MMRDA and Multilateral Funding Agencies at least 120 days prior to consideration by board of Multilateral Funding Agency. Further, semi-annual monitoring reports may be required to be prepared by the MMRDA and may be required to be disclose in the website of MMRDA & Multilateral Funding Agencies."*
9.	9.19 Page 284	Hence the current project is classified as Category 'A' as per the ADB Guidelines. Replace ADB with multilateral funding agency. Check if the same categorization is done by all funding agencies.	Same categorization is not done by all Funding Agencies. The line has been replaced as follows; *"The proposed Metro line is proved to have significant positive effects to the development of Mumbai City. Benefits to the economy, traffic congestion reduction, quick and safety transport, employment opportunities, fuel consumption reduction, and air quality improvement are the obvious positive effects from this Metro line. Besides, the potential adverse environmental impacts on air quality (during construction phase), water environment, noise, solid waste, ecology, population resettlement are also taken into consideration. The current project need to be the categorized as per the policy of Multilateral Funding Agencies. Based on these detailed potential adverse environmental impacts, appropriate mitigation measures have been developed for consideration. The EIA concluded that project impacts from both construction and operation will be minimal, and can be mitigated*

Sr. No	Reference	Remarks	DMRC's Response
			through the use of prevailing current practices and appropriate technologies. With the implementation of the EMP and the monitoring plan, the Project is not expected to have significant environmental impacts."
10.	15.5.1 Page 331	No mention of MMRDA financing model as used for line 7 and 2A.	In the DPR, same finance model has been suggested as provided in the DPR of line no. 7 & 2A. DMRC is not aware of the finance model adopted for implementation of line no. 7 & 2A by MMRDA.
11.	Table 15.2 Page 325	Provide item wise escalation details including taxes, civil, system, design charges etc. as mentioned in Line 4 DPR.	Item wise escalation details including taxes, civil, system, design charges etc. as mentioned in Line 4 DPR has been provided.
12.	15.4 Page 329	EIRR to be calculated considering revised ridership numbers.	No change is required as there is no change in the traffic forecast.
13.	15.6 Page 335, 336 and 337	FIRR to be calculated considering revised ridership numbers.	As there is no change in traffic figures, hence fresh calculation of FIRR is not required.
14.	17.5 Page 350	Remove MMRC and keep only MMRDA.	MMRC removed.
15.	17.7 Page 351	Implementation period is 60 month not 48 months as completion period is 5 years.	Implementation period has been envisaged 48 months in the DPR from the date of approval of the project by the state Government.
16.	18.1 Page 359	The existing suburban rail services are very effective and the model split in favour of public transport is about 88%. As per CMP 2015, PT share is 70%.	Corrected
17.	Page 247	Under impacts due to project construction add vibration, air pollution & water pollution.	Vibration, air pollution & water pollution impact due to project implementation during construction has been incorporated.
18.	Page 259	Under labour camp instead of sewerage drains, mobile STP / septic tank should be provided.	Corrected
19.	Page 266	Under water supply, sanitation and solid waste management during construction instead of sewerage disposal system, mobile STP / septic tanks should be adopted for sewerage disposal.	Corrected
20.	Page 267	Under tree protection, instead of 10 trees, 2 trees should be planted for each tree felled. Thus 171 trees would be planted.	Corrected
21.	Page 268	Under management plan for depot, add solid waste management.	incorporated
22.	Alignment	Propose link way structures (Staircases, escalators and lifts) within the RoW wherever feasible to avoid land acquisition and R&R. For example, Staircase proposed at Swami Samarth Nagar North-West corner involves R&R hence same to be shifted to the suitable locations to avoid R&R.	For smooth pedestrian movement on the pavements, the following sizes have been followed for all stations: o 1500 mm from street edge to entry structure o 2500 mm for the entry structure o 2000 mm as construction margin between entry structure and property

