DETAILED PROJECT REPORT

MUMBAI METRO LINE-11
FROM
WADALA TO CSMT

MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY (MMRDA)

Prepared By

DELHI METRO RAIL CORPORATION LTD.

September, 2018

DETAILED PROJECT REPORT

MUMBAI METRO LINE-11
FROM
WADALA TO CSMT

MUMBAI METROPOLITAN REGION
DEVELOPMENT AUTHORITY (MMRDA)

Prepared By

DELHI METRO RAIL CORPORATION LTD.

September, 2018

Contents

SALIENT FEATURES

1 Gauge
2 Route Length
3 Number of Stations
4 Traffic Projection
5 Train Operation
6 Speed
7 Traction Power Supply
8 Rolling Stock
9 Maintenance Facilities
10 Signaling, Telecommunication and Train Control
11 Fare Collection
12 Structure
13 Estimated Cost
14. Indices

EXECUTIVE SUMMARY

CHAPTER 1 - INTRODUCTION

CHAPTER 2- TRAFFIC DEMAND FORECAST

CHAPTER 3- SYSTEM DESIGN

CHAPTER 4- CIVIL ENGINEERING

CHAPTER 5 – STATION PLANNING

CHAPTER 6–TRAIN OPERATION PLAN

CHAPTER 7 – MAINTENANCE DEPOT

CHAPTER 8 –POWER SUPPLY ARRANGEMENTS

CHAPTER 9 – TUNNEL VENTILATION AND AIR-CONDITIONING SYSTEM

9.18 Space Requirement for Tunnel Ventilation System

9.19 Control and Monitoring Facilities

9.20 Codes and Standards

CHAPTER 10 – ENVIRONMENT & SOCIAL IMPACT ASSESSMENT

CHAPTER 11 – MULTI MODAL TRAFFIC INTEGRATION AT METRO STATIONS

CHAPTER 12- FRIENDLY FEATURES FOR DIFFERENTLY ABLED

CHAPTER 13 - SECURITY MEASURES FOR A METRO RAIL SYSTEM

CHAPTER 14 – DISASTER MANAGEMENT MEASURES

CHAPTER 15 - COST ESTIMATES

CHAPTER 16- FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

CHAPTER 17 - ECONOMIC APPRAISAL

CHAPTER 18- IMPLEMENTATION

CHAPTER 19 - CONCLUSIONS AND RECOMMENDATIONS

APPENDIX

SALIENT FEATURES

1. GAUGE (NOMINAL): 1435 mm

2. ROUTE LENGTH:

Name of Extension	Elevated Length (km)	Underground Length (km)	Total Length (km)
Wadala (Bhakti Park) to CSMT Metro	4.009	8.765	12.774

3. NUMBER OF STATIONS:

Name of Extension	No. of Stations		
	Elevated	Underground	Total
Wadala (Bhakti Park) to CSMT Metro	2	8	10

4. TRAFFIC PROJECTION:

Entire Corridor: CSMT Metro - Wadala – Kasarvadavali – Gaimukh

YEAR	DAILY RIDERSHIP	AVERAGE LEAD (KM)	MAXIMUM PHPDT
2021	11,68,242	11.46	32,460
2031	16,95,705	10.14	36,635

Extension from Wadala (Bhakti Park) to CSMT Metro

YEAR	DAILY RIDERSHIP
2021	1,65,465
2031	3,51,726

5. TRAIN OPERATION:

Sections →	CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh		Bhakti Park to Kapurbawdi	
Particulars ↓	**2021**	**2031**	**2021**	**2031**
Cars/trains	6	8	6	8
Head way (Minutes)	6.50	6.50	3.25	3.25
Max. PHPDT Demand	17460	25058	32460	36635
PHPDT Capacity Available	16209 (20677*)	21711 (27692*)	32418 (41354*)	43422 (55385*)

* @ 8 persons per square meter of standee area

Sections	**Year**	**Head-way (min)**	**Total No. of Rakes**	**Rake Consist**	**Total No. of Cars****	**Provision for No. of cars in DPR of Sep'17**	**Additional No. of cars for Line- 11**
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2021	6.50	46	6-car	276	232	44
Bhakti Park to Kapurbawdi		3.25					
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2031	6.50	46	8-car	368	264	104
Bhakti Park to Kapurbawdi		3.25					

** Total No. of cars shown above are the total cars calculated as per PHPDT data.

#Additional cars requirement for Line-11 has been calculated after subtracting provision for no. of cars in previous Line-4 (Bhakti Park - Gaimukh) DPR (Sep'17) from the total car requirements.

6.

i. Design speed	90 kmph
ii. Maximum operating speed	80 kmph
iii. Schedule 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 near Sewri Metro Station

Power Demand Estimation (MVA)

Load	**Year**	
	2021	**2031**
Traction	4.96	6.62
Auxiliary	22.67	25.82
Total	**27.63**	**32.44**

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 6 coach unit With 6 standees / sqm.	1756
e.	Capacity of 8 coach unit With 6 standees / sqm.	2352
f.	Class of accommodation	One (Air conditioned)

9. MAINTENANCE FACILITIES:

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

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 TVM and Smart card etc.

12. STRUCTURE:

i. Elevated:
Viaduct with Precast twin ‘U’ girders on Single pier with bored cast-in-situ pile foundations upto radius 300m and flatter, for sharper curves and location of Points & Crossings I-Girder.
Station structure with viaduct columns supporting the concourse girders by a cantilever arm.

ii. Underground section with Tunnel Boring and station with cut and cover.

13. COST:

Name of the section	Estimated Cost with all Taxes & Duties including Land Cost (At March 2018 Price Level)	Completion Cost with all Taxes & Duties including Land & IDC (by March 2026 at 5% p.a. escalation)
Wadala (Bhakti Park) to CSMT Metro	Rs. 7085 Crore	Rs. 8739 Crore

14. INDICES:

i)	FIRR	**1.68% (With additional PD income from 10 Ha land)**
ii)	EIRR	**14.93% (On Completion Cost Basis)**

Metro Line 11: Wadala to CSMT

EXECUTIVE SUMMARY

0.1 INTRODUCTION

0.1.1 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 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 – 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. Subsequently, the corridors 2 & 3 were rearranged and DMRC prepared another DPR for the corridor between Charkop – Bandra – Mankhurd

In spite of above, implementation of Mumbai metro remained very slow. So far only one line between Varsova – Andheri – Ghatkopar could be implemented. Other corridors presently under implementation are.

Colaba to Aarey Colony via International Airport.	30.00km
Dahisar (E) to DN Nagar	18.60km
Dahisar (E) to Andheri(E)	16.48km

• DN Nagar to Mandale	23.64km
• Wadala – Ghatkopar – Mulund – Thane – Kasarvadavali	32.32km
• Swami Samarth Nagar to Vikhroli(EEH)	14.48km
Total	**135.52km**

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 – Kanjur Marg	10.00
	(c) Andheri (E) – BKC (Via WEH)	9.00
	Total	**118.00**

Out of 118 km Master Plan network, the work of implementation of about 106 km has already been started by MMRDA.

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 4,355 sq. 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 peak hour station loads and peak hour section loads for the proposed Metro Corridor is given in **Table 0.4** and **0.5**.

Table 0.4: Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2021

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2004	0	2004	CSMT Metro	0	0	7522
42	1	2045	Carnac Bunder	7522	8	104
293	46	2292	Clock Tower	7617	143	368
849	55	3086	Wadi Bunder	7843	320	703
695	72	3710	Darukhana	8225	238	671
171	8	3873	Coal Bunder	8659	56	147
894	72	4695	Hay Bunder	8749	158	404
258	112	4841	Sewri Metro	8995	101	604
3970	761	8050	BPT Hospital	9498	1713	3753

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
1456	233	9273	Ganesh Nagar	11538	776	777
1845	1593	9525	Wadala RTO (Bhatkti Park Metro)	11539	363	10631
2872	1914	10483	Wadala TT	21807	2426	5325
670	429	10724	Anik Nagar (Anik Nagar Bus Dept)	24706	813	1011
1638	300	12062	Suman Nagar	24904	867	1801
3165	791	14435	Siddharth Colony	25838	1208	5419
2561	180	16816	Pestom Sagar (Amar Mahal Junction)	30049	418	2705
479	173	17122	Garodia Nagar	32336	372	497
74	96	17099	Pant Nagar	32460	233	93
519	531	17087	Laxmi Nagar	32321	446	452
2894	5839	14141	Amrut Nagar (Shreyas Cinema)	32326	14471	3663
957	329	14770	Ambewadi (Godrej Company)	21519	879	1164
496	1394	13872	Vikhroli Metro	21803	1776	823
144	245	13771	Surya nagar	20851	629	356
1504	2207	13068	Gandhi nagar	20578	2370	1661
0	41	13027	Naval Housing	19868	170	0
2439	48	15417	Bhandup mahapalika	19699	14	2984
380	449	15348	Bhandup Metro	22669	1027	219
2423	948	16823	Nahur Metro (Shagrila)	21860	2026	4794
548	675	16696	Sonapur	24629	907	579
132	53	16775	Mulund Fire Station	24301	243	41
515	851	16440	Mulund Naka	24099	694	967
719	1163	15995	Teen Hath Naka	24372	1658	641
1116	3208	13903	RTO Thane	23355	4175	1310
1072	1037	13938	Thane Mahapalika Marg (Mahapalika Marg)	20489	1370	920
31	721	13248	Siddheshwar Lake (Cadbury Junction)	20039	515	116
899	1155	12992	Majiwada	19640	2056	1140
574	2081	11485	Kapurbawdi	18724	1940	677
545	1099	10931	Manpada	17460	1862	610
1783	620	12094	Patli Pada (Tikuji Ni wadi)	16209	2404	2317
599	2429	10264	Dongari pada	16122	2793	1084
648	1499	9413	Kavesar Gaon (Vijay Garden)	14413	2757	873
424	1808	8029	kasarvadavali	12530	2690	540
426	1557	6898	Gowniwada	10380	1906	641
0	6898	0	Gaimukh	9115	9115	0
45721	**45722**	**17122**	**PHPDT/Ridership**	**32460**	**71101**	**71102**
			Daily Ridership	**1168242**		

Table 0.5: Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2031

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2366	0	2366	CSMT Metro	0	0	7211
473	165	2674	Carnac Bunder	7211	2347	145
205	186	2693	Clock Tower	5009	120	392
655	294	3054	Wadi Bunder	5281	304	701
820	266	3608	Darukhana	5678	379	1226
95	4	3699	Coal Bunder	6525	7	151
546	19	4225	Hay Bunder	6669	42	221
257	403	4080	Sewri Metro	6848	427	1141
4683	755	8008	BPT Hospital	7563	1879	4172
1804	184	9627	Ganesh Nagar	9855	649	894
2336	1317	10646	Wadala RTO (Bhatkti Park Metro)	10100	320	12234
2990	1002	12633	Wadala TT	22013	1330	6048
617	340	12910	Anik Nagar (Anik Nagar Bus Dept)	26732	438	1064
1724	582	14052	Suman Nagar	27358	1433	2472
6210	2166	18096	Siddharth Colony	28397	5496	6137
1191	335	18952	Pestom Sagar (Amar Mahal Junction)	29038	496	1170
254	2909	16297	Garodia Nagar	29712	7438	198
316	351	16261	Pant Nagar	22472	325	412
720	957	16023	Laxmi Nagar	22559	632	931
8156	1828	22351	Amrut Nagar (Shreyas Cinema)	22859	4667	14815
1078	2404	21024	Ambewadi (Godrej Company)	33008	1300	2133
915	2030	19910	Vikhroli Metro	33840	2513	996
594	1322	19181	Surya Nagar	32324	1182	609
4043	1829	21395	Gandhi Nagar	31751	1689	5355
892	215	22072	Naval Housing	35417	979	1006
235	472	21835	Bhandup Mahapalika	35443	951	335
1654	937	22552	Bhandup Metro	34828	1211	3017
1224	2436	21341	Nahur Metro (Shagrila)	36635	8191	547
260	303	21297	Sonapur	28991	223	266
574	1038	20833	Mulund Fire Station	29034	1950	423
268	353	20749	Mulund Naka	27507	437	527
1245	2145	19849	Teen Hath Naka	27597	2580	1225
1073	1796	19126	RTO Thane	26242	1811	1994
1112	1784	18454	Thane Mahapalika Marg (Mahapalika Marg)	26425	1589	1889
1713	2096	18071	Siddheshwar Lake	26725	2726	2183

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
			(Cadbury Junction)			
1069	2245	16895	Majiwada	26182	2728	1265
2508	1073	18331	KapurBawdi	24719	819	872
8046	4682	21695	Manpada	24771	8219	8506
1130	3545	19280	Patli Pada (Tikuji Ni wadi)	25058	3963	2106
1118	2976	17421	Dongari pada	23201	3028	1669
0	2074	15348	Kavesar Gaon (Vijay Garden)	21843	3209	0
600	0	15948	kasarvadavali	18634	13	738
1156	1495	15609	Gowniwada	19359	2621	1253
0	15609	0	Gaimukh	17991	17991	0
68921	**68921**	**22552**	**PHPDT/Ridership**	**36635**	**100649**	**100648**
		Daily Ridership	**1695705**			

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- 12-2009. 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 and Train Control System

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 Corridor of Mumbai Metro Line 11 from Bhakti Park (Wadala) to CSMT Metro is planned to be operated at maximum safe speed of 90 Km/hr. The trains are to be maintained headway at every about 100 seconds. However, the signaling System shall be designed at minimum 90 second headway in one direction.

0.3.3.1 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 Line 11 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 equipment shall be connected to station equipment room through optical fiber network.
- The CBTC (Communication based Train Control) based system shall be provided in main line & depot (except workshop area) for train operation & primary mode of detection. Secondary detection shall be through Axle Counter.
- 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 Signalling System shall authorized movement of train in normal and degraded operations.
- Track side equipment 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 equipment by monitoring System status of trackside and train borne equipment and enabling preventive maintenance.
- Signalling & Train Control System on the line shall be designed to meet the required headway during peak hours.
- For monitoring inside train saloon, signaling system shall provide radio transmission media to transfer live streams to OCC controller on large video screen & MMI.
- 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. Signalling and Rolling Stock interfaces shall be provided for Passenger Gate System.

0.3.4 Telecommunication

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 & 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, Maintenance Control, Emergency Control, Assistance to Train Traffic Control.
- Data Channels for Signalling, SCADA, Automatic Fare Collection

- Power Supply of Telecommunications, and
- Cables for Telecommunications etc.

0.3.5 Automatic Fare Collection

0.3.5.1 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, amendable for quick fare changes and require overall less manpower. In view of the above computer based automatic fare collection system is proposed**.** Seamless ticketing is now being thought of for Mumbai Metro Rail.

Automatic Fare Collection 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.

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 AFC system shall be of Contactless Smart Token / Card type. For multiple journeys, the stored value smart card shall be utilized and for the single journey, the smart media shall be as utilized as contactless smart token. 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.

It is proposed, the smart NCMC (National Common Mobility card) standard model for implementation of AFC system in Mumbai Metro. The AFC system as per the guidelines issued by Govt of India shall enable seamless travel by different metros and other transport systems across the city besides retail shopping and purchases.

The AFC system shall support the EMV (Europay, MasterCard, and Visa) and RuPay based open loop ticketing following the NCMC standard model for interoperability with other operators by use of non-proprietary standard so that the interface is scalable to other networks (transit operator/ retail outlets/parking/Toll etc) in Mumbai.

The AFC equipments shall support EMV, RuPay, QR, NFC (Near field communication) based ticketing, integration of clearing house, smart card host system of Financial Institutions and integration of mobile application with AFC system.

0.3.5.2 Gate

Retractable Flap Type/Paddle Type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern systems internationally. All these gates will have a functionality of Auto Top on smart cards in case balance goes below the threshold value (as per choice / business rule).

The gate should also capable to NFC enabled Mobile Tickets or any latest type of Ticket media at the time of procurement/installation. The AFC system shall provide access control solutions, offering both access control devised and hardware which can be tailored to accept any ticket media readily available in market (Barcode, QR code, NFC etc).

0.3.5.3 Ticket Vending Machine (TVM)

The 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.

0.3.5.4 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.

0.3.5.5 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

0.3.5.6 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.

The proposed AFC system shall provide interfaces to other operators such as Suburban Rail, Bus, Waterway, 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 a Mass Rapid Transit System (MRTS).

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

Table 0.6 - Size of the coach

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

**Maximum length of coach over couplers/buffers = 23 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
8-car Train (from the year 2031 onwards): DMC+TC+MC+MC+TC+MC+TC+DMC

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

Table 0.6A Carrying Capacity of Medium Rail Vehicles

Particulars	**Driving Motor car**		**Trailer car/Motor car**		**6 Car Train**		**8 Car Train**	
	Normal	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**
Seated	42	42	50	50	284	284	384	384
Standing	120	240	124	248	736	1472	984	1968
Total	162	282	174	298	1020	1756	1368	2352

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

The recommended performance parameters are:

Maximum Design Speed:	90 kmph
Maximum Operating Speed:	80 kmph
Max. Acceleration	1.0 m/s^2 (with AW3 load) 1.2 m/s^2 (with AW2 load)
Max. Deceleration	1.0 m/s^2 (with AW3 load) 1.1 m/s^2 (with AW2 load) >1.35 m/s^2(Emergency Brake)

0.3.6.2 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.

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 (elevated section) and 300 m (underground section) but in extreme cases it can be reduced to 120 m (elevated section) and 200 m (underground section). Minimum curve radius at stations is specified as 1000 m.

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. 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 proposed extension all stations are on level gradient.

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.

0.4.1.3 Design Speed

The maximum sectional speed will be 80 km/h. The scheduled speed has been taken as 35 kmph.

0.4.2 Alignment

- First station of this extension is named as Chhatrapati Shivaji Maharaj Terminus (CSMT) Metro and last station is Ganesh Nagar. Since this corridor is South-West extension of Mumbai Metro corridor from Gaimukh to Wadala (Bhakti Park), thus Ganesh Nagar is not a terminal station rather it is followed by Wadala (Bhakti Park) Station.

- Chainage of Chhatrapati Shivaji Maharaj Terminus proposed metro station is taken as 0.0 for reference and dead end chainage of this station as (-) 530 m.

- Total length of this extension is 12.774 km. It is proposed as partly elevated and partly underground.

- Ten stations have been proposed on this extension of Gaimukh to Wadala (Bhakti Park) corridor. Names of stations are Chhatrapati Shivaji Maharaj Terminus, Carnac Bunder, Clock Tower, Wadi Bandar, Darukhana, Coal Bunder, Hay Bunder, Sewri Metro, BPT Hospital and Ganesh Nagar. 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 2098.1 m and 851.1 m respectively. No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

- This is an extension of Gaimukh to Wadala (Bhakti Park) corridor towards South-West direction.

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.

All stations will be two level stations. For elevated stations, the concourse comprising of passenger facilities and station facilities will be at lower level and the platforms on the higher level, whereas, for underground stations, the concourse will be at higher level and the platforms on the lower level. Stations on the road have been planned cantilever leaving 10.5 m road width either side of the median.

0.4.4 Terminals

Since this is an extension of Gaimukh to Wadala (Bhakti Park) corridor on Wadala (Bhakti Park) end. Thus this section has only one terminal station as mentioned below:

Chhatrapati Shivaji Maharaj Terminus

This Station is proposed to be underground. Scissors cross overs are proposed at the rear end of station.

Scissors Crossovers

Scissors Crossovers will be provided at the terminal station viz. Chhatrapati Shivaji Maharaj Terminus and before Wadala (Bhakti Park) station.

0.4.5 Depot

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

0.4.6 Construction Methodology

0.4.6.1 Underground Construction

For the underground section running under the road, cut and cover method of the underground construction can be employed for the construction of the underground sections. However keeping in view the inconvenience to the traffic movement, it is proposed to tunnel through by using Tunnel Boring Machine (TBM) or New Austrian Tunneling Method (NATM) in the overburden soil mass. Tunnel excavation for a major length of underground section is expected to be carried out by Tunnel Boring Machines. There is some length along the underground alignment where Cut & Cover method has been considered for construction before Switch Over Ramp (SOR). Tunnel boring machines (TBMs) capable of drilling through rock with a finished internal diameter of 5.6 m can be successfully employed for boring tunnels through this stratum. The tunnels are proposed with a minimum cushion cover of 6.0 m.

0.4.6.2 Viaduct–Elevated Structure

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 extension of Gaimukh to Wadala (Bhakti Park) corridor of Mumbai Metro, it is suggested to use Double U-Girder in the superstructure up to 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

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

Depth of Foundation-A foundation must have an adequate depth from considerations of adverse environmental influences. It must also be economically feasible in terms of overall structure. Keeping in view the type of the proposed structure and the subsoil strata, the length of pile may be about 7.5 to 15 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 1200 to 1500 mm diameter may be adopted.

Piles transmit foundation loads through soil strata of low bearing capacity to deeper soil having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance. The minimum diameter of pile should be 1000mm.

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

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

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 4 on Civil Engineering.

0.4.9 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)

0.4.9.1 Summary of Land Requirements

Abstract of land requirements for different components of this extension is given in **Table 0.8 and Table 0.9**.

Table 0.8 Summary of Permanent Land Requirement (All figures in Sq. m)

S.No.	Description	Govt.	Pvt.
1	Stations	12449.79	1556.28
2	Running Section	20584	6977
3	Ramp	3957	0
4	Depot	0	0
4	Staff Quarters	5000	0
5	Office Complex and OCC	0	0
6	RSS	5600	0
7	Ventilation Shaft	800	0
8	Mid Shaft	0	0
9	Ancillary Structure	3150	450
	Total	**51540.79**	**8983.28**

Total Permanent Land = 6.0524 ha
Permanent Land (Govt.) = 5.1541 ha
Permanent Land (Pvt.) = 0.8983 ha

Table 0.9 - Summary of Temporary Land Requirement (All figures in Sq. m)

S. No.	Description	Govt.	Pvt.
1	Temporary Office/ Site Office	4000	0
2	Segment Casting Yard	40000	0
3	For construction of UG Stations by cut and cover method	0	7674

4	Portion of alignment before start of Ramp by cut and cover method	4772	0
	Total	**48772**	**7674**

Total land required for temporary acquisition is **4.8772 ha (Govt.) and 0.7674 ha (Pvt.).**

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 Metro Corridor is from Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park). It is in the southern portion of the Mumbai. In fact this corridor is the southward extension of Gaimukh-Kasarvadavali-Wadala Corridor of Mumbai Metro.

This proposed extension of Gaimukh to Wadala Corridor consists of ten stations. Out of these ten stations, eight are underground and two are elevated. CSMT Metro station is proposed will be an Interchange Station. The placement of these stations has been done considering Right of way, land availability, location, proximity to the Institutions for better ridership and connectivity.

CSMT Metro station (underground) is proposed adjoining to an under-construction underground station of Mumbai Metro Line-3.. At this location concourse of both the stations are planned to be merged by entry structure connections. To attract maximum pedestrian traffic, station locations are finalised at the traffic nodal points.

0.5.1 Salient features

Salient features of a typical Metro 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 at elevated stations is determined by a critical clearance of 5.50-m under the concourse above the road intersection, allowing 3.00-m for the concourse height, about 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 at least 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.

9. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.

10. 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 and between platforms for transfer between lines.
    - Adequate capacity for passenger movements.

- Convenience, including good signage relating to circulation and orientation.
- Safety and security, including a high level of protection against accidents.

11. Following requirements have been taken into account:

    a. Minimum capital cost is incurred consistent with maximizing passenger attraction.
    b. Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
    c. 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.
    d. Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
    e. Provision of display of passenger information and advertising.

12. 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

13. 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**.**

14. 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:

Table 0.10 Station Accommodation Requirements

Non Public Area –at Station	
Station Control Room	Fire Tank & Pump room
Platform Supervisor’s Booth	Staff Area
Station Master’s Office	UPS and Battery Room
Traction Substation	Cleaner’s Room
Information & Enquiries	Security Room
Signaling Room	Staff Toilets
Ticket Office	Refuse Store
Communication Room	Miscellaneous Operations Room
Ticket Hall Supervisor & Excess Fare Collection (Passenger Office	First Aid Room
Station Substation	

0.5.2 Station Types

Total Ten Stations have been planned on this extension. Out of Ten Stations, Eight are Underground and Two are Elevated. Concourse of all elevated stations is proposed along the roads with sufficient Right of way. The stations accommodate the passengers from the eastern port area of Mumbai. Average inter-station distance is 1.27 km approximately varying from 0.85 km to 2.1 km depending upon the site, operational and traffic constraints. List of Station is given in **Table 0.11.**

Table 0.11 List of Stations

S. No.	Station Name	Chainage	Interstation Distance (m)
1	Chhatrapati Shivaji Maharaj Terminus	0.000	
2	Carnac Bunder	1584.597	1584.597
3	Clock Tower	2473.963	889.366
4	Wadi Bundar	3620.461	1146.498
5	Darukhana	4598.000	977.539
6	Coal Bunder	5780.570	1182.570
7	Hay Bunder	6805.016	1024.446
8	Sewri Metro	7656.128	851.112
9	BPT Hospital	9754.193	2098.065
10	Ganesh Nagar	10722.095	967.902
	Wadala(Bhakti Park)	12694.115	1972.020

0.6 TRAIN OPERATION PLAN

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections.
- Economical & optimum train service frequency not only during peak period, but also during off-peak period.
- Optimization of train’s reliability for achieving best possible availability on line.
- A train consists of 6 coaches which will be augmented to 8 coaches in future.
- Multi-tasking of train operation and maintenance staff.

List of stations for the Mumbai Metro Line from CSMT Metro to Gaimukh is given below: -

Table 0.12 - Stations

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
0.	**Dead End**	-530			
1.	CHHATRAPATI SHIVAJI MAHARAJ TERMINUS	0.000	530.000	Underground	Interchange Station
2.	CARNAC BUNDER	1584.597	1584.597	Underground	

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
3.	CLOCK TOWER	2473.963	889.366	Underground	
4.	WADI BUNDER	3620.461	1146.498	Underground	
5.	DARUKHANA	4598.000	977.539	Underground	
6.	COAL BUNDER	5780.570	1182.570	Underground	
7.	HAY BUNDER	6805.016	1024.446	Underground	
8.	SEWRI METRO	7656.128	851.112	Underground	
9.	BPT HOSPITAL	9754.193	2098.065	Elevated	
10.	GANESH NAGAR	10722.095	967.902	Elevated	
11.	WADALA (BHAKTI PARK)	12694.115	1972.020	Elevated	Interchange Station
12.	WADALA TT	13694.115	1000.00	Elevated	
13.	ANIK NAGAR BUS DEPOT	14555.725	861.61	Elevated	
14.	SUMAN NAGAR	15634.115	1078.39	Elevated	
15.	SIDDHARTH COLONY	16688.545	1054.43	Elevated	
16.	AMAR MAHAL JUNCTION	18032.125	1343.58	Elevated	Interchange Station
17.	GARODIA NAGAR	18630.655	598.53	Elevated	
18.	PANT NAGAR	20263.335	1632.68	Elevated	
19.	LAXMI NAGAR	21340.845	1077.51	Elevated	
20.	SHREYES CINEMA	21961.655	620.81	Elevated	
21.	GODREJ COMPANY	23124.475	1162.82	Elevated	
22.	VIKHROLI METRO	23847.595	723.12	Elevated	
23.	SURYA NAGAR	24852.365	1004.77	Elevated	
24.	GANDHI NAGAR	25854.475	1002.11	Elevated	Interchange Station
25.	NAVAL HOUSING	26546.355	691.88	Elevated	
26.	BHANDUP MAHAPALIKA	27325.695	779.34	Elevated	
27.	BHANDUP METRO	28374.525	1048.83	Elevated	
28.	SHANGRILA	29218.175	843.65	Elevated	
29.	SONAPUR	30608.935	1390.76	Elevated	
30.	MULUND FIRE STATION	31721.915	1112.98	Elevated	
31.	MULUND NAKA	33070.015	1348.10	Elevated	

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
32.	TEEN HAATH NAKA (THANE)	34306.365	1236.35	Elevated	
33.	RTO THANE	34984.905	678.54	Elevated	
34.	MAHAPALIKA MARG	36020.875	1035.97	Elevated	
35.	CADBURY JUNCTION	36813.585	792.71	Elevated	
36.	MAJIWADA	37637.875	824.29	Elevated	
37.	KAPURBAWDI	39027.135	1389.26	Elevated	
38.	MANPADA	39892.515	865.38	Elevated	
39.	TIKUJI-NI-WADI	40668.165	775.65	Elevated	
40.	DONGARI PADA	42133.765	1465.60	Elevated	
41.	VIJAY GARDEN	43042.635	908.87	Elevated	
42.	KASARVADAVALI	44116.205	1073.57	Elevated	
43.	GOWNIWADA	45501.145	1384.94	Elevated	
44.	GAIMUKH	46784.235	1283.09	Elevated	
45.	**Dead End**	47684.235	450.00		

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 these corridors has been considered as: 35 kmph.

0.6.2 Train Formation

To meet the above projected traffic demand, the possibility of running trains with composition of 6 and 8 cars with different headway has been examined.

Composition

DMC : Driving Motor Car
TC : Trailer Car
MC : Motor Car

Capacity (@ 6 passengers per square meter of standee area)

Driving Motor Car (DMC)	-282 (42 seated + 240 standing)
Trailer Car (TC)	-298 (50 seated + 248 standing)
Motor Car (MC)	-298 (50 seated + 248 standing)
6 Car Train	- 1756 (284 seated + 1472 standing)
8 Car Train	- 2352 (384 seated + 1968 standing)

0.6.3 Year-Wise Rake Requirement

Based on the projected PHPDT demand, Train operation plan with train carrying capacity @ 6 persons per square meter of standee area for the Mumbai Metro Line: CSMT Metro-Gaimukh' for the year 2021 and 2031 is given below.

The PHPDT capacity provided on the route in different years of operation is tabulated below:

Table 0.13: Capacity Provided for CSMT Metro-Gaimukh

Sections	Year	Head-way (min)	Total No. of Rakes	Rake Consist	Total No. of Cars**	Provision for No. of cars in DPR of Sep'17	Additional No. of cars for Line- 11	Max. PHPDT Demand	PHPDT Capacity Available
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2021	6.50	46	6-car	276	232	44	17460	16209 (20677*)
Bhakti Park to Kapurbawdi		3.25						32460	32418 (41354*)
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2031	6.50	46	8-car	368	264	104	25058	21711 (27692*)
Bhakti Park to Kapurbawdi		3.25						36635	43422 (55385*)

*** @ 8 persons per square meter of standee area***

*** Total No. of cars shown above are the total cars calculated as per PHPDT data.*

 # Additional cars requirement for Line-11 has been calculated after subtracting provision for no. of cars in previous Line-4 (Bhakti Park - Gaimukh) DPR (Sep'17) from the total car requirements.

0.7 MAINTENANCE DEPOT

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 equipment.

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 train 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 (preferably as close to depot as possible) to cater to the required stability facilities.
(v) In case of space constraint for depot two storeyed Stabling lines can also be planned.

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 all key Rolling Stock equipment by suitable advanced condition monitoring techniques available. 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.
- ➢ Increase in the periodic maintenance intervals with predictive maintenance based on condition monitoring.
- ➢ Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.
- ➢ Periodic review of maintenance practices to update replacement cycle of critical components based on experience.
- ➢ 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, ventilation fan & air-conditioning etc) and workshops in depots & other maintenance infrastructure within premises of metro system. The power requirements of Wadala (Bhakti Park) to CSMT Metro 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 parameters: -

(i) Specific energy consumption of rolling stock at Pantograph/ Current Collector – 50 kWh/1000 GTKM for 25 kV ac system as per MOUD guideline.
(ii) Elevated/at –grade station load – initially 250 kW, which will increase to 300 kW in the year 2031.
(iii) Auxiliary load of Underground station is of the order of 2200 kW initially, which will increase to 2500 kW in the year 2031.
(iv) Depot auxiliary load - initially 2000 kW, which will increase to 2200 kW in the year 2031.

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

Table 0.14 Power Demand Estimation (MVA)

Corridor	Load	Year	
		2021	2031
Line 11: Wadala (Bhakti Park) to CSMT Metro (8 Underground & 2 Elevated, 12.77 km)	Traction	4.96 MVA	6.62 MVA
	Auxiliary	22.67 MVA	25.82 MVA
	Total	**27.63 MVA**	**32.44 MVA**

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 this section.

The Mumbai Metro Corridors from Wadala (Bhakti Park) to CSMT Metro is 12.774 Km, which is Extension for Line 4 Corridor of Mumbai Metro Network from Gaimukh to Wadala (35 Km, 34 Elevated stations).

As per the Detailed Project Report for Line 4 Corridor from Gaimukh to Wadala (35 km, 34 Elevated stations), three RSS are planned at following locations:

a) At Gaimukh Depot,
b) Near RTO Thane Station and
c) Near Ghatkopar or Chembur Station.

In view of above planned Receiving Sub-Stations, one Receiving Sub-stations is proposed to cater to load of Wadala (Bhakti Park) to CSMT Metro Section. One RSS will be set up near Sewri Metro Station and the proposed RSS near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented for Emergency Supply in case of Failure of RSS near Sewri Metro Station.

This is an economical solution without compromising reliability. It is proposed to receive power supply for traction as well as auxiliary services from the following grid sub-stations of M/s TATA Power Ltd. at 110 kV voltage through cable feeders:

Table 0.15 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.	Wadala (Bhakti Park) to CSMT Metro	220/110 kV Parel Grid Sub-station or 220/110 kV Proposed Wadala Grid Substation of M/s TATA	Near Sewri Metro Station	2 to 3 km

*Note: Proposed RSS of near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented to meet the additional requirement of this Corridor.

DMRC has done a joint survey/ meeting with M/s MMRDA and M/s TATA Power Company Ltd on 04.06.18 & 05.06.18 for this section for feasibility of Power Supply. 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

Corridor	**Input Source**	**Peak demand – Normal (MVA)**		**Peak demand** – Emergency (MVA)**	
		Year (2021)	**Year (2031)**	**Year (2021)**	**Year (2031)**
Wadala (Bhakti Park) to CSMT Metro	RSS Near Sewri Metro Station				
	Traction	4.96	6.62	9.21	11.39
	Auxiliary	22.67	25.82	25.04	29.22
	Sub-total (A)	27.63	32.44	34.25	40.61
	RSS Near Ghatkopar or Chembur				
	Traction	8.49	9.53	13.45	16.15
	Auxiliary	4.73	6.74	27.40	32.56
	Sub-total (B)	13.22	16.27	40.85	48.71

******In case 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 techno-economic considerations, 25 kV AC traction system is suggested for Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park) (12.774 km) 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 160 kVA capacity at the elevated & 2X900 kVA capacity for underground stations respectively. The requirement of 900/1000 kVA DG set at underground station is dispensable if two 33/0.415 kV Auxiliary Sub-Stations are fed from two different Receiving Sub-Stations which are taking supply from different Grid Sub-Stations. This arrangement will comply with the requirements of NFPA 130, 70 and 110. In view of this, 380 kVA DG Set capacity at each underground station is sufficient for firefighting system and Emergency Lighting and Fire detection & Alarm System.

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

UPS Supply to also be considered for following emergency services:

- Emergency Lighting
- Fire Detection & Fire Alarm system.
- Station Control Room
- Control Supply

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.

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.

0.8.6 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.

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 30-38% 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 72.08 million units in initial years 2021, which will be about 85.74 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 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 for FY 2017 – 18 demand charges Rs 240/ kVA per month and energy charges Rs 7.13/ kWh for TATA company Ltd. 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 TUNNEL VENTILATION AND AIR-CONDITIONING SYSTEM

This chapter covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed corridor from CSMT Metro to Wadala (Bhakti Park). VAC System includes the following:

- Station Air-conditioning System
- Smoke Management System
- Tunnel Ventilation System
- Control and Monitoring facilities

0.9.1 Requirement for Ventilation and Air Conditioning

The underground stations are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide ventilation and air-conditioning in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the official;
- Removing body heat, obnoxious odors and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the tunnel;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, transformer, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Elevators, Escalators, Automatic Fare Collection Gates etc. working in the stations;
- Removing heat from air conditioning plant and Station sub-station and other equipments.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered to be appropriate. In winter season it may not be necessary to warm the ventilating air as the heat generated by the equipments within the station premises would be sufficient to maintain the comfort requirement.

0.9.2 Internal Design Conditions in Underground Stations

With tropical humid ambient conditions of Mumbai, it is essential to maintain appropriate conditions in the underground stations in order to provide a comfort and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the “Designed inside Conditions”.

The patrons will stay for much shorter durations in underground stations, the comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated is given out by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The ‘Effective Temperature’ criterion was used in selecting the comfort condition in earlier corridor of Mumbai and other Metro, in this criteria comfort is defined as the function of temperature and the air velocity experienced by a person. An index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient condition of the metabolic rate and is evaluated based on the changes to the surrounding ambient of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a underground section where the train headway is expected to be six minutes or less, then RWI is the preferred criterion.

0.9.3 Design parameters for VAC system

Based on the above discussion, the following VAC system design parameters are assumed in the present report.

(1) Outside ambient conditions

Based upon ISHRAE-2017 recommended design conditions for 1% criteria is as under

Summer :	34.9 DB, 23.1 WB
Monsoon:	30.9 DB, 27.4 WB

For Mumbai Metro Underground Corridor it is suggested to use 1% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 1% of the total time.

1. Inside design conditions

a.	Platform and Concourse areas:	27^{o}C at 55% RH

2. Tunnel design conditions

a.	Normal conditions	Max. average temperature DB 40^{o}C
b.	Congested conditions	Max. stratified temperature DB 50^{o}C

3. Minimum fresh air

a.	10% or 18 cmh/person	(In station public areas)

0.10 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

0.10.1 Objective and Scope of the Study

The objective of the 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 fundinng agencies. The scope of EIA includes the impacts resulting from pre-construction, during construction and operation phases of CSMT Metro- Wadala (Bhakti Park) 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. The MoEF, Government of India, Notification of 14th September 2006 and its amendment dated 1st December 2009 enlist projects in Schedule that require environmental clearance. However, as per the said notification Railway/ Metro projects do not require environmental clearance from MoEF.

0.10.2 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, minimum 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 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.

The standard methodology for the data collection, impact assessment and formulation of management plans is adopted. The national acts, legislation and laws along with guidelines were consulted with a view to ensuring compliance with various requirements. Environmental baseline data for environmental attributes from primary and secondary sources were collected and compiled. The primary sources include site visits, visual inspection, field studies, monitoring and analysis.

0.10.3 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.

0.10.4 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.

0.10.5 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. 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.

0.10.6 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.

0.11 MULTI MODAL TRAFFIC INTEGRATION

This is extension of Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) at Wadala(Bhakti Park) end. It is being extended from Wadala to CSMT Metro and length of this extension is 12.774 km. It is partly underground and partly elevated. Total Ten stations have been provided out of which eight are underground and two are elevated.

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.

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.

0.11.1 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.

0.12 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 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) "Harmonised Guidelines and Space Standards for Barrier Free Built Environment for Persons with Disabled and Elderly Persons", 2016 (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.

0.12.1 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

0.13 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.

0.13.1 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

0.13.2 Phases of Security

There are three phases of security as under:

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

0.14 DISASTER MANAGEMENT MEASURE

0.14.1 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.

0.14.2 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.

0.14.3 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.

0.14.4 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.

0.15 COST ESTIMATE

Project Cost estimates for Mumbai Metro Line No. 11 from Wadala (Bhakti Park) to CSMT Metro has been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction etc. at March 2018 price level.

The overall Capital Cost of Mumbai Metro Line-11 from Wadala (Bhakti Park) to CSMT Metro at March 2018 price level works out to **Rs. 6135 Crores** excluding applicable Taxes & Duties of **Rs. 950 crores** for Option-I and **Rs. 3248 Crores** excluding applicable Taxes & Duties of **Rs. 474 crores** for Option-II as tabulated hereunder.

Table 0.17 – Summary of Cost Estimate

Name of the section	Option	Capital Cost (Rs. Crore)	Taxes & Duties (Rs. Crore)	Total (Rs. Crore)
Wadala(Bhakti Park) to CSMT Metro	I	6135	950	7085
	II	3248	474	3722

Option-I: 8 Underground Stations and 2 Elevated Stations

Table 0.18 A - Capital Cost Estimate

Total length = 12.774 km
Ramp = 0.427 km; UG C&C = 0.236 km; UG TBM = 8.316 km; Elevated = 3.795 km
Total Station =10, Elevated = 2 & UG = 8

March 2018 level

S. No.	Item	Amount (Rs. in Cr.) Without taxes
1.0	Land and R & R incl. Hutments etc.	280.36
2.0	Alignment and Formation	1405.74
3.0	Station Buildings	2878.62
4.0	Depot Augmentation	19.63
5.0	P-Way	141.20
6.0	Traction & power supply incl. OHE , ASS etc. Excl. lifts & Escalators	187.82
7.0	Signalling and Telecom.	215.12
8.0	Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection	95.66
9.0	Rolling Stock (3.2 m wide Coaches)	396.00
10.0	Capital expenditure on security	5.24

S. No.	Item	Amount (Rs. in Cr.) Without taxes
11.0	Staff quarter for O & M	31.81
12.0	Capital expenditure on Multimodal Traffic Integration	26.50
13.0	**Total of all items except Land**	**5455.96**
14.0	**General Charges incl. Design charges @ 5 % on all items except land#**	**272.80**
15.0	**Total of all items including G. Charges except land**	**5728.76**
16.0	**Contingencies @ 3 %**	**171.86**
17.0	**Gross Total**	**5900.62**
	Cost without land	**5901**
	Cost with land including contingencies on land	**6135**

Table 0.18 B - Details of Taxes and Duties

Basic Customs duty = 5.1500
CGST Customs Duty = 9.4635
SGST Customs Duty = 9.4635
Total Customs Duty = 24.0770
General IGST = 12
General CGST = 6
General SGST = 6

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties		Total Taxes & Duties (Cr.)
			Total Customs Duty (Cr.)	Total GST (CGST & SGST) (Cr.)	
1	**Alignment & Formation**				
	Underground	1215.37	87.79	102.09	**189.88**
	Elevated	190.36		22.84	**22.84**
2	**Station Buildings**				
	a) Underground station-civil works	2118.96	153.05	177.99	**331.05**
	b) Underground station-EM works	581.44	70.00	34.89	**104.88**
	Elevated station - civil works	70.88		8.51	**8.51**
	Elevated station-EM works	18.10	0.87	1.74	**2.61**
3	**Depot**				
	Civil works	7.85	0.57	0.66	**1.23**
	EM and M&P works	11.78	0.57	1.70	**2.26**
4	**P-Way**	141.20	27.20	5.08	**32.28**
5	**Traction & power supply**				
	Traction and power supply	187.82	18.09	20.29	**38.37**
6	**S and T Works**				
	S & T	159.68	30.76	5.75	**36.50**
	AFC	55.44	10.01	2.49	**12.51**

	PSD	89.24	17.19	3.21	**20.40**
7	**R & R hutments**	52.63		6.32	**6.32**
8	**Misc.**				
	Civil works	111.98	0.00	13.44	**13.44**
	EM works	47.23	0.00	8.50	**8.50**
9	**Rolling stock**	396.00	57.47	5.86	**63.33**
10	**Rent on Temporary Land**	34.85		6.27	**6.27**
11	**General Charges**	272.80		49.10	**49.10**
	Total	**5763.61**	**473.56**	**476.73**	**950.29**
	Total taxes & Duties				**950**
Rate of Taxes & Duties on Total cost without taxes & duties					**16.49%**
Total Central GST & Basic Customs duty					525.79
Total State GST					424.50
Total Taxes & Duties					**950.29**

Option-II: 1 Underground Station and 9 Elevated Stations

Table 0.19 A - Capital Cost Estimate

Total length = 12.774km UG = 2.2 km; Elevated = 10.574km

Total Station =10, Elevated = 9 & UG = 1

March 2018 level

S. No.	**Item**	**Amount (Rs. in Cr.) Without taxes**
1.0	Land and R & R incl. Hutments etc.	280.36
2.0	Alignment and Formation	827.87
3.0	Station Buildings	784.92
4.0	Depot Augmentation	19.63
5.0	P-Way	141.20
6.0	Traction & power supply incl. OHE , ASS etc. Excl. lifts & Escalators	161.83
7.0	Signalling and Telecom.	221.56
8.0	Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection	116.75
9.0	Rolling Stock (3.2 m wide Coaches)	396.00
10.0	Capital expenditure on security	5.24
11.0	Staff quarter for O & M	31.81
12.0	Capital expenditure on Multimodal Traffic Integration	26.50
13.0	**Total of all items except Land**	**2785.94**
14.0	**General Charges incl. Design charges @ 5 % on all items except land#**	**139.30**
15.0	**Total of all items including G. Charges except land**	**2925.23**
16.0	**Contingencies @ 3 %**	**87.76**
17.0	**Gross Total**	**3012.99**
	Cost without land	**3013**
	Cost with land including contingencies on land	**3248**