Sr. No	Reference	Remarks	DMRC's Response
			These sizes allow for smooth pedestrian movement as well as construction. - In the case of Swami Samartha Nagar NW entry structure, the carriageway has been proposed as a consistent 14.0m throughout the station length. This has been retained from the existing road width. However, the existing road narrows down at the spot where the NW staircase is located. To maintain a consistent width, the road widening causes extra land acquisition.
23.	Alignment	At Jogeshwari (W) station: Tower type structure proposed for concourse operations and other commercial on abutting pvt. Property (North) which is currently under development. DMRC is requested to avoid the LA of Pvt. Properties and explore the alternatives or restrict the same to available Carriageway (North) with staircase connectivity.	The location of Jogeshwari (W) does not allow for a cantilever / portal station due to the following: - The level difference between the proposed flyover and the rail level is not adequate to accommodate a concourse. If the rail level were raised to allow for the same, the height of the station would make the link way structures (staircases / escalators) too large to be accommodated on the available carriageway. - Carriageway is only available towards the eastern end of the station. Staircases proposed only at this end would be in violation of NFPA130. - The school building to the south of the alignment is only 10.77m away from the alignment which is not adequate to accommodate a concourse. The only possibility is to have a tower type of station at this location.
24.	Alignment	At JVLR stations: as per your earlier communication, the JVLR station proposed by DMRC is conflicting with ongoing 14 storey building. DMRC is requested to review the alignment in detail at said location and suitably rearrange alignment to avoid LA & R&R which will effects the projects feasibility. Also review the entire alignment in detail to avoid such hurdles and minimize the same.	Alignment feasibility on southern side of the JVLR was checked. It is observed that this side also there is hardly any space for passing of the alignment, if alignment is taken on this side of road one mosque and at least two multi storeyed buildings will be affected.
26.		The DPR suggest setting up of receiving stations which will step down the voltage from 220 kv to 33 kv. The 33 kv will be distributed and will be stepped down to 25 kv and 440 volts to utilize the electrical energy. The double conversation of energy will involve expenditure and also MMRDA will have to pay for the losses of energy in double conversion. The MMRDA's need is not to convert the electrical energy from high voltage to utilization voltage but to use	The power requirement for Metro Line has to be very very reliable and the total distribution and utilisation have to be well monitored and controlled by the Metro Authority with minimum resources. The suggestion of taking 33 KV at various locations is not considered desirable for the following reasons: - (i)There will be separate connection at each station from the distribution authority.

Sr. No	Reference	Remarks	DMRC's Response
		it at the desired voltage. It is therefore desirable to check from the power supply authorities whether the power can be supplied to Metro line-6 at kv. This will eliminate the requirement of manpower for the maintenance and operation of the 25 kv traction sub-stations. Further the quality of power in Mumbai is quite good. There are not many interruptions experienced even by the domestic users. Therefore it may be possible to get a reliable feeder at 440 volts form the power supply companies. This will eliminate the cost of operation and maintenance of the auxiliary sub-station. At the most MMRDA can help the power supply companies with a suitable piece of land to set up their sub-station for metro use which in any case will be required by DMRC. Pl. review.	(ii)There is limit up to which power can be obtained at 33 KV, generally 15 MVA. (iii)The tariff meter and control of maximum demand will not be possible if 33 KV supply is taken at several locations. (iv)There will be considerable drain of resources in taking shut downs and extending the feed from one section to the other in case of break down or shut down. Further, 25 KV traction supply is a single-phase supply and traction transformer is a specialised equipment generally not used by the power supply authorities, which is generally taken at the same location of the RSS combining the traction and auxiliary supply. Moreover, as misunderstood, circuit of 25 KV & 33 KV will be separate and not as mentioned above i.e. 33 KV will be down-stepped to 25KV. Accordingly, in consideration of the tariff, the flexibility in operation and maintenance and reliability, it is felt desirable to obtain the power for Metro operation at receiving sub-station at a voltage exceeding 66 KV and above.
27.		The DPR indicates that the schedule maintenance will fall due in 15 days. The other schedules are multiples of 15. The time for IOH, POH is not given but is expected to be between 15 days to 1 month. Due to extensive use of the rakes, all the rakes will fall due for the major schedules simultaneously. It is not clear from the DPR how the train operation will be managed when almost all trains will fall due for the major schedules.' Pl. review.	As per DMRC experience, the time taken for Intermediate Overhaul (IOH) & Periodic Overhaul (POH) is approximately 10 & 20 days respectively. Delivery of trains by manufacture is staggered and these also get commissioned in a phased manner. Hence, there is always some interval between commissioning of one train to another and therefore their maintenance schedules are also separated. Further, the schedules are planned on the basis of kms earned as well as time whichever is earlier with a tolerance band of ± 5%. Hence, planning for schedule does not create any problem.
28.		The description of the alignment in para.4.2.7.1 does not indicate any crossing facilities between the two end stations. In case of failure of rake takes place in mid-section, it will have to be pulled to depot hampering the train operation during this period. The provision of cross over in the mid-section will reduce this time. From the description it looks as if the Western Railway is being crossed in a curve. The bridge design is not yet finalized but DMRC may have to ensure that minimum piers between the tracks are planned so that obtaining the clearance from the WR is	Train reversal facility has been provided on both terminal station i.e. Swami Samarth Nagar and Vikhroli (EEH). Emergency crossovers are provided at JVLR and SEEPZ Village station. Alignment plan may be referred in this regard. Construction across the railway line will be done by balanced cantilever method without constructing any pier between the railway lines.