Table 0.19 B - Details of Taxes and Duties

Basic Customs duty = 5.1500

CGST Customs Duty = 9.4635

SGST Customs Duty = 9.4635

Total Customs Duty = 24.0770
General IGST = 12
General CGST = 6
General SGST = 6

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties		Total Taxes & Duties (Cr.)
			Total Customs Duty (Cr.)	Total GST (CGST & SGST) (Cr.)	
1	**Alignment & Formation**				
	Underground	342.15	24.71	28.74	**53.45**
	Elevated	485.72		58.29	**58.29**
2	**Station Buildings**				
	a) Underground station-civil works	264.87	19.13	22.25	**41.38**
	b) Underground station-EM works	72.68	8.75	4.36	**13.11**
	Elevated station - civil works	305.94		36.71	**36.71**
	Elevated station-EM works	81.45	3.92	7.82	**11.74**
3	**Depot**	0.00		0.00	**0.00**
	Civil works	0.00	0.00	0.00	**0.00**
	EM and M&P works				
4	**P-Way**	7.85	0.57	0.66	**1.23**
5	**Traction & power supply**	11.78	0.57	1.70	**2.26**
	Traction and power supply	141.20	27.20	5.08	**32.28**
6	**S and T Works**				
	S & T	161.83	15.59	17.48	**33.06**
	AFC				
	PSD	159.68	30.76	5.75	**36.50**
7	**R & R hutments**	61.88	11.17	2.78	**13.96**
8	**Misc.**	59.98	11.55	2.16	**13.71**
	Civil works	52.63		6.32	**6.32**
	EM works				
9	**Rolling stock**	111.98	0.00	13.44	**13.44**
10	**Rent on Temporary Land**	68.32	0.00	12.30	**12.30**
11	**General Charges**	396.00	57.47	5.86	**63.33**
	Total	**2960.08**	**211.39**	**263.03**	**474.43**
	Total taxes & Duties				**474**
Rate of Taxes & Duties on Total cost without taxes & duties					**16.03%**
Total Central GST & Basic Customs duty					259.82
Total State GST					214.60
Total Taxes & Duties					**474.43**

0.16 FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

The Mumbai Metro Line Project (Wadla i.e. Bhakti Park to CSMT Metro station) is proposed to be constructed at an estimated cost of Rs.7085.00 Crore and Rs. 3722.00 Crore with all taxes and land cost for Option-I and II respectively. The route length of the proposed metro rail system and estimated cost at March 2018 price level without and with all taxes are placed in table 0.20 as under:

Table 0.20 Cost Details

Option	Name of Corridor	Distance (KMs)	Estimated cost without taxes (Rs/Crore)	Estimated cost with all taxes & land cost (Rs/Crore)
I	Wadala(Bhakti Park) to CSMT Metro	12.774	6135.00	7085.00
II			3248.00	3722.00

The estimated cost at March 2018 price level includes an amount of Rs.5.24 Crore as one-time charges of security personal towards cost of weapons, barricades, and handheld 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 01.04.2019 and is expected to be completed on 31.03.2024 with Revenue Opening Date (ROD) as 01.04.2024 for the corridors. 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 and all taxes & duties)

Figures in Rs. Crore

Financial Year	Estimated Cost including cost of land and all taxes & duties at March 2018 Price Level	Completion Cost including cost of land cost and all taxes & duties
2019-20	436.00	458.00
2020-21	776.00	856.00
2021-22	1116.00	1292.00
2022-23	1699.00	2065.00
2023-24	1699.00	2168.00
2024-25	1019.00	1366.00
2025-26	340.00	478.00
Total	**7085.00**	**8683.00**

The cost of Land of Rs. 319 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 2024-25 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 @14.00% once in every two years. The fare structure for the FY 2024-25 as per the proposed fare slabs is shown in the table 0.22 below:

Table 0.22 Fare Structure in 2024-25

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 2024-25	
SLAB	**FARE (Rs)**
0-3 km	10.00
3-12 km	20.00
12-18 km	30.00
18 km and More	40.00

Option-I

The **Financial Internal Rate of Return (FIRR) for this extension(CSMT-Wadala) alone with the incremental traffic** for 30 years business model including construction period is worked out as (-) 0.27% and hence on its own not viable due to major portion of this stretch being underground 1.68%.

As GoM considers the CSMT Wadala connectivity important to serve MbPT and other areas, DMRC has examined the financial viability of entire line between CSMT and Shivaji Chowk(CSMT-Wadala-Kasarvadavali-Gaimukh-Shivaji Chowk) with projected traffic as a whole and also the costs and cash flows taken for the respective stretches in earlier DPRs and also of this connection. The financial internal rate of return of complete line as above comes to 7.63 %.

Option-II

If only 2.2 km section of this corridor is planned underground with 1 underground station and rest of the corridor is planned to be elevated then the financial internal rate of return works out to 3.32%.

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 Central and State Government Control Delhi Metro Rail Corporation (DMRC) /Bangalore Metro Rail Corporation (BMRC)/Chennai Metro Rail Corporation (CMRL) etc.

(ii) Design, Built, Fund, Operate & Transfer (DBFOT), and
(iii) Public Private Partnership

SPV Model: - MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2. The funding pattern under this model (SPV) with sharing of overall taxes and duties, post GST in the ratio of 1:2 is placed in table 0.23:

Table 0.23 A: Funding pattern under SPV model (with all taxes and land) (Option-I)

Particulars	With Taxes & Duties	
	Amount	**% of contribution**
Equity By GOI	1282.00	15.33%
Equity By GOM	1282.00	15.33%
SD for Overall Taxes by GOM (2/3)	778.00	9.30%
SD for Overall Taxes by GOI (1/3)	391.00	4.67%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	4631.00	55.37%
Total	**8364.00**	**100.00%**
SD for Land by GOM	319.00	
Total	**8683.00**	
PTA for Interest During Construction @1.40% (*) by GOM	56.00	
Grand Total	**8739.00**	

(*) In the case of loan @12% from domestic borrowings, the IDC works out to Rs. 416 crore

Table 0.23 B: Funding pattern under SPV model (with all taxes and land) (Option-II)

Particulars	With Taxes & Duties	
	Amount	**% of contribution**
Equity By GOI	650.00	15.39%
Equity By GOM	650.00	15.39%
SD for Overall Taxes by GOM (2/3)	388.00	9.19%
SD for Overall Taxes by GOI (1/3)	195.00	4.62%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	2341.00	55.42%
Total	**4224.00**	**100.00%**
SD for Land by GOM	319.00	
Total	**4543.00**	
PTA for Interest During Construction @1.40% (*) by GOM	29.00	
Grand Total	**8739.00**	

Design, Built, Fund, Operate & Transfer (DBFOT) 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 Equity internal rate of return (EIRR) in the range of 16% to 18% or a comfort of guaranteed ridership.

The funding pattern under this model is given in table 0.24 as under: -

Table 0.24 Funding pattern under BOT – (16% EIRR)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% Of contribution
VGF by GOI	1673.00	20.00%
VGF by GOM	6179.00	73.88%
Equity by Concessionaire	171.00	2.04%
Concessionaire's debt @12% PA	341.00	4.08%
Sub-Total	**8364.00**	**100.00%**
Land Free by GOM	319.00	
Sub-Total	**8683.00**	
IDC	112.00	
Grand Total	**8795.00**	

0.16.1 Recommendations

The FIRR for the corridor with all taxes but without grant as revenue from MbPT works out to (-) 0.27%. Hence this extension is not considered viable. However, FIRR of entire line from CSMT to Shiwaji Chowk with grant of Rs. 1839 Crore as revenue from MbPT in the years from 2019-20 to 2025 -26 is calculated as 7.63% and hence corridor with complete length up to Shivaji Chowk is viable. EIRR of entire line is also worked out as 17.41%.

FIRR for this independent corridor, if only 2.2 km is planned to be underground works out to 3.32% and EIRR in this case is 21.12%.

As per Metro Rail Policy 2017, issued by the Ministry of Housing and Urban Affairs, (MOH&UA), GOI, apart from financial viability, the economic and social viability of the project is also required to be assessed. The Economic Internal Rate of Return (EIRR) for any metro rail project proposal should be 14% and above for consideration of its approval. Accordingly, the metro corridors as discussed above are recommended for implementation provided the required EIRR works out to 14% or above.

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

Table 0.25

(Rs. in crore)

Particulars	SPV Model (Option-I)	DBFOT Model without additional PD Income	DBFOT Model with additional PD Income
GOI	1673.00	1673.00	1673.00
GOM	2379.00	6498.00	6285.00
Total	**4052.00**	**8171.00**	**7958.00**

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. However, the state government may also explore the other sources of revenue from Transit Oriented Development and Value Capture Financing, which will be made available to metro authorities to meet out the O&M Expenses and servicing the debt properly.

0.17 ECONOMIC APPRAISAL

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.

0.17.1 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.

0.17.2 Economic Performance Indicators

For Calculation of EIRR, Project period is considered from 2017 - 2048 due to amalgamation of all parts of this line in one as done in combined FIRR. EIRR of the entire line works out to 17.41 % and hence economically also viable.

If only 2.2 km is planned to be underground then EIRR of this section works out to 21.12%.

0.18 IMPLEMENTATION PLAN

It is recommended that the project be implemented fully as a Government funded. By this route the project can be completed at the shortest time and at the lowest cost. Moreover, line 4 is already being implemented by MMRDA as fully Government and this is the extension of the same line.

0.18.1 Implementation Schedule

A suggested project implementation schedule for Project Implementation is given in Table 0.27.

Table 0.27 Project Implementation Schedule

S. No.	Item of Work	Completion Date
1	Submission of Final DPR to State Govt.	D
2	Approval of DPR by State Government	D+0.5 month
3	Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+1 month
4.	Sanction of Project by GOI	D+2 months
5.	Selection of GC	D+12 months
6.	Tendering	D+24 months
7.	Implementation of the project	D+58 months
8.	Testing and Commissioning	D+59 months
9.	CMRS Sanction	D+60 months
10.	ROD	D+60 months

0.18.2 Institutional Arrangements

The State Govt. of Maharashtra will have to approve the implementation of the project by Mumbai Metropolitan Region Development Authority (MMRDA).

0.18.3 Legal Cover for Mumbai Metro

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

0.19 CONCLUSIONS

0.19.1 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 extend Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) to CSMT Metro at Wadala (Bhakti Park) end for implementation.

0.19.2 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.

0.19.3 Project Cost

Estimated Cost of the project at March 2018 price level is Rs.7085 Crore and Rs.3722 Crore with land and all the taxes and duties for option-I & option-II respectively and completion cost at 5% p.a. escalation is estimated to be Rs.8683 Crores and Rs.4543 Crores including land and all the taxes and duties, but excluding

IDC for Option-I and II respectively. It is Rs. 8739 Crore & Rs. 4572 Crore including IDC for Option-I and II respectively.

0.19.4 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.

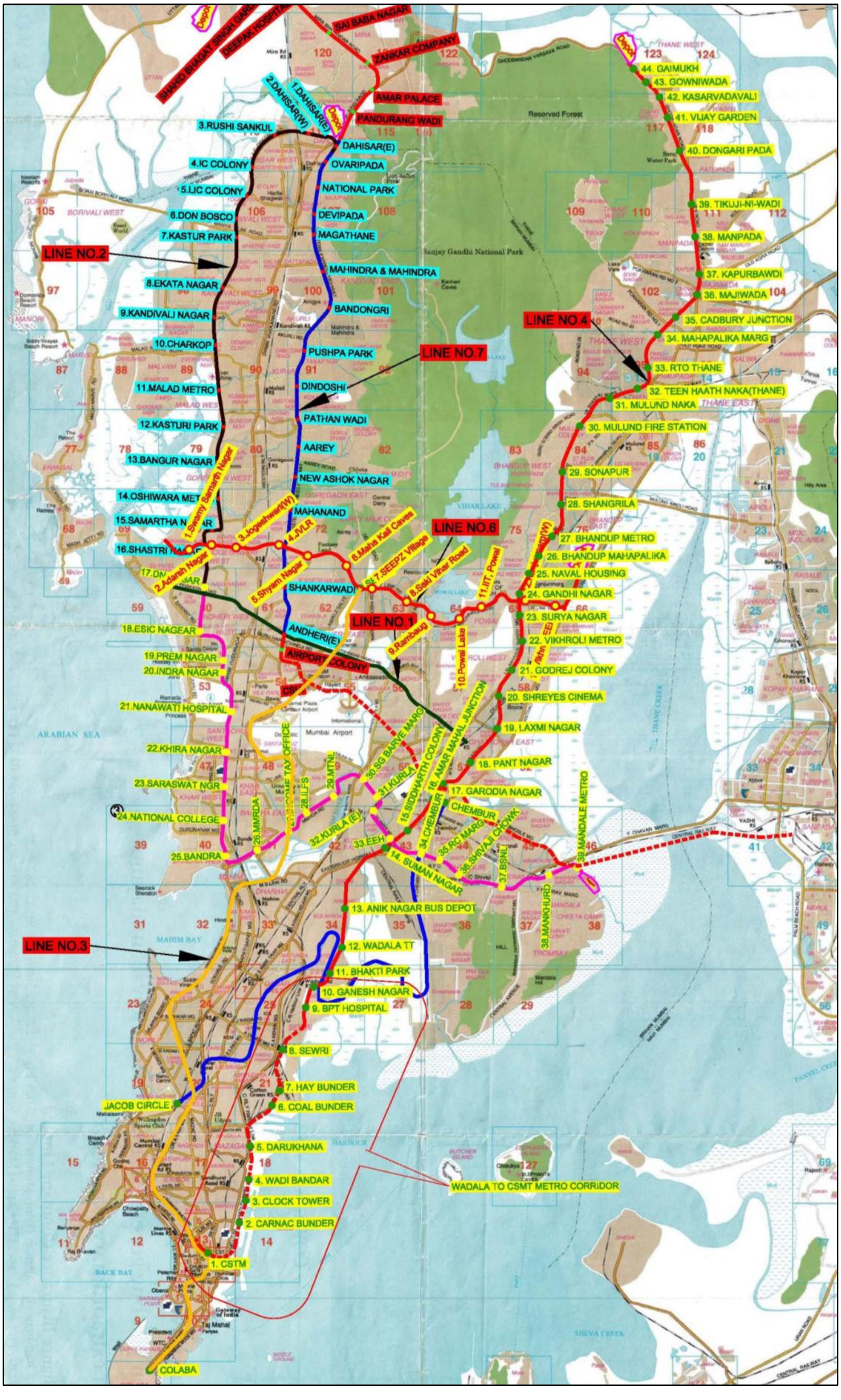
0.19.5 Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR):

The Financial Internal Rate of Return (FIRR) for the extension upto CSMT without grant as revenue from MbPT is worked out as -0.27% for Option-I. However, considering the total line from CSMT to Shivaji Chowk with MbPT contribution as grant (Revenue) is worked out as 7.63%. The EIRR works out to 17.41%.

For Option-II, FIRR works out to 3.32% and EIRR works out to 21.12%.

0.20 Conclusion:

This extension is recommended for implementation with the entire line and with the contribution from MbPT as taken in FIRR. However, it is also recommended that significant development in MbPT area should be made to get the full utility of this extended length and also to get the requisite ridership.


LINE NO.2
LINE NO.7
LINE NO.4
LINE NO.6
LINE NO.1
LINE NO.3
WADALA TO CSMT METRO CORRIDOR
Depot
SHAHID BHAGAT SINGH GARDEN
DEEPAK HOSPITAL
SAI BABA NAGAR
ZANKAR COMPANY
AMAR PALACE
PANDURANG WADI
1.DAHISAR(E)
2.DAHISAR(W)
3.RUSHI SANKUL
4.IC 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 AR
16.SHASTRI NAGAR
17.D.N.NAGAR
18.ESIC NAGEAR
19.PREM NAGAR
20.INDRA NAGAR
21.NANAWATI HOSPITAL
22.KHIRA NAGAR
23.SARASWAT NGR
24.NATIONAL COLLEGE
25.BANDRA
26.MMRDA
27.INCOME TAX OFFICE
28.ILFS
29.MTNL
30.SG BARVE MARG
31.KURLA
32.KURLA (E)
33.EEH
34.CHEMBUR
35.RC MARG
36.SHIVAJI CHOWK
37.BSNL
38.MANKHURD
39.MANDALE METRO
DAHISAR(E)
OVARIPADA
NATIONAL PARK
DEVIPADA
MAGATHANE
MAHINDRA & MAHINDRA
BANDONGRI
PUSHPA PARK
DINDOSHI
PATHAN WADI
AAREY
NEW ASHOK NAGAR
MAHANAND
SHANKARWADI
ANDHERI(E)
AIRPORT COLONY
CSIA
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
1. CSTM
2. CARNAC BUNDER
3. CLOCK TOWER
4. WADI BANDAR
5. DARUKHANA
6. COAL BUNDER
7. HAY BUNDER
8. SEWRI
9. BPT HOSPITAL
10. GANESH NAGAR
11. BHAKTI PARK
12. WADALA TT
13. ANIK NAGAR BUS DEPOT
14. SUMAN NAGAR
15.SIDDHARTH COLONY
16. AMAR MAHAL JUNCTION
17. GARODIA NAGAR
18. PANT NAGAR
19. LAXMI NAGAR
20. SHREYES CINEMA
21. GODREJ COLONY
22. VIKHROLI METRO
23. SURYA NAGAR
24. GANDHI NAGAR
25. NAVAL HOUSING
26. BHANDUP MAHAPALIKA
27. BHANDUP METRO
28. SHANGRILA
29. SONAPUR
30. MULUND FIRE STATION
31. MULUND NAKA
32. TEEN HAATH NAKA(THANE)
33. RTO THANE
34. MAHAPALIKA MARG
35. CADBURY JUNCTION
36. MAJIWADA
37. KAPURBAWDI
38. MANPADA
39. TIKUJI-NI-WADI
40. DONGARI PADA
41. VIJAY GARDEN
42. KASARVADAVALI
43. GOWNIWADA
44. GAIMUKH
CHEMBUR
JACOB CIRCLE
COLABA
ARABIAN SEA
MAHIM BAY
BACK BAY
Sanjay Gandhi National Park
VIHAR LAKE
Mumbai Airport

Metro Line 11: Wadala to CSMT

EXECUTIVE SUMMARY

0.1 INTRODUCTION

0.1.1 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 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 – 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. Subsequently, the corridors 2 & 3 were rearranged and DMRC prepared another DPR for the corridor between Charkop – Bandra – Mankhurd

In spite of above, implementation of Mumbai metro remained very slow. So far only one line between Varsova – Andheri – Ghatkopar could be implemented. Other corridors presently under implementation are.

Colaba to Aarey Colony via International Airport.	30.00km
Dahisar (E) to DN Nagar	18.60km
Dahisar (E) to Andheri(E)	16.48km

• DN Nagar to Mandale	23.64km
• Wadala – Ghatkopar – Mulund – Thane – Kasarvadavali	32.32km
• Swami Samarth Nagar to Vikhroli(EEH)	14.48km
Total	**135.52km**

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 – Kanjur Marg	10.00
	(c) Andheri (E) – BKC (Via WEH)	9.00
	Total	**118.00**

Out of 118 km Master Plan network, the work of implementation of about 106 km has already been started by MMRDA.

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 4,355 sq. 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 peak hour station loads and peak hour section loads for the proposed Metro Corridor is given in **Table 0.4** and **0.5**.

Table 0.4: Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2021

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2004	0	2004	CSMT Metro	0	0	7522
42	1	2045	Carnac Bunder	7522	8	104
293	46	2292	Clock Tower	7617	143	368
849	55	3086	Wadi Bunder	7843	320	703
695	72	3710	Darukhana	8225	238	671
171	8	3873	Coal Bunder	8659	56	147
894	72	4695	Hay Bunder	8749	158	404
258	112	4841	Sewri Metro	8995	101	604
3970	761	8050	BPT Hospital	9498	1713	3753

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
1456	233	9273	Ganesh Nagar	11538	776	777
1845	1593	9525	Wadala RTO (Bhatkti Park Metro)	11539	363	10631
2872	1914	10483	Wadala TT	21807	2426	5325
670	429	10724	Anik Nagar (Anik Nagar Bus Dept)	24706	813	1011
1638	300	12062	Suman Nagar	24904	867	1801
3165	791	14435	Siddharth Colony	25838	1208	5419
2561	180	16816	Pestom Sagar (Amar Mahal Junction)	30049	418	2705
479	173	17122	Garodia Nagar	32336	372	497
74	96	17099	Pant Nagar	32460	233	93
519	531	17087	Laxmi Nagar	32321	446	452
2894	5839	14141	Amrut Nagar (Shreyas Cinema)	32326	14471	3663
957	329	14770	Ambewadi (Godrej Company)	21519	879	1164
496	1394	13872	Vikhroli Metro	21803	1776	823
144	245	13771	Surya nagar	20851	629	356
1504	2207	13068	Gandhi nagar	20578	2370	1661
0	41	13027	Naval Housing	19868	170	0
2439	48	15417	Bhandup mahapalika	19699	14	2984
380	449	15348	Bhandup Metro	22669	1027	219
2423	948	16823	Nahur Metro (Shagrila)	21860	2026	4794
548	675	16696	Sonapur	24629	907	579
132	53	16775	Mulund Fire Station	24301	243	41
515	851	16440	Mulund Naka	24099	694	967
719	1163	15995	Teen Hath Naka	24372	1658	641
1116	3208	13903	RTO Thane	23355	4175	1310
1072	1037	13938	Thane Mahapalika Marg (Mahapalika Marg)	20489	1370	920
31	721	13248	Siddheshwar Lake (Cadbury Junction)	20039	515	116
899	1155	12992	Majiwada	19640	2056	1140
574	2081	11485	Kapurbawdi	18724	1940	677
545	1099	10931	Manpada	17460	1862	610
1783	620	12094	Patli Pada (Tikuji Ni wadi)	16209	2404	2317
599	2429	10264	Dongari pada	16122	2793	1084
648	1499	9413	Kavesar Gaon (Vijay Garden)	14413	2757	873
424	1808	8029	kasarvadavali	12530	2690	540
426	1557	6898	Gowniwada	10380	1906	641
0	6898	0	Gaimukh	9115	9115	0
45721	**45722**	**17122**	**PHPDT/Ridership**	**32460**	**71101**	**71102**
			Daily Ridership	**1168242**		

Table 0.5: Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2031

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2366	0	2366	CSMT Metro	0	0	7211
473	165	2674	Carnac Bunder	7211	2347	145
205	186	2693	Clock Tower	5009	120	392
655	294	3054	Wadi Bunder	5281	304	701
820	266	3608	Darukhana	5678	379	1226
95	4	3699	Coal Bunder	6525	7	151
546	19	4225	Hay Bunder	6669	42	221
257	403	4080	Sewri Metro	6848	427	1141
4683	755	8008	BPT Hospital	7563	1879	4172
1804	184	9627	Ganesh Nagar	9855	649	894
2336	1317	10646	Wadala RTO (Bhatkti Park Metro)	10100	320	12234
2990	1002	12633	Wadala TT	22013	1330	6048
617	340	12910	Anik Nagar (Anik Nagar Bus Dept)	26732	438	1064
1724	582	14052	Suman Nagar	27358	1433	2472
6210	2166	18096	Siddharth Colony	28397	5496	6137
1191	335	18952	Pestom Sagar (Amar Mahal Junction)	29038	496	1170
254	2909	16297	Garodia Nagar	29712	7438	198
316	351	16261	Pant Nagar	22472	325	412
720	957	16023	Laxmi Nagar	22559	632	931
8156	1828	22351	Amrut Nagar (Shreyas Cinema)	22859	4667	14815
1078	2404	21024	Ambewadi (Godrej Company)	33008	1300	2133
915	2030	19910	Vikhroli Metro	33840	2513	996
594	1322	19181	Surya Nagar	32324	1182	609
4043	1829	21395	Gandhi Nagar	31751	1689	5355
892	215	22072	Naval Housing	35417	979	1006
235	472	21835	Bhandup Mahapalika	35443	951	335
1654	937	22552	Bhandup Metro	34828	1211	3017
1224	2436	21341	Nahur Metro (Shagrila)	36635	8191	547
260	303	21297	Sonapur	28991	223	266
574	1038	20833	Mulund Fire Station	29034	1950	423
268	353	20749	Mulund Naka	27507	437	527
1245	2145	19849	Teen Hath Naka	27597	2580	1225
1073	1796	19126	RTO Thane	26242	1811	1994
1112	1784	18454	Thane Mahapalika Marg (Mahapalika Marg)	26425	1589	1889
1713	2096	18071	Siddheshwar Lake	26725	2726	2183

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
			(Cadbury Junction)			
1069	2245	16895	Majiwada	26182	2728	1265
2508	1073	18331	KapurBawdi	24719	819	872
8046	4682	21695	Manpada	24771	8219	8506
1130	3545	19280	Patli Pada (Tikuji Ni wadi)	25058	3963	2106
1118	2976	17421	Dongari pada	23201	3028	1669
0	2074	15348	Kavesar Gaon (Vijay Garden)	21843	3209	0
600	0	15948	kasarvadavali	18634	13	738
1156	1495	15609	Gowniwada	19359	2621	1253
0	15609	0	Gaimukh	17991	17991	0
68921	**68921**	**22552**	**PHPDT/Ridership**	**36635**	**100649**	**100648**
		Daily Ridership	**1695705**			

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- 12-2009. 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 and Train Control System

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 Corridor of Mumbai Metro Line 11 from Bhakti Park (Wadala) to CSMT Metro is planned to be operated at maximum safe speed of 90 Km/hr. The trains are to be maintained headway at every about 100 seconds. However, the signaling System shall be designed at minimum 90 second headway in one direction.