Sr. No	Reference	Remarks	DMRC's Response
		less difficult. Pl. review.	
29.		The alignment starts with the chainage of -822.541. It is presumed that this extra length has been provided for stable a failed rake but the length provided appears to be on a higher side. The extra length provided may be reviewed. Pl. review.	There are two curves of radii 260 m and 125 m just before the Swami Samarth Nagar station. Similarly after Swami Samarth Nagar station, there is a curve of 125 m radius. There is no suitable space to provide crossovers for train reversal. Hence alignment has been extended on rear end to facilitate the train reversal and stabling of trains on the end of the train operations.
30.		Heavy equipments have been planned for the maintenance. It is presumed that these equipments are being planned separately for every metro line. The equipments like transformers, convertors, and wheel etc. which can be transported on truck can be maintained at a centralized location for all the metro lines which will reduce the cost of depot equipment for all the metro lines. The need of costly equipment like under floor wheel lathe may be reviewed and surface wheel lathe can be provided at a centralized location for all the metro lines which will reduce the cost substantially. Pl. review	It is learned that in Mumbai, different agencies are executing metro project for different lines. Similarly, planning for operation of metro trains on different lines is not clear. Hence, any lack of co-ordination among them may affect the maintenance & operations of trains. Non-availability of major unit exchange spare like transformers, convertors etc. in each depot may therefore affect the maintenance work and so availability of trains. Unit Exchange spares are based on type of stock. Stock on different line may be different (3/ (2A, 2B & 7)). Generally in DMRC, independent depots are planned for each line and are self-sufficient in major spares. As far as, provisioning of Machinery & plant for individual depots is concerned, 'Under Floor Wheel Lathe' for a depot in each line is unavoidable. However, the provision of 'Vertical Turret Lathe (VTL)' and 'Wheel pressing machine' needed for wheel disc preparation & wheel set assembling can be considered at one centralized depot catering to self & one more depot subject to observations of para above. VTL and wheel pressing equipment procurement shall be deferred to approx. 3 year + ROD.
31.		The OCC can be planned at a centralized location for all the metro lines which will cut down the cost of SCADA. If combining all metro lines is felt difficult, 3 or 4 metro lines can be combined which can reduce the cost of the SCADA equipment considerably. Pl. review.	OCC, if planned at a centralized location for 3-4 Metro Lines, can reduce the cost of power SCADA equipment provided at the OCC because of sharing basis. The cost of power SCADA equipment at individual Lines will, however, remain the same.

ABBREVIATIONS

AAQM	:	Ambient Air Quality Monitoring
AC	:	Alternating Current
ACC/POL	:	Accident/Pollution
ACD	:	Additional Custom Duty
ADB	:	Asian Development Bank
AFC	:	Automatic Fare Collection
AMC	:	Additional Metropolitan Commissioner
APL	:	Above Poverty Line
ASHARE	:	American Society of Heating And Refrigeration Engineering
ATP	:	Automatic Train Control
BGL	:	Below Ground Level
BIS	:	Bureau of Indian Standards
BMS	:	Building Management System
BOT	:	Built Operate Transfer
BPL	:	Below Poverty Line
BS	:	British Standard
CATC	:	Continuous Automatic Train Control
CCTV	:	Closed-Circuit Television
CD	:	Custom Duty
CBTCS	:	Communication Based Train Control System
CENELEC	:	Committee European De Normalization Electro Technique
CER	:	Certified Emission Reductions
CIBSE	:	Chartered Institute of Building Services Engineering
CIDCO	:	City & Industrial Development Corporation Of Maharashtra Ltd.
CMH	:	Cubic Meter Hour
CPCB	:	Central Pollution Control Board
CRZ	:	Coastal Regulation Zone
CSTM	:	Chhatrapati Shivaji Terminus
CT	:	Central Taxes
CTS	:	Comprehensive Transportation Study
CVD	:	Counter Vail Duty
CWR	:	Continuous Welded Rails
DB	:	Dry Bulb
DC	:	Direct Current
DCBM	:	Dahisar - Charkop - Bandra - Mankhurd
DCOS	:	Deputy Controller Of Store
DMRC	:	Delhi Metro Rail Corporation
DMRTS	:	Delhi Mass Rapid Transit System
DPR	:	Detailed Project Report
DTC	:	Driving Trailer Car
ED	:	Excise Duty
EIRR	:	Economic Internal Rate of Return
EMC	:	Electromagnetic Compatibility
EMI	:	Electromagnetic Interference
EPABX	:	Electronic Private Automatic Branch Exchange
ESIA	:	Environmental And Social Impact Assessment
FIRR	:	Financial Internal Rate of Return
G.C.	:	General Consultants