0.3.3.1 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 Line 11 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 equipment shall be connected to station equipment room through optical fiber network.
- The CBTC (Communication based Train Control) based system shall be provided in main line & depot (except workshop area) for train operation & primary mode of detection. Secondary detection shall be through Axle Counter.
- 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 Signalling System shall authorized movement of train in normal and degraded operations.
- Track side equipment 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 equipment by monitoring System status of trackside and train borne equipment and enabling preventive maintenance.
- Signalling & Train Control System on the line shall be designed to meet the required headway during peak hours.
- For monitoring inside train saloon, signaling system shall provide radio transmission media to transfer live streams to OCC controller on large video screen & MMI.
- 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. Signalling and Rolling Stock interfaces shall be provided for Passenger Gate System.

0.3.4 Telecommunication

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 & 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, Maintenance Control, Emergency Control, Assistance to Train Traffic Control.
- Data Channels for Signalling, SCADA, Automatic Fare Collection

- Power Supply of Telecommunications, and
- Cables for Telecommunications etc.

0.3.5 Automatic Fare Collection

0.3.5.1 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, amendable for quick fare changes and require overall less manpower. In view of the above computer based automatic fare collection system is proposed**.** Seamless ticketing is now being thought of for Mumbai Metro Rail.

Automatic Fare Collection 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.

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 AFC system shall be of Contactless Smart Token / Card type. For multiple journeys, the stored value smart card shall be utilized and for the single journey, the smart media shall be as utilized as contactless smart token. 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.

It is proposed, the smart NCMC (National Common Mobility card) standard model for implementation of AFC system in Mumbai Metro. The AFC system as per the guidelines issued by Govt of India shall enable seamless travel by different metros and other transport systems across the city besides retail shopping and purchases.

The AFC system shall support the EMV (Europay, MasterCard, and Visa) and RuPay based open loop ticketing following the NCMC standard model for interoperability with other operators by use of non-proprietary standard so that the interface is scalable to other networks (transit operator/ retail outlets/parking/Toll etc) in Mumbai.

The AFC equipments shall support EMV, RuPay, QR, NFC (Near field communication) based ticketing, integration of clearing house, smart card host system of Financial Institutions and integration of mobile application with AFC system.

0.3.5.2 Gate

Retractable Flap Type/Paddle Type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern systems internationally. All these gates will have a functionality of Auto Top on smart cards in case balance goes below the threshold value (as per choice / business rule).

The gate should also capable to NFC enabled Mobile Tickets or any latest type of Ticket media at the time of procurement/installation. The AFC system shall provide access control solutions, offering both access control devised and hardware which can be tailored to accept any ticket media readily available in market (Barcode, QR code, NFC etc).

0.3.5.3 Ticket Vending Machine (TVM)

The 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.

0.3.5.4 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.

0.3.5.5 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

0.3.5.6 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.

The proposed AFC system shall provide interfaces to other operators such as Suburban Rail, Bus, Waterway, 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 a Mass Rapid Transit System (MRTS).

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

Table 0.6 - Size of the coach

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

**Maximum length of coach over couplers/buffers = 23 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
8-car Train (from the year 2031 onwards): DMC+TC+MC+MC+TC+MC+TC+DMC

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

Table 0.6A Carrying Capacity of Medium Rail Vehicles

Particulars	Driving Motor car		Trailer car/Motor car		6 Car Train		8 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush	Normal	Crush
Seated	42	42	50	50	284	284	384	384
Standing	120	240	124	248	736	1472	984	1968
Total	162	282	174	298	1020	1756	1368	2352

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

The recommended performance parameters are:

Maximum Design Speed: 90 kmph
Maximum Operating Speed: 80 kmph
Max. Acceleration 1.0 m/s^2 (with AW3 load)
1.2 m/s^2 (with AW2 load)
Max. Deceleration 1.0 m/s^2 (with AW3 load)
1.1 m/s^2 (with AW2 load)
>1.35 m/s^2(Emergency Brake)

0.3.6.2 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.

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 (elevated section) and 300 m (underground section) but in extreme cases it can be reduced to 120 m (elevated section) and 200 m (underground section). Minimum curve radius at stations is specified as 1000 m.

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. 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 proposed extension all stations are on level gradient.

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.

0.4.1.3 Design Speed

The maximum sectional speed will be 80 km/h. The scheduled speed has been taken as 35 kmph.

0.4.2 Alignment

- First station of this extension is named as Chhatrapati Shivaji Maharaj Terminus (CSMT) Metro and last station is Ganesh Nagar. Since this corridor is South-West extension of Mumbai Metro corridor from Gaimukh to Wadala (Bhakti Park), thus Ganesh Nagar is not a terminal station rather it is followed by Wadala (Bhakti Park) Station.

- Chainage of Chhatrapati Shivaji Maharaj Terminus proposed metro station is taken as 0.0 for reference and dead end chainage of this station as (-) 530 m.

- Total length of this extension is 12.774 km. It is proposed as partly elevated and partly underground.

- Ten stations have been proposed on this extension of Gaimukh to Wadala (Bhakti Park) corridor. Names of stations are Chhatrapati Shivaji Maharaj Terminus, Carnac Bunder, Clock Tower, Wadi Bandar, Darukhana, Coal Bunder, Hay Bunder, Sewri Metro, BPT Hospital and Ganesh Nagar. 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 2098.1 m and 851.1 m respectively. No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

- This is an extension of Gaimukh to Wadala (Bhakti Park) corridor towards South-West direction.

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.

All stations will be two level stations. For elevated stations, the concourse comprising of passenger facilities and station facilities will be at lower level and the platforms on the higher level, whereas, for underground stations, the concourse will be at higher level and the platforms on the lower level. Stations on the road have been planned cantilever leaving 10.5 m road width either side of the median.

0.4.4 Terminals

Since this is an extension of Gaimukh to Wadala (Bhakti Park) corridor on Wadala (Bhakti Park) end. Thus this section has only one terminal station as mentioned below:

Chhatrapati Shivaji Maharaj Terminus

This Station is proposed to be underground. Scissors cross overs are proposed at the rear end of station.

Scissors Crossovers

Scissors Crossovers will be provided at the terminal station viz. Chhatrapati Shivaji Maharaj Terminus and before Wadala (Bhakti Park) station.

0.4.5 Depot

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

0.4.6 Construction Methodology

0.4.6.1 Underground Construction

For the underground section running under the road, cut and cover method of the underground construction can be employed for the construction of the underground sections. However keeping in view the inconvenience to the traffic movement, it is proposed to tunnel through by using Tunnel Boring Machine (TBM) or New Austrian Tunneling Method (NATM) in the overburden soil mass. Tunnel excavation for a major length of underground section is expected to be carried out by Tunnel Boring Machines. There is some length along the underground alignment where Cut & Cover method has been considered for construction before Switch Over Ramp (SOR). Tunnel boring machines (TBMs) capable of drilling through rock with a finished internal diameter of 5.6 m can be successfully employed for boring tunnels through this stratum. The tunnels are proposed with a minimum cushion cover of 6.0 m.

0.4.6.2 Viaduct–Elevated Structure

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 extension of Gaimukh to Wadala (Bhakti Park) corridor of Mumbai Metro, it is suggested to use Double U-Girder in the superstructure up to 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

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

Depth of Foundation-A foundation must have an adequate depth from considerations of adverse environmental influences. It must also be economically feasible in terms of overall structure. Keeping in view the type of the proposed structure and the subsoil strata, the length of pile may be about 7.5 to 15 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 1200 to 1500 mm diameter may be adopted.

Piles transmit foundation loads through soil strata of low bearing capacity to deeper soil having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance. The minimum diameter of pile should be 1000mm.

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

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

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 4 on Civil Engineering.

0.4.9 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)

0.4.9.1 Summary of Land Requirements

Abstract of land requirements for different components of this extension is given in **Table 0.8 and Table 0.9**.

Table 0.8 Summary of Permanent Land Requirement (All figures in Sq. m)

S.No.	Description	Govt.	Pvt.
1	Stations	12449.79	1556.28
2	Running Section	20584	6977
3	Ramp	3957	0
4	Depot	0	0
4	Staff Quarters	5000	0
5	Office Complex and OCC	0	0
6	RSS	5600	0
7	Ventilation Shaft	800	0
8	Mid Shaft	0	0
9	Ancillary Structure	3150	450
	Total	**51540.79**	**8983.28**

Total Permanent Land = 6.0524 ha
Permanent Land (Govt.) = 5.1541 ha
Permanent Land (Pvt.) = 0.8983 ha

Table 0.9 - Summary of Temporary Land Requirement (All figures in Sq. m)

S. No.	Description	Govt.	Pvt.
1	Temporary Office/ Site Office	4000	0
2	Segment Casting Yard	40000	0
3	For construction of UG Stations by cut and cover method	0	7674

4	Portion of alignment before start of Ramp by cut and cover method	4772	0
	Total	**48772**	**7674**

Total land required for temporary acquisition is **4.8772 ha (Govt.) and 0.7674 ha (Pvt.).**

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 Metro Corridor is from Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park). It is in the southern portion of the Mumbai. In fact this corridor is the southward extension of Gaimukh-Kasarvadavali-Wadala Corridor of Mumbai Metro.

This proposed extension of Gaimukh to Wadala Corridor consists of ten stations. Out of these ten stations, eight are underground and two are elevated. CSMT Metro station is proposed will be an Interchange Station. The placement of these stations has been done considering Right of way, land availability, location, proximity to the Institutions for better ridership and connectivity.

CSMT Metro station (underground) is proposed adjoining to an under-construction underground station of Mumbai Metro Line-3.. At this location concourse of both the stations are planned to be merged by entry structure connections. To attract maximum pedestrian traffic, station locations are finalised at the traffic nodal points.

0.5.1 Salient features

Salient features of a typical Metro 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 at elevated stations is determined by a critical clearance of 5.50-m under the concourse above the road intersection, allowing 3.00-m for the concourse height, about 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 at least 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.

9. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.

10. 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 and between platforms for transfer between lines.
    - Adequate capacity for passenger movements.

- Convenience, including good signage relating to circulation and orientation.
- Safety and security, including a high level of protection against accidents.

11. Following requirements have been taken into account:

    a. Minimum capital cost is incurred consistent with maximizing passenger attraction.
    b. Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
    c. 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.
    d. Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
    e. Provision of display of passenger information and advertising.

12. 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

13. 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.

14. 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:

Table 0.10 Station Accommodation Requirements

Non Public Area –at Station	
Station Control Room	Fire Tank & Pump room
Platform Supervisor's Booth	Staff Area
Station Master's Office	UPS and Battery Room
Traction Substation	Cleaner's Room
Information & Enquiries	Security Room
Signaling Room	Staff Toilets
Ticket Office	Refuse Store
Communication Room	Miscellaneous Operations Room
Ticket Hall Supervisor & Excess Fare Collection (Passenger Office	First Aid Room
Station Substation	

0.5.2 Station Types

Total Ten Stations have been planned on this extension. Out of Ten Stations, Eight are Underground and Two are Elevated. Concourse of all elevated stations is proposed along the roads with sufficient Right of way. The stations accommodate the passengers from the eastern port area of Mumbai. Average inter-station distance is 1.27 km approximately varying from 0.85 km to 2.1 km depending upon the site, operational and traffic constraints. List of Station is given in **Table 0.11.**

Table 0.11 List of Stations

S. No.	Station Name	Chainage	Interstation Distance (m)
1	Chhatrapati Shivaji Maharaj Terminus	0.000	
2	Carnac Bunder	1584.597	1584.597
3	Clock Tower	2473.963	889.366
4	Wadi Bundar	3620.461	1146.498
5	Darukhana	4598.000	977.539
6	Coal Bunder	5780.570	1182.570
7	Hay Bunder	6805.016	1024.446
8	Sewri Metro	7656.128	851.112
9	BPT Hospital	9754.193	2098.065
10	Ganesh Nagar	10722.095	967.902
	Wadala(Bhakti Park)	12694.115	1972.020

0.6 TRAIN OPERATION PLAN

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections.
- Economical & optimum train service frequency not only during peak period, but also during off-peak period.
- Optimization of train’s reliability for achieving best possible availability on line.
- A train consists of 6 coaches which will be augmented to 8 coaches in future.
- Multi-tasking of train operation and maintenance staff.

List of stations for the Mumbai Metro Line from CSMT Metro to Gaimukh is given below: -

Table 0.12 - Stations

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
0.	**Dead End**	-530			
1.	CHHATRAPATI SHIVAJI MAHARAJ TERMINUS	0.000	530.000	Underground	Interchange Station
2.	CARNAC BUNDER	1584.597	1584.597	Underground	

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
3.	CLOCK TOWER	2473.963	889.366	Underground	
4.	WADI BUNDER	3620.461	1146.498	Underground	
5.	DARUKHANA	4598.000	977.539	Underground	
6.	COAL BUNDER	5780.570	1182.570	Underground	
7.	HAY BUNDER	6805.016	1024.446	Underground	
8.	SEWRI METRO	7656.128	851.112	Underground	
9.	BPT HOSPITAL	9754.193	2098.065	Elevated	
10.	GANESH NAGAR	10722.095	967.902	Elevated	
11.	WADALA (BHAKTI PARK)	12694.115	1972.020	Elevated	Interchange Station
12.	WADALA TT	13694.115	1000.00	Elevated	
13.	ANIK NAGAR BUS DEPOT	14555.725	861.61	Elevated	
14.	SUMAN NAGAR	15634.115	1078.39	Elevated	
15.	SIDDHARTH COLONY	16688.545	1054.43	Elevated	
16.	AMAR MAHAL JUNCTION	18032.125	1343.58	Elevated	Interchange Station
17.	GARODIA NAGAR	18630.655	598.53	Elevated	
18.	PANT NAGAR	20263.335	1632.68	Elevated	
19.	LAXMI NAGAR	21340.845	1077.51	Elevated	
20.	SHREYES CINEMA	21961.655	620.81	Elevated	
21.	GODREJ COMPANY	23124.475	1162.82	Elevated	
22.	VIKHROLI METRO	23847.595	723.12	Elevated	
23.	SURYA NAGAR	24852.365	1004.77	Elevated	
24.	GANDHI NAGAR	25854.475	1002.11	Elevated	Interchange Station
25.	NAVAL HOUSING	26546.355	691.88	Elevated	
26.	BHANDUP MAHAPALIKA	27325.695	779.34	Elevated	
27.	BHANDUP METRO	28374.525	1048.83	Elevated	
28.	SHANGRILA	29218.175	843.65	Elevated	
29.	SONAPUR	30608.935	1390.76	Elevated	
30.	MULUND FIRE STATION	31721.915	1112.98	Elevated	
31.	MULUND NAKA	33070.015	1348.10	Elevated	

CSMT METRO TO GAIMUKH					
S. No	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
32.	TEEN HAATH NAKA (THANE)	34306.365	1236.35	Elevated	
33.	RTO THANE	34984.905	678.54	Elevated	
34.	MAHAPALIKA MARG	36020.875	1035.97	Elevated	
35.	CADBURY JUNCTION	36813.585	792.71	Elevated	
36.	MAJIWADA	37637.875	824.29	Elevated	
37.	KAPURBAWDI	39027.135	1389.26	Elevated	
38.	MANPADA	39892.515	865.38	Elevated	
39.	TIKUJI-NI-WADI	40668.165	775.65	Elevated	
40.	DONGARI PADA	42133.765	1465.60	Elevated	
41.	VIJAY GARDEN	43042.635	908.87	Elevated	
42.	KASARVADAVALI	44116.205	1073.57	Elevated	
43.	GOWNIWADA	45501.145	1384.94	Elevated	
44.	GAIMUKH	46784.235	1283.09	Elevated	
45.	**Dead End**	47684.235	450.00		

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 these corridors has been considered as: 35 kmph.

0.6.2 Train Formation

To meet the above projected traffic demand, the possibility of running trains with composition of 6 and 8 cars with different headway has been examined.

Composition

DMC : Driving Motor Car
TC : Trailer Car
MC : Motor Car

Capacity (@ 6 passengers per square meter of standee area)

Driving Motor Car (DMC)	-282 (42 seated + 240 standing)
Trailer Car (TC)	-298 (50 seated + 248 standing)
Motor Car (MC)	-298 (50 seated + 248 standing)
6 Car Train	- 1756 (284 seated + 1472 standing)
8 Car Train	- 2352 (384 seated + 1968 standing)

0.6.3 Year-Wise Rake Requirement

Based on the projected PHPDT demand, Train operation plan with train carrying capacity @ 6 persons per square meter of standee area for the Mumbai Metro Line: CSMT Metro-Gaimukh' for the year 2021 and 2031 is given below.

The PHPDT capacity provided on the route in different years of operation is tabulated below:

Table 0.13: Capacity Provided for CSMT Metro-Gaimukh

Sections	Year	Head-way (min)	Total No. of Rakes	Rake Consist	Total No. of Cars**	Provision for No. of cars in DPR of Sep'17	Additional No. of cars for Line- 11	Max. PHPDT Demand	PHPDT Capacity Available
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2021	6.50	46	6-car	276	232	44	17460	16209 (20677*)
Bhakti Park to Kapurbawdi		3.25						32460	32418 (41354*)
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2031	6.50	46	8-car	368	264	104	25058	21711 (27692*)
Bhakti Park to Kapurbawdi		3.25						36635	43422 (55385*)

***** *@ 8 persons per square meter of standee area*

*** Total No. of cars shown above are the total cars calculated as per PHPDT data.*

 # Additional cars requirement for Line-11 has been calculated after subtracting provision for no. of cars in previous Line-4 (Bhakti Park - Gaimukh) DPR (Sep'17) from the total car requirements.

0.7 MAINTENANCE DEPOT

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 equipment.

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 train 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 (preferably as close to depot as possible) to cater to the required stability facilities.
(v) In case of space constraint for depot two storeyed Stabling lines can also be planned.

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 all key Rolling Stock equipment by suitable advanced condition monitoring techniques available. 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.
- ➢ Increase in the periodic maintenance intervals with predictive maintenance based on condition monitoring.
- ➢ Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.
- ➢ Periodic review of maintenance practices to update replacement cycle of critical components based on experience.
- ➢ 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, ventilation fan & air-conditioning etc) and workshops in depots & other maintenance infrastructure within premises of metro system. The power requirements of Wadala (Bhakti Park) to CSMT Metro 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 parameters: -

(i) Specific energy consumption of rolling stock at Pantograph/ Current Collector – 50 kWh/1000 GTKM for 25 kV ac system as per MOUD guideline.
(ii) Elevated/at –grade station load – initially 250 kW, which will increase to 300 kW in the year 2031.
(iii) Auxiliary load of Underground station is of the order of 2200 kW initially, which will increase to 2500 kW in the year 2031.
(iv) Depot auxiliary load - initially 2000 kW, which will increase to 2200 kW in the year 2031.

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

Table 0.14 Power Demand Estimation (MVA)

Corridor	Load	Year	
		2021	**2031**
Line 11: Wadala (Bhakti Park) to CSMT Metro (8 Underground & 2 Elevated, 12.77 km)	Traction	4.96 MVA	6.62 MVA
	Auxiliary	22.67 MVA	25.82 MVA
	Total	**27.63 MVA**	**32.44 MVA**

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 this section.

The Mumbai Metro Corridors from Wadala (Bhakti Park) to CSMT Metro is 12.774 Km, which is Extension for Line 4 Corridor of Mumbai Metro Network from Gaimukh to Wadala (35 Km, 34 Elevated stations).

As per the Detailed Project Report for Line 4 Corridor from Gaimukh to Wadala (35 km, 34 Elevated stations), three RSS are planned at following locations:

a) At Gaimukh Depot,
b) Near RTO Thane Station and
c) Near Ghatkopar or Chembur Station.

In view of above planned Receiving Sub-Stations, one Receiving Sub-stations is proposed to cater to load of Wadala (Bhakti Park) to CSMT Metro Section. One RSS will be set up near Sewri Metro Station and the proposed RSS near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented for Emergency Supply in case of Failure of RSS near Sewri Metro Station.

This is an economical solution without compromising reliability. It is proposed to receive power supply for traction as well as auxiliary services from the following grid sub-stations of M/s TATA Power Ltd. at 110 kV voltage through cable feeders:

Table 0.15 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.	Wadala (Bhakti Park) to CSMT Metro	220/110 kV Parel Grid Sub-station or 220/110 kV Proposed Wadala Grid Substation of M/s TATA	Near Sewri Metro Station	2 to 3 km

*Note: Proposed RSS of near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented to meet the additional requirement of this Corridor.