GC	:	Generalized Cost
GOI	:	Government of India
GoM	:	Government of Maharashtra
GST	:	Goods & Services Tax
GTKM	:	Gross Ton Kilometer
IDC	:	Interest During Construction
IEC	:	International Electro Technical Commission
IEEE	:	Institute Of Electrical And Electronics Engineers
IET	:	International Emission Trading
IMD	:	India Meteorological Department
IPT	:	Intermediate Public Transport
IRS	:	Indian Railway Standard
ITU	:	International Telecommunication Union
JICA	:	Japan Bank For International Cooperation
KLD	:	Kilo Litres Per Day
KMPH	:	Kilo Meter Per Hour
KVA	:	Kilo Volt Ampere
LAA	:	Land Acquisition Act
LACP	:	Link Aggregation Control Protocol
LCD	:	Liquid Crystal Display
LED	:	Light Emitting Diode
LOS	:	Level Of Service
LWR	:	Long Welded Rails
M.C.	:	Metropolitan Commissioner
MC	:	Motor Car
MCB	:	Miniature Circuit Breaker
MCGM	:	Municipal Corporation Of Greater Mumbai
MLD	:	Million Litres Per Day
MMR	:	Mumbai Metropolitan Region
MMRC	:	Mumbai Metro Rail Corporation Ltd.
MMRDA	:	Mumbai Metropolitan Region Development Authority
MMTPL	:	Mumbai Metro Transport Pvt Ltd
MOEF	:	Ministry Of Environment And Forest
MOUD	:	Ministry Of Urban Development
MRT	:	Mass Rapid Transit
MRTS	:	Mass Rapid Transit System
MRVC	:	Mumbai Rail Vikas Corporation
MUTP	:	Mumbai Urban Transport Project
MVA	:	Mega Volt Ampere
NAAQS	:	National Ambient Air Quality
NFPA	:	National Fire Protection Association
NGO	:	Non-Government Organization
NMIA	:	Navi Mumbai International Airport
NMS	:	Network Management System
O&M	:	Operation And Maintenance
OCC	:	Operation Control Center
ODA	:	Official Development Assistance
OHE	:	Over Head Equipment
ONAF	:	Oil Natural Air Forced
PA	:	Pass through Assistance
PAFS	:	Project Affected Families

PAPS	:	Project Affected Persons
PHPDT	:	Peak-Hour-Peak-Direction-Traffic
Pnvl	:	Panvel
PV	:	Personalized Vehicles
QOS	:	Quality of Service
R&R	:	Rehabilitation And Resettlement
RAP	:	Resettlement Action Plan
RMC	:	Regional Meteorological Centre
RMPU	:	Roof Mounted Packaged Units
ROR	:	Rest of The Region
RSS	:	Receiving Sub-Station
SBES	:	Small Business Enterprises
SCADA	:	Supervisory Control And Data Acquisition
SCR	:	Station Control Room
SD	:	Subordinate Debt
SDH	:	Synchronous Digital Hierarchy
SEEPZ	:	Santacruz Electronics Export Processing Zone
SEIAA	:	State Environmental Impact Assessment Authority
SNMP	:	Simple Network Management Protocol
SPM	:	Suspended Particulate Matter
SPV	:	Special Purpose Vehicle
TBM	:	Tunnel Boring Machine
TC	:	Trailer Car
TETRA	:	Terrestrial Trunked Radio
TR	:	Ton of Refrigeration
TSS	:	Traction Sub-Station
UA	:	Urban Agglomeration
UIC	:	Union Internationale Des Chemins De Fer
UPS	:	Uninterrupted Power Supply
VAT	:	Value Added Tax
VLAN	:	Virtual Local Area Network
VOC	:	Vehicle operating Cost
WB	:	World Bank
WB	:	Wet Bulb
WFSL	:	Western Freeway Sea Link