DMRC has done a joint survey/ meeting with M/s MMRDA and M/s TATA Power Company Ltd on 04.06.18 & 05.06.18 for this section for feasibility of Power Supply. 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

Corridor	**Input Source**	**Peak demand – Normal (MVA)**		**Peak demand** – Emergency (MVA)**	
		Year (2021)	**Year (2031)**	**Year (2021)**	**Year (2031)**
Wadala (Bhakti Park) to CSMT Metro	RSS Near Sewri Metro Station				
	Traction	4.96	6.62	9.21	11.39
	Auxiliary	22.67	25.82	25.04	29.22
	Sub-total (A)	27.63	32.44	34.25	40.61
	RSS Near Ghatkopar or Chembur				
	Traction	8.49	9.53	13.45	16.15
	Auxiliary	4.73	6.74	27.40	32.56
	Sub-total (B)	13.22	16.27	40.85	48.71

******In case 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 techno-economic considerations, 25 kV AC traction system is suggested for Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park) (12.774 km) 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 160 kVA capacity at the elevated & 2X900 kVA capacity for underground stations respectively. The requirement of 900/1000 kVA DG set at underground station is dispensable if two 33/0.415 kV Auxiliary Sub-Stations are fed from two different Receiving Sub-Stations which are taking supply from different Grid Sub-Stations. This arrangement will comply with the requirements of NFPA 130, 70 and 110. In view of this, 380 kVA DG Set capacity at each underground station is sufficient for firefighting system and Emergency Lighting and Fire detection & Alarm System.

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

UPS Supply to also be considered for following emergency services:

- Emergency Lighting
- Fire Detection & Fire Alarm system.
- Station Control Room
- Control Supply

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.

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.

0.8.6 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.

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 30-38% 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 72.08 million units in initial years 2021, which will be about 85.74 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 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 for FY 2017 – 18 demand charges Rs 240/ kVA per month and energy charges Rs 7.13/ kWh for TATA company Ltd. 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 TUNNEL VENTILATION AND AIR-CONDITIONING SYSTEM

This chapter covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed corridor from CSMT Metro to Wadala (Bhakti Park). VAC System includes the following:

- Station Air-conditioning System
- Smoke Management System
- Tunnel Ventilation System
- Control and Monitoring facilities

0.9.1 Requirement for Ventilation and Air Conditioning

The underground stations are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide ventilation and air-conditioning in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the official;
- Removing body heat, obnoxious odors and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the tunnel;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, transformer, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Elevators, Escalators, Automatic Fare Collection Gates etc. working in the stations;
- Removing heat from air conditioning plant and Station sub-station and other equipments.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered to be appropriate. In winter season it may not be necessary to warm the ventilating air as the heat generated by the equipments within the station premises would be sufficient to maintain the comfort requirement.

0.9.2 Internal Design Conditions in Underground Stations

With tropical humid ambient conditions of Mumbai, it is essential to maintain appropriate conditions in the underground stations in order to provide a comfort and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the “Designed inside Conditions”.

The patrons will stay for much shorter durations in underground stations, the comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated is given out by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The ‘Effective Temperature’ criterion was used in selecting the comfort condition in earlier corridor of Mumbai and other Metro, in this criteria comfort is defined as the function of temperature and the air velocity experienced by a person. An index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient condition of the metabolic rate and is evaluated based on the changes to the surrounding ambient of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a underground section where the train headway is expected to be six minutes or less, then RWI is the preferred criterion.

0.9.3 Design parameters for VAC system

Based on the above discussion, the following VAC system design parameters are assumed in the present report.

(1) Outside ambient conditions

Based upon ISHRAE-2017 recommended design conditions for 1% criteria is as under

Summer :	34.9 DB, 23.1 WB
Monsoon:	30.9 DB, 27.4 WB

For Mumbai Metro Underground Corridor it is suggested to use 1% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 1% of the total time.

1. Inside design conditions

a.	Platform and Concourse areas:	27^{o}C at 55% RH

2. Tunnel design conditions

a.	Normal conditions	Max. average temperature DB 40^{o}C
b.	Congested conditions	Max. stratified temperature DB 50^{o}C

3. Minimum fresh air

a.	10% or 18 cmh/person	(In station public areas)

0.10 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

0.10.1 Objective and Scope of the Study

The objective of the 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 fundinng agencies. The scope of EIA includes the impacts resulting from pre-construction, during construction and operation phases of CSMT Metro- Wadala (Bhakti Park) 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. The MoEF, Government of India, Notification of 14th September 2006 and its amendment dated 1st December 2009 enlist projects in Schedule that require environmental clearance. However, as per the said notification Railway/ Metro projects do not require environmental clearance from MoEF.

0.10.2 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, minimum 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 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.

The standard methodology for the data collection, impact assessment and formulation of management plans is adopted. The national acts, legislation and laws along with guidelines were consulted with a view to ensuring compliance with various requirements. Environmental baseline data for environmental attributes from primary and secondary sources were collected and compiled. The primary sources include site visits, visual inspection, field studies, monitoring and analysis.

0.10.3 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.

0.10.4 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.

0.10.5 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. 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.

0.10.6 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.

0.11 MULTI MODAL TRAFFIC INTEGRATION

This is extension of Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) at Wadala(Bhakti Park) end. It is being extended from Wadala to CSMT Metro and length of this extension is 12.774 km. It is partly underground and partly elevated. Total Ten stations have been provided out of which eight are underground and two are elevated.

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.

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.

0.11.1 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.

0.12 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 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) "Harmonised Guidelines and Space Standards for Barrier Free Built Environment for Persons with Disabled and Elderly Persons", 2016 (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.

0.12.1 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

0.13 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.

0.13.1 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

0.13.2 Phases of Security

There are three phases of security as under:

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

0.14 DISASTER MANAGEMENT MEASURE

0.14.1 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.

0.14.2 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.

0.14.3 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.

0.14.4 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.

0.15 COST ESTIMATE

Project Cost estimates for Mumbai Metro Line No. 11 from Wadala (Bhakti Park) to CSMT Metro has been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction etc. at March 2018 price level.

The overall Capital Cost of Mumbai Metro Line-11 from Wadala (Bhakti Park) to CSMT Metro at March 2018 price level works out to **Rs. 6135 Crores** excluding applicable Taxes & Duties of **Rs. 950 crores** for Option-I and **Rs. 3248 Crores** excluding applicable Taxes & Duties of **Rs. 474 crores** for Option-II as tabulated hereunder.

Table 0.17 – Summary of Cost Estimate

Name of the section	Option	Capital Cost (Rs. Crore)	Taxes & Duties (Rs. Crore)	Total (Rs. Crore)
Wadala(Bhakti Park) to CSMT Metro	I	6135	950	7085
	II	3248	474	3722

Option-I: 8 Underground Stations and 2 Elevated Stations

Table 0.18 A - Capital Cost Estimate

Total length = 12.774 km
Ramp = 0.427 km; UG C&C = 0.236 km; UG TBM = 8.316 km; Elevated = 3.795 km
Total Station =10, Elevated = 2 & UG = 8

March 2018 level

S. No.	Item	Amount (Rs. in Cr.) Without taxes
1.0	Land and R & R incl. Hutments etc.	280.36
2.0	Alignment and Formation	1405.74
3.0	Station Buildings	2878.62
4.0	Depot Augmentation	19.63
5.0	P-Way	141.20
6.0	Traction & power supply incl. OHE , ASS etc. Excl. lifts & Escalators	187.82
7.0	Signalling and Telecom.	215.12
8.0	Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection	95.66
9.0	Rolling Stock (3.2 m wide Coaches)	396.00
10.0	Capital expenditure on security	5.24

S. No.	Item	Amount (Rs. in Cr.) Without taxes
11.0	Staff quarter for O & M	31.81
12.0	Capital expenditure on Multimodal Traffic Integration	26.50
13.0	**Total of all items except Land**	**5455.96**
14.0	**General Charges incl. Design charges @ 5 % on all items except land#**	**272.80**
15.0	**Total of all items including G. Charges except land**	**5728.76**
16.0	**Contingencies @ 3 %**	**171.86**
17.0	**Gross Total**	**5900.62**
	Cost without land	**5901**
	Cost with land including contingencies on land	**6135**

Table 0.18 B - Details of Taxes and Duties

Basic Customs duty = 5.1500
CGST Customs Duty = 9.4635
SGST Customs Duty = 9.4635
Total Customs Duty = 24.0770
General IGST = 12
General CGST = 6
General SGST = 6

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties		Total Taxes & Duties (Cr.)
			Total Customs Duty (Cr.)	Total GST (CGST & SGST) (Cr.)	
1	**Alignment & Formation**				
	Underground	1215.37	87.79	102.09	**189.88**
	Elevated	190.36		22.84	**22.84**
2	**Station Buildings**				
	a) Underground station-civil works	2118.96	153.05	177.99	**331.05**
	b) Underground station-EM works	581.44	70.00	34.89	**104.88**
	Elevated station - civil works	70.88		8.51	**8.51**
	Elevated station-EM works	18.10	0.87	1.74	**2.61**
3	**Depot**				
	Civil works	7.85	0.57	0.66	**1.23**
	EM and M&P works	11.78	0.57	1.70	**2.26**
4	**P-Way**	141.20	27.20	5.08	**32.28**
5	**Traction & power supply**				
	Traction and power supply	187.82	18.09	20.29	**38.37**
6	**S and T Works**				
	S & T	159.68	30.76	5.75	**36.50**
	AFC	55.44	10.01	2.49	**12.51**

	PSD	89.24	17.19	3.21	**20.40**
7	**R & R hutments**	52.63		6.32	**6.32**
8	**Misc.**				
	Civil works	111.98	0.00	13.44	**13.44**
	EM works	47.23	0.00	8.50	**8.50**
9	**Rolling stock**	396.00	57.47	5.86	**63.33**
10	**Rent on Temporary Land**	34.85		6.27	**6.27**
11	**General Charges**	272.80		49.10	**49.10**
	Total	**5763.61**	**473.56**	**476.73**	**950.29**
	Total taxes & Duties				**950**
Rate of Taxes & Duties on Total cost without taxes & duties					**16.49%**
Total Central GST & Basic Customs duty					525.79
Total State GST					424.50
Total Taxes & Duties					**950.29**

Option-II: 1 Underground Station and 9 Elevated Stations

Table 0.19 A - Capital Cost Estimate

Total length = 12.774km UG = 2.2 km; Elevated = 10.574km

Total Station =10, Elevated = 9 & UG = 1

March 2018 level

S. No.	Item	Amount (Rs. in Cr.) Without taxes
1.0	Land and R & R incl. Hutments etc.	280.36
2.0	Alignment and Formation	827.87
3.0	Station Buildings	784.92
4.0	Depot Augmentation	19.63
5.0	P-Way	141.20
6.0	Traction & power supply incl. OHE , ASS etc. Excl. lifts & Escalators	161.83
7.0	Signalling and Telecom.	221.56
8.0	Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection	116.75
9.0	Rolling Stock (3.2 m wide Coaches)	396.00
10.0	Capital expenditure on security	5.24
11.0	Staff quarter for O & M	31.81
12.0	Capital expenditure on Multimodal Traffic Integration	26.50
13.0	**Total of all items except Land**	**2785.94**
14.0	**General Charges incl. Design charges @ 5 % on all items except land#**	**139.30**
15.0	**Total of all items including G. Charges except land**	**2925.23**
16.0	**Contingencies @ 3 %**	**87.76**
17.0	**Gross Total**	**3012.99**
	Cost without land	**3013**
	Cost with land including contingencies on land	**3248**

Table 0.19 B - Details of Taxes and Duties

Basic Customs duty = 5.1500

CGST Customs Duty = 9.4635

SGST Customs Duty = 9.4635

Total Customs Duty = 24.0770
General IGST = 12
General CGST = 6
General SGST = 6

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties		Total Taxes & Duties (Cr.)
			Total Customs Duty (Cr.)	Total GST (CGST & SGST) (Cr.)	
1	**Alignment & Formation**				
	Underground	342.15	24.71	28.74	**53.45**
	Elevated	485.72		58.29	**58.29**
2	**Station Buildings**				
	a) Underground station-civil works	264.87	19.13	22.25	**41.38**
	b) Underground station-EM works	72.68	8.75	4.36	**13.11**
	Elevated station - civil works	305.94		36.71	**36.71**
	Elevated station-EM works	81.45	3.92	7.82	**11.74**
3	**Depot**	0.00		0.00	**0.00**
	Civil works	0.00	0.00	0.00	**0.00**
	EM and M&P works				
4	**P-Way**	7.85	0.57	0.66	**1.23**
5	**Traction & power supply**	11.78	0.57	1.70	**2.26**
	Traction and power supply	141.20	27.20	5.08	**32.28**
6	**S and T Works**				
	S & T	161.83	15.59	17.48	**33.06**
	AFC				
	PSD	159.68	30.76	5.75	**36.50**
7	**R & R hutments**	61.88	11.17	2.78	**13.96**
8	**Misc.**	59.98	11.55	2.16	**13.71**
	Civil works	52.63		6.32	**6.32**
	EM works				
9	**Rolling stock**	111.98	0.00	13.44	**13.44**
10	**Rent on Temporary Land**	68.32	0.00	12.30	**12.30**
11	**General Charges**	396.00	57.47	5.86	**63.33**
	Total	**2960.08**	**211.39**	**263.03**	**474.43**
	Total taxes & Duties				**474**
Rate of Taxes & Duties on Total cost without taxes & duties					**16.03%**
Total Central GST & Basic Customs duty					259.82
Total State GST					214.60
Total Taxes & Duties					**474.43**

0.16 FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

The Mumbai Metro Line Project (Wadla i.e. Bhakti Park to CSMT Metro station) is proposed to be constructed at an estimated cost of Rs.7085.00 Crore and Rs. 3722.00 Crore with all taxes and land cost for Option-I and II respectively. The route length of the proposed metro rail system and estimated cost at March 2018 price level without and with all taxes are placed in table 0.20 as under:

Table 0.20 Cost Details

Option	Name of Corridor	Distance (KMs)	Estimated cost without taxes (Rs/Crore)	Estimated cost with all taxes & land cost (Rs/Crore)
I	Wadala(Bhakti Park) to CSMT Metro	12.774	6135.00	7085.00
II			3248.00	3722.00

The estimated cost at March 2018 price level includes an amount of Rs.5.24 Crore as one-time charges of security personal towards cost of weapons, barricades, and handheld 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 01.04.2019 and is expected to be completed on 31.03.2024 with Revenue Opening Date (ROD) as 01.04.2024 for the corridors. 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 and all taxes & duties)

Figures in Rs. Crore

Financial Year	Estimated Cost including cost of land and all taxes & duties at March 2018 Price Level	Completion Cost including cost of land cost and all taxes & duties
2019-20	436.00	458.00
2020-21	776.00	856.00
2021-22	1116.00	1292.00
2022-23	1699.00	2065.00
2023-24	1699.00	2168.00
2024-25	1019.00	1366.00
2025-26	340.00	478.00
Total	**7085.00**	**8683.00**

The cost of Land of Rs. 319 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 2024-25 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 @14.00% once in every two years. The fare structure for the FY 2024-25 as per the proposed fare slabs is shown in the table 0.22 below:

Table 0.22 Fare Structure in 2024-25

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 2024-25	
SLAB	**FARE (Rs)**
0-3 km	10.00
3-12 km	20.00
12-18 km	30.00
18 km and More	40.00

Option-I

The **Financial Internal Rate of Return (FIRR) for this extension(CSMT-Wadala) alone with the incremental traffic** for 30 years business model including construction period is worked out as (-) 0.27% and hence on its own not viable due to major portion of this stretch being underground 1.68%.

As GoM considers the CSMT Wadala connectivity important to serve MbPT and other areas, DMRC has examined the financial viability of entire line between CSMT and Shivaji Chowk(CSMT-Wadala-Kasarvadavali-Gaimukh-Shivaji Chowk) with projected traffic as a whole and also the costs and cash flows taken for the respective stretches in earlier DPRs and also of this connection. The financial internal rate of return of complete line as above comes to 7.63 %.

Option-II

If only 2.2 km section of this corridor is planned underground with 1 underground station and rest of the corridor is planned to be elevated then the financial internal rate of return works out to 3.32%.

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 Central and State Government Control Delhi Metro Rail Corporation (DMRC) /Bangalore Metro Rail Corporation (BMRC)/Chennai Metro Rail Corporation (CMRL) etc.

(ii) Design, Built, Fund, Operate & Transfer (DBFOT), and
(iii) Public Private Partnership

SPV Model: - MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2. The funding pattern under this model (SPV) with sharing of overall taxes and duties, post GST in the ratio of 1:2 is placed in table 0.23:

Table 0.23 A: Funding pattern under SPV model (with all taxes and land) (Option-I)

Particulars	With Taxes & Duties	
	Amount	**% of contribution**
Equity By GOI	1282.00	15.33%
Equity By GOM	1282.00	15.33%
SD for Overall Taxes by GOM (2/3)	778.00	9.30%
SD for Overall Taxes by GOI (1/3)	391.00	4.67%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	4631.00	55.37%
Total	**8364.00**	**100.00%**
SD for Land by GOM	319.00	
Total	**8683.00**	
PTA for Interest During Construction @1.40% (*) by GOM	56.00	
Grand Total	**8739.00**	

(*) In the case of loan @12% from domestic borrowings, the IDC works out to Rs. 416 crore

Table 0.23 B: Funding pattern under SPV model (with all taxes and land) (Option-II)

Particulars	With Taxes & Duties	
	Amount	**% of contribution**
Equity By GOI	650.00	15.39%
Equity By GOM	650.00	15.39%
SD for Overall Taxes by GOM (2/3)	388.00	9.19%
SD for Overall Taxes by GOI (1/3)	195.00	4.62%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	2341.00	55.42%
Total	**4224.00**	**100.00%**
SD for Land by GOM	319.00	
Total	**4543.00**	
PTA for Interest During Construction @1.40% (*) by GOM	29.00	
Grand Total	**8739.00**	

Design, Built, Fund, Operate & Transfer (DBFOT) 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 Equity internal rate of return (EIRR) in the range of 16% to 18% or a comfort of guaranteed ridership.

The funding pattern under this model is given in table 0.24 as under: -

Table 0.24 Funding pattern under BOT – (16% EIRR)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	**% Of contribution**
VGF by GOI	1673.00	20.00%
VGF by GOM	6179.00	73.88%
Equity by Concessionaire	171.00	2.04%
Concessionaire's debt @12% PA	341.00	4.08%
Sub-Total	**8364.00**	**100.00%**
Land Free by GOM	319.00	
Sub-Total	**8683.00**	
IDC	112.00	
Grand Total	**8795.00**	

0.16.1 Recommendations

The FIRR for the corridor with all taxes but without grant as revenue from MbPT works out to (-) 0.27%. Hence this extension is not considered viable. However, FIRR of entire line from CSMT to Shiwaji Chowk with grant of Rs. 1839 Crore as revenue from MbPT in the years from 2019-20 to 2025 -26 is calculated as 7.63% and hence corridor with complete length up to Shivaji Chowk is viable. EIRR of entire line is also worked out as 17.41%.

FIRR for this independent corridor, if only 2.2 km is planned to be underground works out to 3.32% and EIRR in this case is 21.12%.

As per Metro Rail Policy 2017, issued by the Ministry of Housing and Urban Affairs, (MOH&UA), GOI, apart from financial viability, the economic and social viability of the project is also required to be assessed. The Economic Internal Rate of Return (EIRR) for any metro rail project proposal should be 14% and above for consideration of its approval. Accordingly, the metro corridors as discussed above are recommended for implementation provided the required EIRR works out to 14% or above.

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

Table 0.25

(Rs. in crore)

Particulars	SPV Model (Option-I)	DBFOT Model without additional PD Income	DBFOT Model with additional PD Income
GOI	1673.00	1673.00	1673.00
GOM	2379.00	6498.00	6285.00
Total	**4052.00**	**8171.00**	**7958.00**

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. However, the state government may also explore the other sources of revenue from Transit Oriented Development and Value Capture Financing, which will be made available to metro authorities to meet out the O&M Expenses and servicing the debt properly.

0.17 ECONOMIC APPRAISAL

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.

0.17.1 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.

0.17.2 Economic Performance Indicators

For Calculation of EIRR, Project period is considered from 2017 - 2048 due to amalgamation of all parts of this line in one as done in combined FIRR. EIRR of the entire line works out to 17.41 % and hence economically also viable.

If only 2.2 km is planned to be underground then EIRR of this section works out to 21.12%.

0.18 IMPLEMENTATION PLAN

It is recommended that the project be implemented fully as a Government funded. By this route the project can be completed at the shortest time and at the lowest cost. Moreover, line 4 is already being implemented by MMRDA as fully Government and this is the extension of the same line.

0.18.1 Implementation Schedule

A suggested project implementation schedule for Project Implementation is given in Table 0.27.

Table 0.27 Project Implementation Schedule

S. No.	Item of Work	Completion Date
1	Submission of Final DPR to State Govt.	D
2	Approval of DPR by State Government	D+0.5 month
3	Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+1 month
4.	Sanction of Project by GOI	D+2 months
5.	Selection of GC	D+12 months
6.	Tendering	D+24 months
7.	Implementation of the project	D+58 months
8.	Testing and Commissioning	D+59 months
9.	CMRS Sanction	D+60 months
10.	ROD	D+60 months

0.18.2 Institutional Arrangements

The State Govt. of Maharashtra will have to approve the implementation of the project by Mumbai Metropolitan Region Development Authority (MMRDA).

0.18.3 Legal Cover for Mumbai Metro

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

0.19 CONCLUSIONS

0.19.1 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 extend Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) to CSMT Metro at Wadala (Bhakti Park) end for implementation.

0.19.2 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.

0.19.3 Project Cost

Estimated Cost of the project at March 2018 price level is Rs.7085 Crore and Rs.3722 Crore with land and all the taxes and duties for option-I & option-II respectively and completion cost at 5% p.a. escalation is estimated to be Rs.8683 Crores and Rs.4543 Crores including land and all the taxes and duties, but excluding

IDC for Option-I and II respectively. It is Rs. 8739 Crore & Rs. 4572 Crore including IDC for Option-I and II respectively.

0.19.4 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.

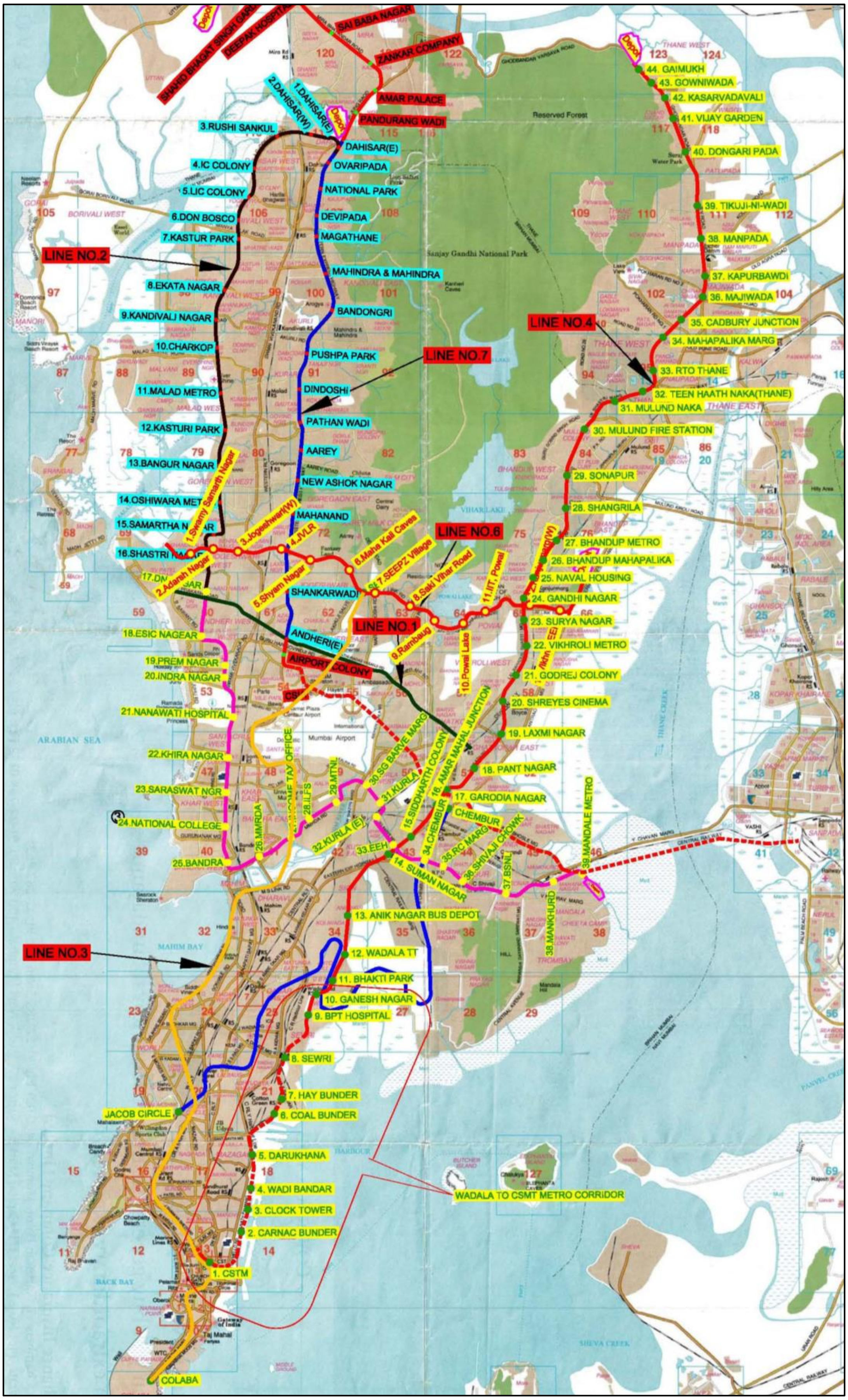
0.19.5 Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR):

The Financial Internal Rate of Return (FIRR) for the extension upto CSMT without grant as revenue from MbPT is worked out as -0.27% for Option-I. However, considering the total line from CSMT to Shivaji Chowk with MbPT contribution as grant (Revenue) is worked out as 7.63%. The EIRR works out to 17.41%.

For Option-II, FIRR works out to 3.32% and EIRR works out to 21.12%.

0.20 Conclusion:

This extension is recommended for implementation with the entire line and with the contribution from MbPT as taken in FIRR. However, it is also recommended that significant development in MbPT area should be made to get the full utility of this extended length and also to get the requisite ridership.


LINE NO.2
LINE NO.7
LINE NO.4
LINE NO.6
LINE NO.1
LINE NO.3
WADALA TO CSMT METRO CORRIDOR
Depot
SHAHID BHAGAT SINGH GARDEN
DEEPAK HOSPITAL
SAI BABA NAGAR
ZANKAR COMPANY
AMAR PALACE
PANDURANG WADI
1.DAHISAR(E)
2.DAHISAR(W)
3.RUSHI SANKUL
4.IC 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
16.SHASTRI NAGAR
17.D.N. NAGAR
18.ESIC NAGEAR
19.PREM NAGAR
20.INDRA NAGAR
21.NANAWATI HOSPITAL
22.KHIRA NAGAR
23.SARASWAT NGR
24.NATIONAL COLLEGE
25.BANDRA
26.MMRDA
27.INCOME TAX OFFICE
28.ILFS
29.MTNL
30.SG BARVE MARG
31.KURLA
32.KURLA (E)
33.EEH
34.CHEMBUR
35.RC MARG
36.SHIVAJI CHOWK
37.BSNL
38.MANKHURD
39.MANDALE METRO
DAHISAR(E)
OVARIPADA
NATIONAL PARK
DEVIPADA
MAGATHANE
MAHINDRA & MAHINDRA
BANDONGRI
PUSHPA PARK
DINDOSHI
PATHAN WADI
AAREY
NEW ASHOK NAGAR
MAHANAND
SHANKARWADI
ANDHERI(E)
AIRPORT COLONY
CSIA
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)
44. GAIMUKH
43. GOWNIWADA
42. KASARVADAVALI
41. VIJAY GARDEN
40. DONGARI PADA
39. TIKUJI-NI-WADI
38. MANPADA
37. KAPURBAWDI
36. MAJIWADA
35. CADBURY JUNCTION
34. MAHAPALIKA MARG
33. RTO THANE
32. TEEN HAATH NAKA(THANE)
31. MULUND NAKA
30. MULUND FIRE STATION
29. SONAPUR
28. SHANGRILA
27. BHANDUP METRO
26. BHANDUP MAHAPALIKA
25. NAVAL HOUSING
24. GANDHI NAGAR
23. SURYA NAGAR
22. VIKHROLI METRO
21. GODREJ COLONY
20. SHREYES CINEMA
19. LAXMI NAGAR
18. PANT NAGAR
17. GARODIA NAGAR
16. AMAR MAHAL JUNCTION
15.SIDDHARTH COLONY
14. SUMAN NAGAR
13. ANIK NAGAR BUS DEPOT
12. WADALA TT
11. BHAKTI PARK
10. GANESH NAGAR
9. BPT HOSPITAL
8. SEWRI
7. HAY BUNDER
6. COAL BUNDER
5. DARUKHANA
4. WADI BANDAR
3. CLOCK TOWER
2. CARNAC BUNDER
1. CSTM
CHEMBUR
JACOB CIRCLE
COLABA
ARABIAN SEA
MAHIM BAY
BACK BAY
HARBOUR
Sanjay Gandhi National Park
Reserved Forest
THANE WEST
THANE EAST
BORIVALI WEST
VIHAR LAKE
Mumbai Airport

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 km 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. Subsequently, the corridors 2 & 3 were rearranged and DMRC prepared another DPR for the corridor between Charkop – Bandra – Mankhurd

In spite of above, the implementation of Mumbai metro remained very slow. So far only one line between Varsova – Andheri – Ghatkopar could be implemented. Other corridors presently under implementation are

•	Colaba to Aarey Colony via International Airport.	30.00km
•	Dahisar (E) to DN Nagar	18.60km
•	Dahisar (E) to Andheri(E)	16.48km
•	DN Nagar to Mandale	23.64km
•	Wadala – Ghatkopar – Mulund – Thane – Kasarvadavali	32.32km
•	Swami Samarth Nagar to Vikhroli(EEH)	14.48km
	Total	**135.52km**

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 - 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:

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 – Kanjur Marg	10.00
	(c) Andheri (E) – BKC (Via WEH)	9.00
	Total	**118.00**

Out of 118 km Master Plan network, the work of implementation of about 106 km has already been started by MMRDA.

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 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.

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% during 1971-81 to 2.58% in 1991-2001.

TABLE 1.1: 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)	**6.87**	**9.81**	**12.86**	**16.65**		**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**	**0.40**	**0.77**		**5.24**	**14.87**	**6.77**	
	Raigad District									

Sr. No.	Area	Population					Annual Compound growth rate (%)			
		1971	1981	1991	2001	2011*	1971-1981	1981-1991	1991-2001	2001-2011
C	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		0	7.18	4.14	
	Uran			0.02	0.03		0		4.14	
	Sub Total (C)	**0.053**	**0.09**	**0.19**	**0.28**		**5.82**	**7.56**	**3.52**	
C	**Urban MMR (A+B+C)**	**6.98**	**10.00**	**13.45**	**17.70**		**4.04**	**3.08**	**2.84**	
D	**Rural MMR**	**1.08**	**1.25**	**1.16**	**1.05**		**1.47**	**-0.74**	**-0.99**	
E	**Grand Total**	**8.06**	**11.25**	**14.61**	**18.75**		**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 offer 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-car rake during peak hours, as against the rated carrying capacity of 1,700, having Dense Crush Load of 14 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	251 km
- Monorail Network	179 km
- Suburban Rail Network	237 km

Total	667 km

Of the total network, the metro corridors are being by MMRDA/MMRC are shown in Figure **1.2**.

1.4 STUDY OBJECTIVES

The objective of the assignment is to review, update & prepare Detailed Project Report (DPR) for the proposed Wadala (Bhakti Park) to Kasarvadavali 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 pedestrianization in the influence area of stations as available in the existing DPRs

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, firefighting 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 19 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 including route alignment, Geometric Design parameters, geotechnical investigation, construction methodology, land details and utility details etc.

v. Chapter five consists Station Planning.

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 deals with Tunnel Ventilation and Air conditioning System.

x. Chapter ten presents the environment impact assessment and social impact assessment of the proposed metro rail corridor.

xi. Multi Model Traffic integration at metro station is presented in chapter eleven.

xii. Chapter twelve consists friendly features for differently abled.

xiii. Chapter thirteen is on Security Measures for a metro system

xiv. Chapter fourteen is on Disaster Management Measures.

xv. Cost estimate is in chapter fifteen.

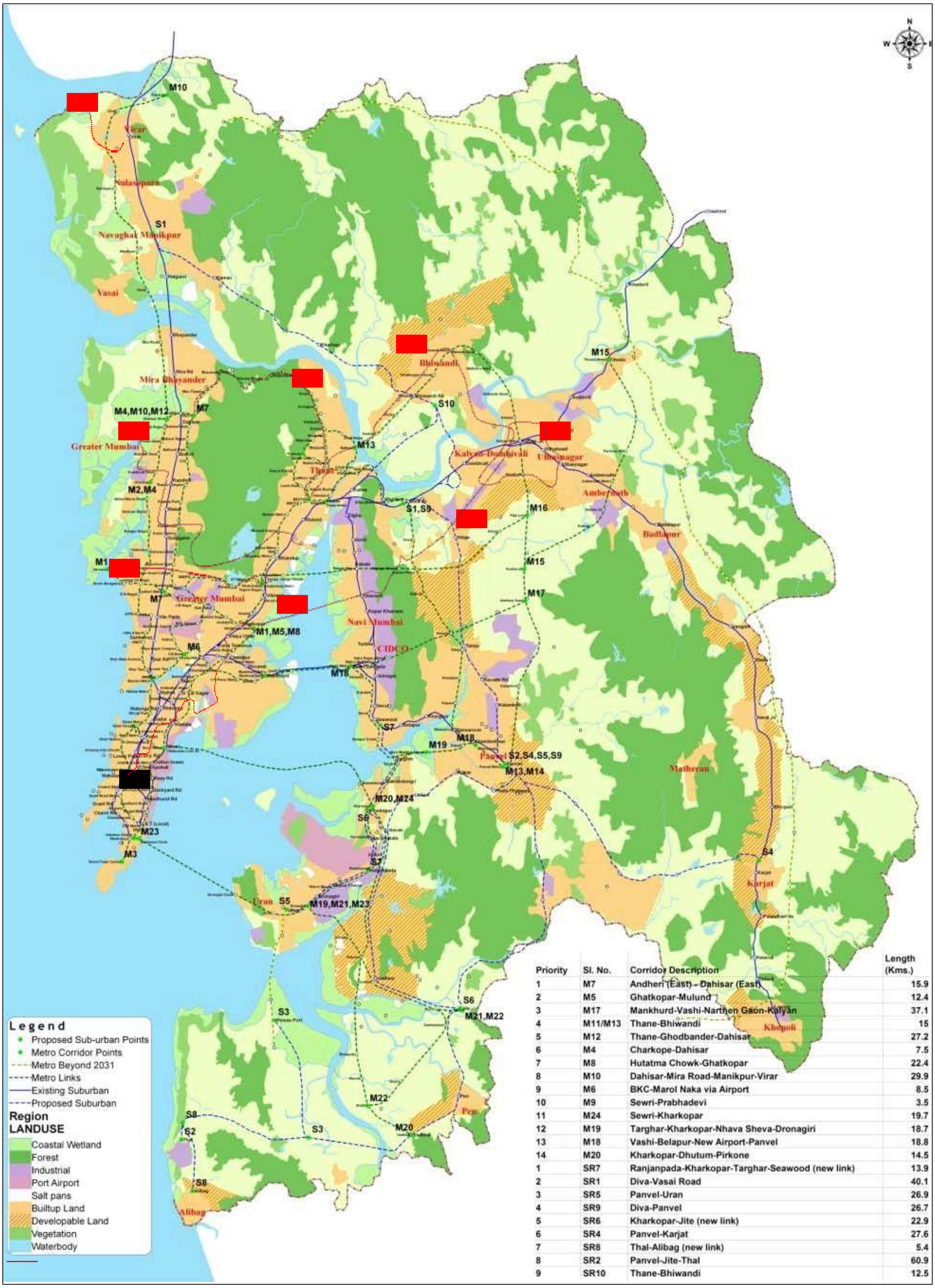
xvi. Chapter sixteen presents the financial analysis, financial viability, financing options.

xvii. Chapter seventeen is on economic appraisal

xviii. Chapter eighteen is on implementation strategies.

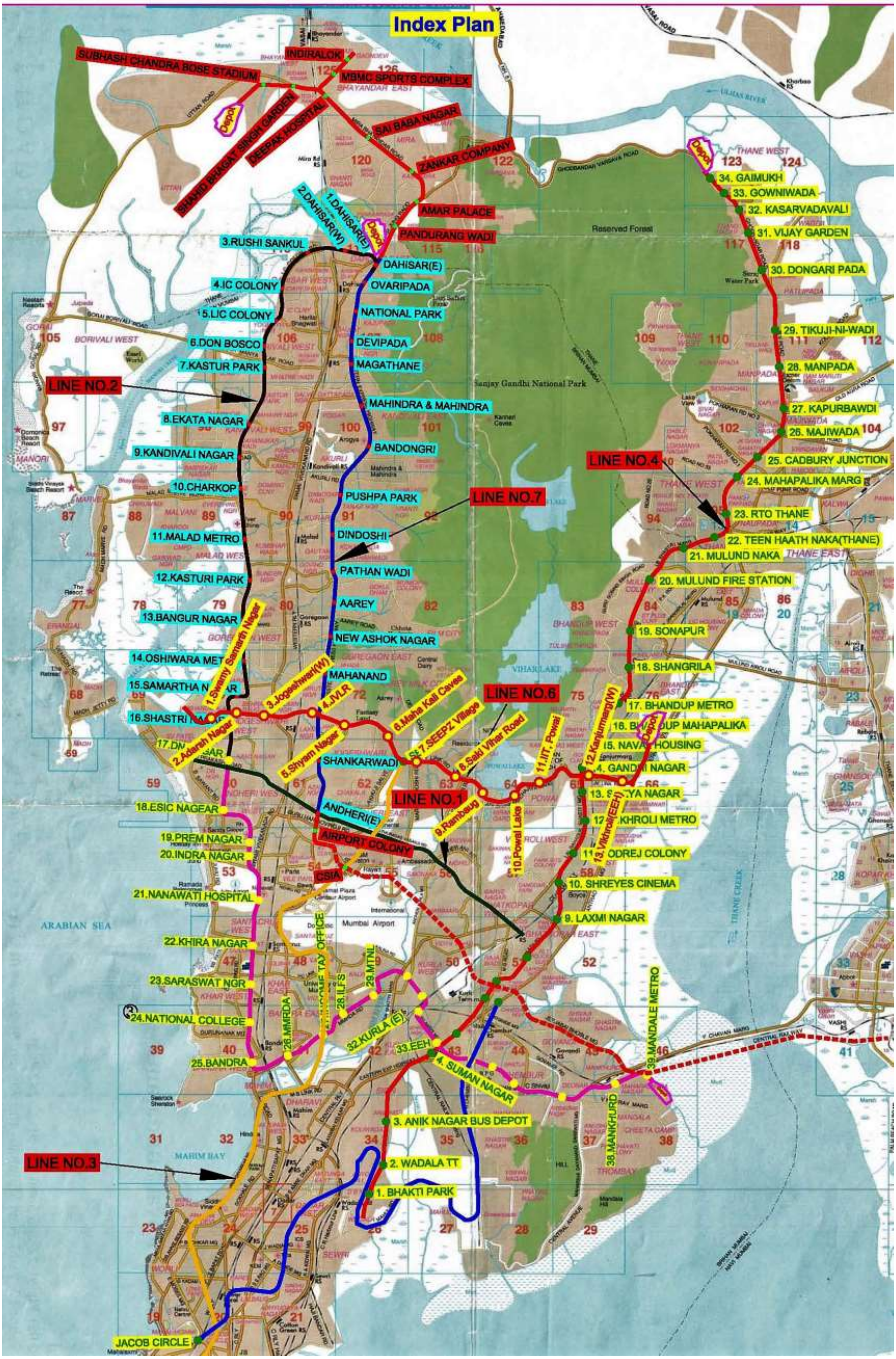
xix. Chapter nineteen consists conclusions and recommendations

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
SUBHASH CHANDRA BOSE STADIUM
INDIRALOK
MBMC SPORTS COMPLEX
SHAHID BHAGAT SINGH GARDEN
DEEPAK HOSPITAL
SAI BABA NAGAR
ZANKAR COMPANY
AMAR PALACE
PANDURANG WADI
Depot
1.DAHISAR(E)
2.DAHISAR(W)
3.RUSHI SANKUL
4.IC 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
16.SHASTRI NAGAR
17.DN NAGAR
18.ESIC NAGEAR
19.PREM NAGAR
20.INDRA NAGAR
21.NANAWATI HOSPITAL
22.KHIRA NAGAR
23.SARASWAT NGR
24.NATIONAL COLLEGE
25.BANDRA
26.MMRDA
27.INCOME TAX OFFICE
28.ILFS
29.MTNL
32.KURLA (E)
33.EEH
4. SUMAN NAGAR
3. ANIK NAGAR BUS DEPOT
2. WADALA TT
1. BHAKTI PARK
JACOB CIRCLE
LINE NO.2
LINE NO.3
LINE NO.7
LINE NO.1
LINE NO.6
LINE NO.4
DAHISAR(E)
OVARIPADA
NATIONAL PARK
DEVIPADA
MAGATHANE
MAHINDRA & MAHINDRA
BANDONGRI
PUSHPA PARK
DINDOSHI
PATHAN WADI
AAREY
NEW ASHOK NAGAR
MAHANAND
SHANKARWADI
ANDHERI(E)
AIRPORT COLONY
CSIA
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)
34. GAIMUKH
33. GOWNIWADA
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
14. GANDHI NAGAR
13. SURYA NAGAR
12. VIKHROLI METRO
11. GODREJ COLONY
10. SHREYES CINEMA
9. LAXMI NAGAR
38. MANKHURD
39. MANDALE METRO
Sanjay Gandhi National Park
Reserved Forest
ARABIAN SEA
MAHIM BAY
Mumbai Airport
VIHAR LAKE
THANE CREEK
ULHAS RIVER
BORIVALI WEST
THANE WEST
THANE EAST

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 land use 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%

Employment	Survey (2005)	Projected (2031)
Other Employment		
Residential		
Film Industry	12.1%	5.0%
Shop	0.8%	0.5%
Restaurant/Eating Place	14.6%	8.0%
Hotel	0.6%	0.5%
Entertainment/Tourism	1.2%	1.3%
Place of Education	0.8%	0.8%
Health Facility	2.0%	2.0%
Agriculture	1.6%	1.5%
Construction Site	0.7%	0.2%
Varies day to day	1.3%	1.5%
Others	8.4%	5.2%
	5.6%	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

Mumbai Port Trust Redevelopment Master Plan

Metro Line from CSMT to Wadala passes through the Mumbai Port Trust area which is envisaged to be redeveloped into major commercial and entertainment hub. The area spans to about 10 kms in length along the eastern coast having an area of about 500 Ha for redevelopment. The draft masterplan proposes to develop a new financial centre, Government office, hotels, commercial as well as residential properties in close proximity to the proposed metro line 11 and the existing sub-urban railway stations. The waterfront area is also proposed as a tourist and recreational zone which will have features such as the Mumbai Eye, Tourist Ferry Services, Cruises and Ropeway Connection to Elephanta Caves among other things.

Entire planning area is divided into 4 zones. Following are the zone wise projected population and employment of the area:

S. No.	Description	Zone 1	Zone 2	Zone 3	Zone 4	Total
A	Total developable Area	35,38,600	1,30,600	3,90,900	937,200	49,97,300
B	Estimated Residential Population	1,76,488	6,514	19,496	46,743	2,49,240
C	Estimated commercial Population	75,301	2,779	8,318	19,944	1,06,343
D	**Total population**	**2,51,789**	**9,293**	**27,814**	**66,686**	**3,55,583**

The estimated addition to trips based on the above estimations have been considered while estimating the ridership figures.

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 generalized 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.

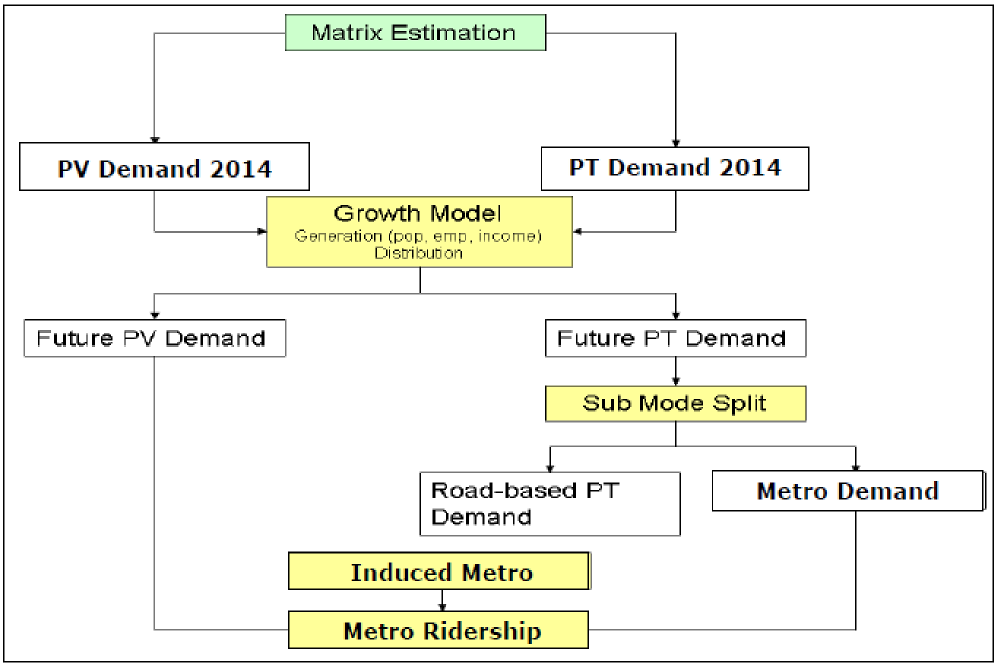
Figure 2.1 shows the progression of the model structure from the 2014 structure in which separate demand matrices for private and public transport were developed from observed data.

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.

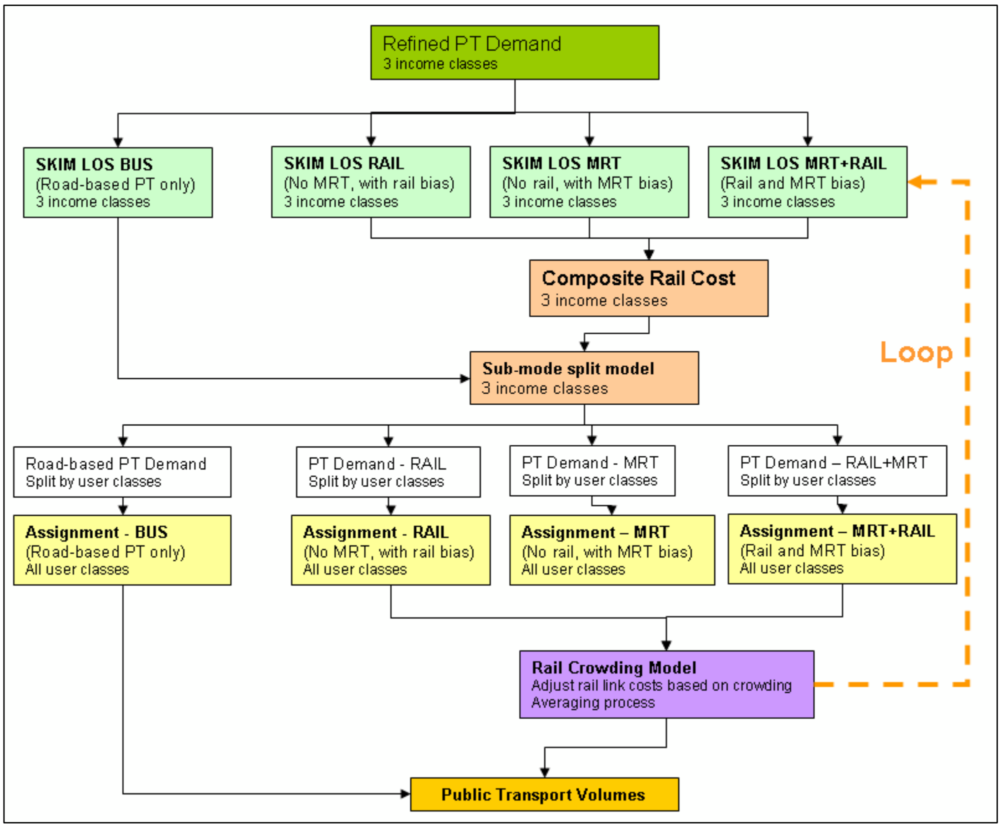
Road Network Assumptions

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 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 mass transit corridors have been considered;
  - Monorail at Wadala
  - Monorail at Chembur
  - Lokmanya Tilak Terminus with LTT Metro
  - Suburban Stations at Vikhroli and Kanjur Marg
  - Metro at Kanjur Marg
  - Monorail/Metro at Kasarvadavali
- 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** and **2.9**.

Table 2.8 Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2021

Boarding	Alighting	Vol (CSMT Metro-Gaimukh)	Stations	Vol (Gaimukh-CSMT Metro)	Boarding	Alighting
2004	0	2004	CSMT Metro	0	0	7522
42	1	2045	Carnac Bunder	7522	8	104
293	46	2292	Clock Tower	7617	143	368
849	55	3086	Wadi Bunder	7843	320	703
695	72	3710	Darukhana	8225	238	671
171	8	3873	Coal Bunder	8659	56	147
894	72	4695	Hay Bunder	8749	158	404
258	112	4841	Sewri Metro	8995	101	604
3970	761	8050	BPT Hospital	9498	1713	3753
1456	233	9273	Ganesh Nagar	11538	776	777
1845	1593	9525	Wadala RTO (Bhatkti Park Metro)	11539	363	10631
2872	1914	10483	Wadala TT	21807	2426	5325
670	429	10724	Anik Nagar (Anik Nagar Bus Dept)	24706	813	1011
1638	300	12062	Suman Nagar	24904	867	1801
3165	791	14435	Siddharth Colony	25838	1208	5419
2561	180	16816	Pestom Sagar (Amar Mahal Junction)	30049	418	2705
479	173	17122	Garodia Nagar	32336	372	497
74	96	17099	Pant Nagar	32460	233	93

Boarding	Alighting	Vol (CSMT Metro-Gaimukh)	Stations	Vol (Gaimukh-CSMT Metro)	Boarding	Alighting
519	531	17087	Laxmi Nagar	32321	446	452
2894	5839	14141	Amrut Nagar (Shreyas Cinema)	32326	14471	3663
957	329	14770	Ambewadi (Godrej Company)	21519	879	1164
496	1394	13872	Vikhroli Metro	21803	1776	823
144	245	13771	Surya nagar	20851	629	356
1504	2207	13068	Gandhi nagar	20578	2370	1661
0	41	13027	Naval Housing	19868	170	0
2439	48	15417	Bhandup mahapalika	19699	14	2984
380	449	15348	Bhandup Metro	22669	1027	219
2423	948	16823	Nahur Metro (Shagrila)	21860	2026	4794
548	675	16696	Sonapur	24629	907	579
132	53	16775	Mulund Fire Station	24301	243	41
515	851	16440	Mulund Naka	24099	694	967
719	1163	15995	Teen Hath Naka	24372	1658	641
1116	3208	13903	RTO Thane	23355	4175	1310
1072	1037	13938	Thane Mahapalika Marg (Mahapalika Marg)	20489	1370	920
31	721	13248	Siddheshwar Lake (Cadbury Junction)	20039	515	116
899	1155	12992	Majiwada	19640	2056	1140
574	2081	11485	Kapurbawdi	18724	1940	677
545	1099	10931	Manpada	17460	1862	610
1783	620	12094	Patli Pada (Tikuji Ni wadi)	16209	2404	2317
599	2429	10264	Dongari pada	16122	2793	1084
648	1499	9413	Kavesar Gaon (Vijay Garden)	14413	2757	873
424	1808	8029	kasarvadavali	12530	2690	540
426	1557	6898	Gowniwada	10380	1906	641
0	6898	0	Gaimukh	9115	9115	0
45721	**45722**	**17122**	**PHPDT/Ridership**	**32460**	**71101**	**71102**
			Daily Ridership	**1168242**		

Trip Length Distribution CSMT Metro - Gaimukh -2021		
Stage	**No. of Trips**	**%**
<=2	3649	3.12
<=4	13969	11.96
<=6	9892	8.47
<=9	26949	23.07
<=12	16287	13.94
<=15	14699	12.58
<=18	11252	9.63
<=21	7418	6.35

Trip Length Distribution CSMT Metro - Gaimukh -2021		
Stage	**No. of Trips**	**%**
<=24	4320	3.7
<=27	3743	3.2
<=30	2045	1.75
<=35	1459	1.25
<=40	672	0.57
>40	470	0.4
	116824	**100**

Table 2.9 Peak Hr. Ridership for Metro Line (CSMT Metro - Wadala – Kasarvadavali - Gaimukh) for Horizon year 2031

Boarding	Alighting	Vol (CSMT Metro-Gaimukh)	Stations	Vol (Gaimukh-CSMT Metro)	Boarding	Alighting
2366	0	2366	CSMT Metro	0	0	7211
473	165	2674	Carnac Bunder	7211	2347	145
205	186	2693	Clock Tower	5009	120	392
655	294	3054	Wadi Bunder	5281	304	701
820	266	3608	Darukhana	5678	379	1226
95	4	3699	Coal Bunder	6525	7	151
546	19	4225	Hay Bunder	6669	42	221
257	403	4080	Sewri Metro	6848	427	1141
4683	755	8008	BPT Hospital	7563	1879	4172
1804	184	9627	Ganesh Nagar	9855	649	894
2336	1317	10646	Wadala RTO (Bhatkti Park Metro)	10100	320	12234
2990	1002	12633	Wadala TT	22013	1330	6048
617	340	12910	Anik Nagar (Anik Nagar Bus Dept)	26732	438	1064
1724	582	14052	Suman Nagar	27358	1433	2472
6210	2166	18096	Siddharth Colony	28397	5496	6137
1191	335	18952	Pestom Sagar (Amar Mahal Junction)	29038	496	1170
254	2909	16297	Garodia Nagar	29712	7438	198
316	351	16261	Pant Nagar	22472	325	412
720	957	16023	Laxmi Nagar	22559	632	931
8156	1828	22351	Amrut Nagar (Shreyas Cinema)	22859	4667	14815
1078	2404	21024	Ambewadi (Godrej Company)	33008	1300	2133
915	2030	19910	Vikhroli Metro	33840	2513	996
594	1322	19181	Surya Nagar	32324	1182	609
4043	1829	21395	Gandhi Nagar	31751	1689	5355
892	215	22072	Naval Housing	35417	979	1006
235	472	21835	Bhandup Mahapalika	35443	951	335
1654	937	22552	Bhandup Metro	34828	1211	3017
1224	2436	21341	Nahur Metro (Shagrila)	36635	8191	547
260	303	21297	Sonapur	28991	223	266
574	1038	20833	Mulund Fire Station	29034	1950	423
268	353	20749	Mulund Naka	27507	437	527

Boarding	Alighting	Vol (CSMT Metro-Gaimukh)	Stations	Vol (Gaimukh-CSMT Metro)	Boarding	Alighting
1245	2145	19849	Teen Hath Naka	27597	2580	1225
1073	1796	19126	RTO Thane	26242	1811	1994
1112	1784	18454	Thane Mahapalika Marg (Mahapalika Marg)	26425	1589	1889
1713	2096	18071	Siddheshwar Lake (Cadbury Junction)	26725	2726	2183
1069	2245	16895	Majiwada	26182	2728	1265
2508	1073	18331	KapurBawdi	24719	819	872
8046	4682	21695	Manpada	24771	8219	8506
1130	3545	19280	Patli Pada (Tikuji Ni wadi)	25058	3963	2106
1118	2976	17421	Dongari pada	23201	3028	1669
0	2074	15348	Kavesar Gaon (Vijay Garden)	21843	3209	0
600	0	15948	kasarvadavali	18634	13	738
1156	1495	15609	Gowniwada	19359	2621	1253
0	15609	0	Gaimukh	17991	17991	0
68921	**68921**	**22552**	**PHPDT/Ridership**	**36635**	**100649**	**100648**
		Daily Ridership	**1695705**			

Trip Length Distribution CSMT Metro - Gaimukh -2031		
Stage	**No. of Trips**	**%**
<=2	13727	8.09
<=4	24612	14.51
<=6	15468	9.12
<=9	26535	15.65
<=12	38269	22.57
<=15	17150	10.11
<=18	9987	5.89
<=21	10442	6.16
<=24	4747	2.8
<=27	4545	2.68
<=30	1848	1.09
<=35	1172	0.69
<=40	653	0.38
>40	416	0.25
	169570	**100**

CHAPTER – 3

SYSTEM DESIGN

3.0 INTRODUCTION

This is an extension of Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) towards South-West direction. It is being extended from Wadala (Bhakti Park) to CSMT and length of this extension is 12.774 km which is partly elevated and partly underground. Total Ten stations have been provided out of which Two are Elevated and Eight are Underground.

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

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- 12-2009. 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 Main Lines

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 ~65cm, on viaducts complying of performance criteria laid down by Railway Board vide letter Circular No. 2009/Proj/InAs/9/2, dated 02.05.2010.

In the underground section similar track structure with base plate spacing ~70cm is proposed on slab after first stage concrete.

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 meter 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 meter 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.

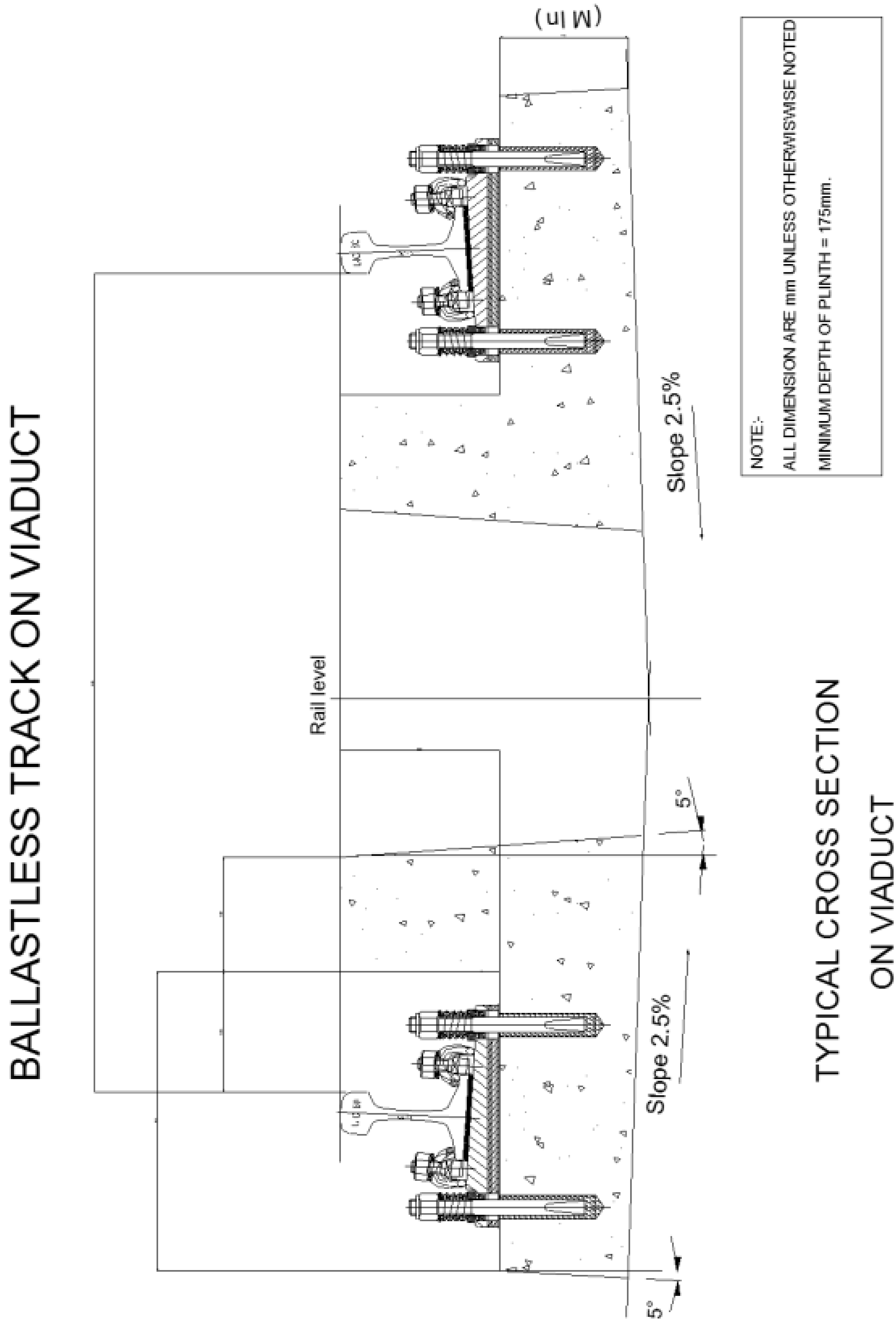
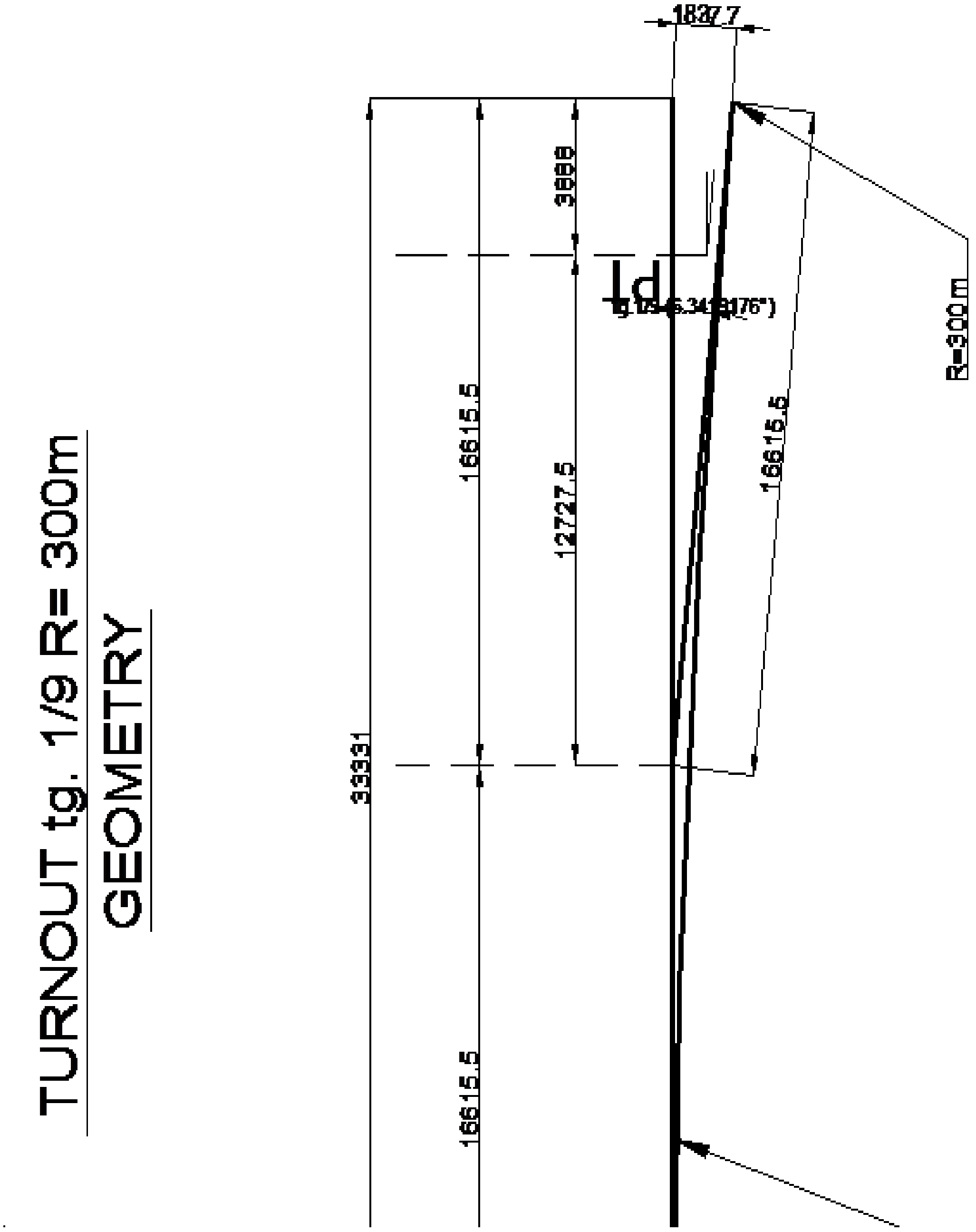


Fig No. 3.1

Fig No. 3.2


TURNOUT tg. 1/9 R= 300m
GEOMETRY
1827.7
3888
16615.5
12727.5
33331
16615.5
16615.5
ld
tg.1/9 (6.341176")
R=300 m

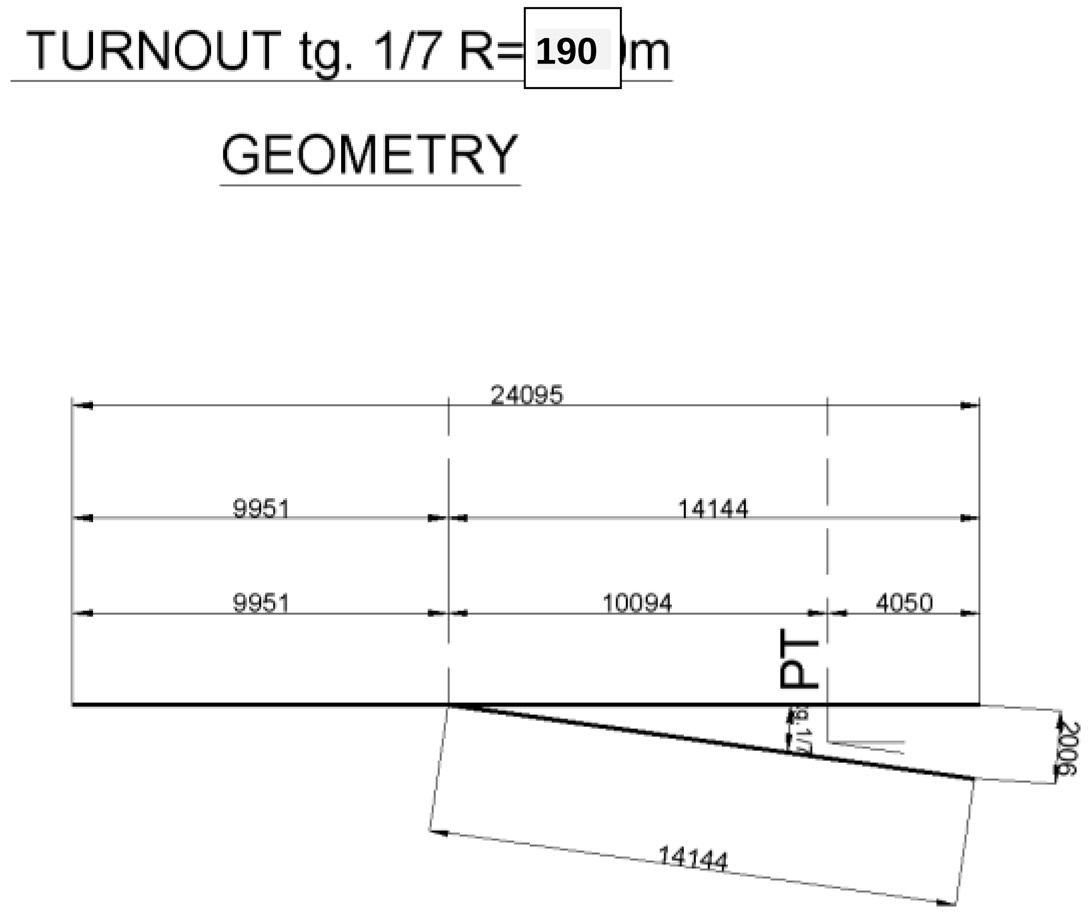

TURNOUT tg. 1/7 R=190m
GEOMETRY
24095
9951
14144
9951
10094
4050
PT
tg.1/7
2006
14144

Fig No. 3.3

DOUBLE CROSSOVER tg. 1/9 R= 300m C.L. 4500

AXLE SCHEME

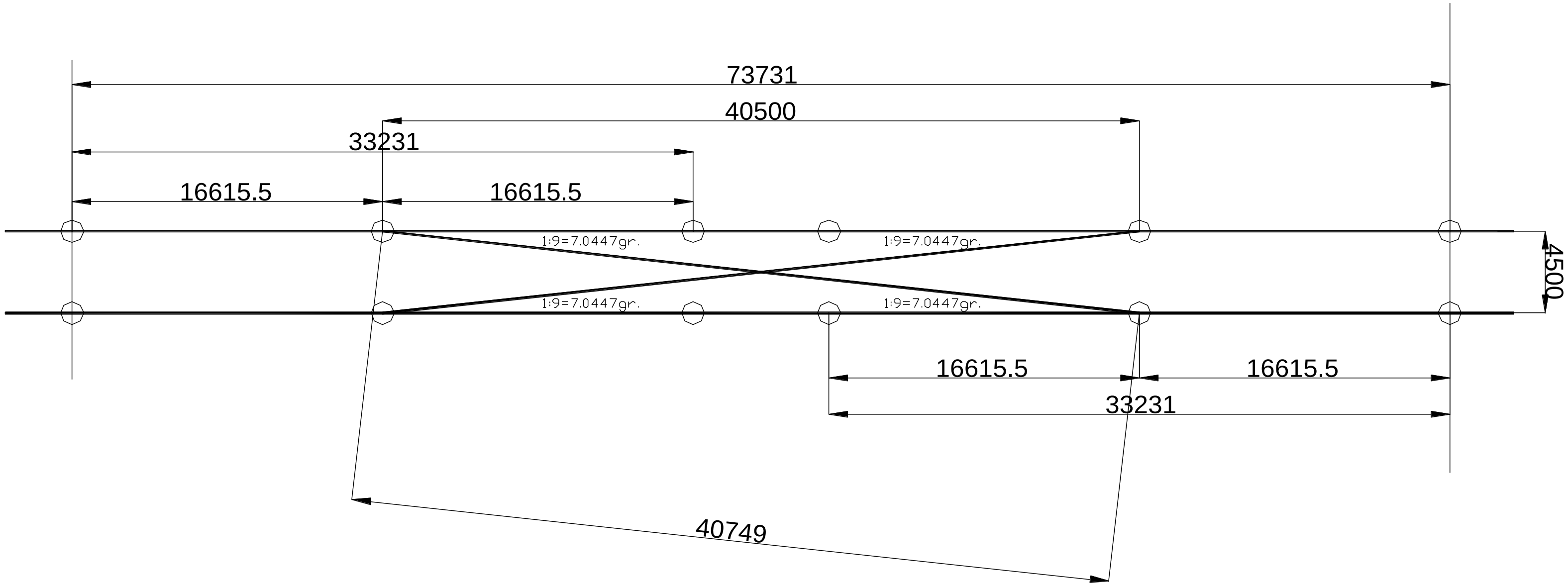


Fig No. 3.4

3.2 TRACTION SYSTEM

3.2.1 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:-

3.2.2 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 –** In future, 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. In DC traction system it is mostly imported.

- Though in underground section higher side tunnel diameter is required.

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-** The regeneration is 18%, because 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.

- **Higher Consumption of Specific Energy:** As per MOUD guideline specific energy consumption in 750 V dc system is 60 kWh/GTKM and in 25 KV ac system is 50 kWh/GTKM. The specific energy consumption in 750 V dc system is higher as compared to 25 kV ac system. Hence operating cost will increase in 750 V dc system (copy enclosed).

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.

d) 2x25 kV ac single phase Traction System

The following are the benefit of 2x25 kV ac traction system used for Chhatrapati Shivaji Maharaj Terminus (CSMT) to Gaimukh (47 km) corridor:

- The electromagnetic interference in of 2x25 kV systems is very less and hence no BT/RC system is required which has its own maintenance and reliability issues. However, additional space for autotransformer shall be required.

- The line loss in of 2x25 kV system is almost half as compared to 25 kV conventional system.

- In the event of 2 x 25 kV traction systems being adopted no of neutral section shall reduce.

- Load balancing will be better on all the three phase using Scott connected transformer.

- Since the OHE current is much lower in the of 2x25 kV systems; hence the OHE voltage profile will be better than conventional system. In fact the voltage drop at the terminal end for the similar load will be almost half in of 2x25 kV system.

- Harmonics: since the fault currents are much higher in of 2x25 kV & 220/132 kV side, there are less harmonics on the system. Fifth harmonics on the system are in the range of 1% of less as compared to around 3% or higher, in case of conventional system. Due to fewer harmonic, the reliability of the Traction installation equipment and of electric rolling stock in expected to be better.

- Substation spacing: The inter-spacing between sub-station is almost double in of 2x25 kV system as compared to conventional system. Therefore the number of substation almost reduces to half in the 2x25 kV AT system (with proper planning) as compared to the conventional system. This brings in substantial saving of costly space of around 2000 sq. m. in Mumbai metro area, besides saving due to use of lesser high voltage cable.

- 2x25 kV system is highly suitable for high dense load, as the voltage fed to the system at 25 kV as system due to better voltages and thus improved efficiency of the rolling stock.

- Arcing problems are encountered at BT overlap in 25 kV system and there have been melting cases of contact wire at the BT overlap location when bridging by stationary pantograph. No such problem will be encountered in 2x25 kV system.

- With the use of 2x25 kV system return conductor shall be replaced be feeder wire and the design shall be finalized accordingly.

In view of above techno-economic considerations, 2x25 kV AC traction system is suggested for Chhatrapati Shivaji Terminus (CSMT) to Gaimukh (47 km) corridor, otherwise 25 kV AC system is preferred.

3.3 SIGNALLING AND TRAIN CONTROL SYSTEM

3.3.1 Introduction

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.

This portion provides the main design features of the signaling and train control for the operation of Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro of extension of Mumbai Metro Line 4 Corridor taking into account the proven and advance system being used worldwide.

The Proposed Corridor of Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro are planned to be operated at maximum safe speed of 90 Km/hr. The trains are to be maintained headway at every about 100 seconds. 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 signalling system design for this metro line will cater the following:

- Continuous Automatic Train Control System (CATC)
- Unattended Train Operation (UTO) System
- Automatic Train Operation (ATO)System
- Communication based Automatic Train Control (ATC) System
- Automatic Train Protection (ATP) System
- On board Equipment
- Cab Signalling
- Fall-Back Block Working System
- Interlocking device (Computer based Interlocking)
- Track side Radio equipment
- Track Vacancy Detection System
- Electric Point Machine
- Track side Signals

- Centralized Traffic Control System
- Power Supply of signalling
- Cable for signalling
- Half Height Integrated Platform Gate (PG)
- Display of CCTV images from Train to OCC
- Onboard Radio Antennas, Large Video Screen, MMIs etc

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 Line 11 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 equipment shall be connected to station equipment room through optical fiber network.
- The CBTC (Communication based Train Control) based system shall be provided in main line & depot (except workshop area) for train operation & primary mode of detection. Secondary detection shall be through Axle Counter.
- 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 Signalling System shall authorized movement of train in normal and degraded operations.
- Track side equipment 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 equipment by monitoring System status of trackside and train borne equipment and enabling preventive maintenance.
- Signalling & Train Control System on the line shall be designed to meet the required headway during peak hours.

- For monitoring inside train saloon, signaling system shall provide radio transmission media to transfer live streams to OCC controller on large video screen & MMI.
- 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. Signalling and Rolling Stock interfaces shall be provided for Passenger Gate System.

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 UTO (Unattended Train Operation), ATO (Automatic Train Operation), ATP (Automatic Train Protection) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

Wireless communication system shall be used for communication between the wayside and train borne CBTC system. Radio for CBTC shall work in License free ISM band.

The Signalling 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 - UTO, ATO, ATP, and ATS sub-systems. The Train- borne Automatic Train Control System will consist of Unattended Train Operation (UTO), Automatic Train Operation (ATO) and Automatic Train Protection (ATP).

This vital system maintains the safety of the train operations on the principle of moving block including separation of trains enforcement of speed restrictions and safe operation through interlocking.

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. ATP mode shall be the normal mode of operation in event of failure of ATO-UTO Mode. In this mode, the train control and signaling system shall

- Provide Cab Signalling.
- Determine continuously and protect the train in excess of MSS & LOMA.
- 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.
- Enable opening of train doors as per stopping platform when train is docked.

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. ATO Mode shall be normal mode of operation in the event of failure of UTO Mode. In ATO mode the train control and signalling system shall carry out the following function:

- Accelerate and decelerate the train by applying traction power, coasting, and applying and removing brakes.
- Automatically control speed, acceleration, preventing unnecessary braking and stopping.
- Automatic operation of train between stations and stop the train at stations.
- Provide all indications necessary to operate the train.
- Determine continuously the Maximum Safe Speed (MSS) and Limit of Movement Authority (LOMA) with ATP function.
- Train doors open indication on the correct side when the train is docked if permitted by the ATP door release.
- Prevent the train from starting if train doors are not detected closed.

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 direct line 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:

- Train movement control (Automatic Route setting, train dispatch, inter station stop, platform/system hold & release dwell time, skip-stop, auto crew/RS management etc.).
- 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.
- Event & fault logging.
- System distinguishes between a train ready signal in ATP and a train ready signal in ATP / ATO mode.

3.3.9 Automatic Turn Back (ATB)

To minimize the turn back time at terminal and intermediate station, Automatic Turn Back mode (Cycle mode/Sequence mode) is introduced to automatically operate more than one route one after the other in a sequential manner

.

ATB function is a part of ATO/UTO mode function. At the terminal station or intermediate station the train shall be operated automatically by the onboard ATC to the turn back track and back to the terminal station without driver.

3.3.10 Restricted Mode (RM)/ Run of Site Mode (ROS)

This mode shall be available only when On Board ATC in operation. If the On-Board ATC does not receive ATP information, train shall be manually driven by driver using ATP (CBTC on board) with constant speed supervision. If train speed is exceeded to 25 Km/h, On Board ATC shall apply the emergency break. The On Board ATC give cab signal as soon as the train get ATP information or train reach a track position where normal running can be resumed. RM mode shall be operated in depot.

3.3.11 Cut Off Mode

This mode shall used in case of On Board ATC failure. In this mode, the train speed is controlled entirely by the Train Operator in accordance with line side signals and verbal instruction from controller. The rolling stock provides equipment that limits speed less than 25 Kmph. If safety cut out switch is handled, On Board ATC power supply is shut down.

3.3.12 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 & 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 CBI system is used for controlling vehicle movements into or out of stations automatically from a workstation. Interlocking 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 based on 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 axle counters, relays, point operating machines, power supply etc.

3.3.13 Track Vacancy Detection

Primary mode of track vacancy detection system on main line shall be through Radio and secondary detection can be through Axle Counter.

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. In view of advantages of Axle counter, the track detection system by Axle Counter is recommended for secondary detection system.

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

3.3.14 Wayside Signals

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

3.3.15 Cab Signalling

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 is transmitted by the wayside radio equipment to on board Radio equipment & vice versa. The data is computed by the on-board equipment and displayed on a screen on DMI for monitoring/controlling the running of train.

Vital information concerning the safe working of the train is 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 on circular speed gauge with speed pointer preferably with disguise color.
- Auxiliary driving information: state of brakes (service brake, emergency brake), state of the connection between the on-board and the track side equipment.

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.

3.3.16 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.

3.3.17 Train Depot: Signalling

All depot lines except the workshop area 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. Track vacancy detection using Radio & Axle Counter will be used in the depot as well.

The Depot shall be equipped with all mode of train operation including UTO mode except depot workshop line. The trains shall be controlled from DCC and OCC as well.

A test track with similar Signalling and Train control system as adopted in Main Line shall be provided at Depot.

3.3.18 Signalling Mode Of Operation

There are six signalling modes of operation which shall be available but only one single signalling 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) Unattended Train Operation (UTO) Mode
e) Run on Sight Mode (ROS) Mode
f) Automatic Train Reversal / Turn Back (ATB) Mode

3.3.19 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 Meter 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.

3.3.20 Display of CCTV images from Train to OCC

For monitoring of train saloons, there shall be provision at OCC for displaying live video streams for the onboard CCTV cameras on each train as selected by the OCC operator on large video screen & MMIs. Onboard camera shall be provided by rolling stock, Signaling shall provide the radio infrastructure for transmission of CCTV live stream from train to OCC through use of one of the available ISM band (preferably 5.8 GHz band) frequency. Data transmission network of CCTV & CBTC shall be separate and redundancy in radio units.

Provision shall be made for displaying a minimum of four live streams from a train at OCC. Signaling shall also provide sufficient size large video screen display and MMI at OCC as per requirement. Display shall be sufficient good quality of operator to view required simultaneous live streams. However, actual bandwidth requirement, number of live streams per train, size of large video screen, etc. shall be finalized as per requirement during design stage.

3.3.21 Centralized Traffic Control (CTC)

The Metro 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 OCC system is to operate the train in UTO/ATO mode (in CBTC) and construct the routes of the trains from the origin up to the destination automatically / manually under normal / abnormal conditions, the OCC system will provide effectively alternatives to minimize the delay of the train.

It supplies all the information required to the centralized traffic control operator in order to check the normal operations of the trains. The OCC system interfaces to the external systems (interlocking, Radio equipment, SCADA, PIDS, PAS, etc.) to monitor and control the traffic and to ensure the safe operations of trains.

The OCC 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 OCC is interfaced with signaling devices set along the track 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 metro rail environment with high MTBF. The servers for the OCC shall be self diagnostic and fault noticing functions.
- Operation during emergency situation can be planed through the back-up CTC (BCC) when OCC is not functional.
- 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 & efficiently. 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.

3.3.22 Fall- Back Block Working System

A Fall-Back block working system shall be used by using secondary detection (axle counters) & Track Side Signals in case of failure of CBTC System or wayside communication link become unavailable.

The Fall-Back Block working system shall follow fixed block working, it can temporarily be worked to maintain safety and smooth operation with the help of Line Side Signals provided at each station / interlocking. When the Fall-Back Block working system is operated, it is necessary to check no other trains exist in the protection area to keep safety operation at first on priority.

3.3.23 Rooms For Signalling At OCC & Stations

The OCC 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 Signalling 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 Direct Line large projection Display.

B) Central Signalling Equipment Room

This room includes all equipment managing the Signalling System included in the OCC 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) 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) 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 OCC rooms (Signaling, Telecom, AFC equipments). UPS room should be available adjacent to Signalling Equipment rooms at Stations and OCC. UPS room shall be available at Central location at all stations.

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

➢ The signaling technical room	: 40m^2
➢ The maintenance room	: 30m^2
➢ The power supply room	: 50m^2

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

3.3.24 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 OCC may be located at terminal station inside the premises of the station or in Depot. The BCC could be located around other terminal station / locations / Depot. The BCC shall be similar to OCC, and also, BCC shall provide full redundancies of all systems and communications.

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

3.3.25 Power Supply

Uninterrupted Power Supply provision is must for the Signalling System to have high availability. The concept of the power supply system is of immense importance, because the availability of the Signalling System entirely depends on its power supply.

All devices along the line are computerized devices and therefore need to be fed with low-voltage power supply. The low-voltage power supply shall be designed in a way to ensure the quality and reliability of the supply to all components of the Signalling System. The Uninterrupted Power Supply System shall have sufficient backup time and in built redundancies to ensure very high of Availability and reliability.

The solutions that are usually implemented on metro rail include:

- Redundancy of mains feeder (delivery from multiple cables/sources),
- Back-up of the AC supply by means of uninterrupted power supplies and associated batteries,
- Batteries capacity based on system consumption and autonomy with Back-up time requirements.
- Architecture and dimension of the system allowing failures and/or maintenance without service disruption (possibility to switch off one or several converters or other modules without impact).

The Uninterrupted Power Supply system shall be designed for use of Signalling equipments, Telecom equipments, AFC equipment & PSD equipments as per requirement.

3.3.26 Standards

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

Table 3.1

Description	Standards
Train protection system	Train Protection system shall be based on CBTC (Communication based Train Control) System. The system architecture shall provide in redundancy. The system will conform to IEEE 1474 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 etc.
Block Working	Moving Block working concept may be followed in CBTC System and Fixed Block working in failure of CBTC system.
Default Mode of Operation	The system shall be capable of Unattended Train Operation (UTO), however, the mode of operation may be decided / finalized by metro at detail design stage.
Maximum Safe Speed of Operation	90 Km/h
Grade of Automation	GOA4 (UTO) / GOA3 (DTO)
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 in depot (except workshop line) may be through radio (CBTC System) and secondary detection it may be through Axle Counter.
Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and less maintenance cost.
Uninterrupted power Supply	Uninterrupted Power Supply System is Common for Signalling,

Description	Standards
at stations as well as for OCC	Telecommunications, AFC and PSD systems.
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 in redundancy.
Fall Back CTC	Backup OCC (BCC)
Platform Gate	Half height Integrated Platform Gate System
On board CCTV Stream	Display of CCTV images from Train to OCC on Large Video Screen and MMIs
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 equipment 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.

3.3.27 Space Requirement For Signalling 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 Signalling, Telecommunication, AFC and PSD systems) at all stations, the area required shall be approximately minimum 50 sqm.

At Non-interlocking stations, Signalling & PSD Equipments shall be installed in the Telecommunication Equipment Room (TER) available at the station.
At the OCC and the Depot, the areas required shall be as per the final configuration of the equipment and network configuration keeping space for further expansion.

3.3.28 Maintenance Philosophy For Signalling Systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and Telecommunication equipment 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 equipment 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.

3.4 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 & 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, Maintenance Control, Emergency Control, Assistance to Train Traffic 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

A) 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 144 fiber optical fiber cables may be laid along track as per present commercial requirement for revenue.

B) Gigabit Ethernet Network (WAN)

A totally IP Based High Capacity, highly reliable and fault tolerant, MPLS Ethernet Network shall be provided. IP network shall have important data therefore Ethernet requires high reliability. Considering the rapidly increased demand during the operation for top-level backbone network 10Gbps 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 transmission line are configured as a dual system.
Redundant Layer-3, Layer-2 switches and Routers at each station, depot & OCC shall be provided to meet requirement of other Telecom systems (like CCTV, AFC 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. Data lines of sufficient quantity and bandwidth shall be provided to other systems between Central Terminal Unit and Remote Terminal Unit.

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 1 site with rooftop towers with Base Station and minimum 4 Base Stations for coverage in U/G feeding LCX cable with repeaters shall be required along the proposed Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro.

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

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, Face detection & tracking features 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 provide the Access only to the Authorized Personnel in operational rooms and shall not allow the same Card for Travel in 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	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 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 Telecommunication equipments shall be approximately 40 sqm. The Telecommunication Room shall be used for Signaling, Telecommunication, AFC & PSD systems equipments at non- interlocking stations. In interlocking station, Telecommunication Room shall be used for Telecommunication, AFC & PSD systems equipments. Uninterrupted Power Supply (UPS) System shall be common for Signaling, Telecommunication, AFC & PSD systems equipments at input stage and installed in UPS room at every station, depot and OCC which is approximately 50 sqm at station. 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, amendable for quick fare changes and require overall less manpower. In view of the above computer based automatic fare collection system is proposed**.** Seamless ticketing is now being thought of for Mumbai Metro Rail.

Automatic Fare Collection 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.

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 AFC system shall be of Contactless Smart Token / Card type. For multiple journeys, the stored value smart card shall be utilized and for the single journey, the smart media shall be as utilized as contactless smart token. 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.

It is proposed, the smart NCMC (National Common Mobility card) standard model for implementation of AFC system in Mumbai Metro. The AFC system as per the guidelines issued by Govt of India shall enable seamless travel by different metros and other transport systems across the city besides retail shopping and purchases.

The AFC system shall support the EMV (Europay, MasterCard, and Visa) and RuPay based open loop ticketing following the NCMC standard model for interoperability with other operators by use of non-proprietary standard so that the interface is scalable to other networks (transit operator/ retail outlets/parking/Toll etc) in Mumbai. The AFC equipments shall support EMV, RuPay, QR, NFC (Near field communication) based ticketing, integration of clearing house, smart card host system of Financial Institutions and integration of mobile application with AFC system.

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 internationally. All these gates will have a functionality of Auto Top on smart cards in case balance goes below the threshold value (as per choice / business rule).

The gate should also capable to NFC enabled Mobile Tickets or any latest type of Ticket media at the time of procurement/installation. The AFC system shall provide access control solutions, offering both access control devised and hardware which can be tailored to accept any ticket media readily available in market (Barcode, QR code, NFC etc).

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)

The 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).

The system must support minimum standard & specification for CSC & devices and recommendations to be used for the implementation of National Common Mobility program in the multimodal and multi operator environment within the practical limits of transport.

b) **Other Media (for Single Journey Tickets)**

Media for Single Journey Tickets shall be determined at design stage, 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

- The AFC machines and system shall provide a complete audit trail of all transactions, transfers of cash and other payments.
- Cash handling equipment and systems shall be an integral part of the audit trail.
- 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

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

- 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).

- The SC shall include the power and data communication links to each item of AFC equipment and CC system interface.
- 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.
- The SC shall be able to download data to the AFC machines individually or as groups.
- 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.
- The SC shall be able to monitor certain critical functions of the AFC system and collect data for warnings and alarms.
- 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.
- 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.

3.5.14 AFC Equipment Requirement

The AFC equipment required at various locations of Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro are tabulated at Annexure for projection years 2021 and 2031. However, the exact number and type shall depend on the final station layout and traffic being catered to.

3.5.15 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. The System should also capable to NFC enabled Mobile Tickets (ISO18092 or equivalent) or any latest type of Ticket media (Barcode, QR code etc).
Gates	Computer controlled retractable flap type automatic gates at entry and exit. There will be following types of gates : - Entry - Exit - Reversible The System shall support the EMV and RuPay based open loop ticketing following the NCMC standard model for interoperability.
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.
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.

3.5.16 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.

The proposed AFC system shall provide interfaces to other operators such as Suburban Rail, Bus, Waterway, 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 3.5 Entry/Exit Gates

Fig 3.6: Ticket Office Machine

Fig 3.7: Ticket vending machine

Fig. 3.8 Ticket Reader/Add Value Machine

Annexure 3.1

Table 3.4

AFC Equipments for Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro (Projection for 2021)

Sr. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
1	CSMT Metro	2004	7522	33	125	2	5	2	2	4	2	2
2	Carnac Bunder	50	105	1	2	2	2	2	2	4	2	2
3	Clock Tower	436	414	7	7	2	2	2	2	4	2	2
4	Wadi Bunder	1168	757	19	13	2	2	2	2	4	2	2
5	Darukhana	933	743	16	12	2	2	2	2	4	2	2
6	Coal Bunder	227	154	4	3	2	2	2	2	4	2	2
7	Hay Bunder	1052	476	18	8	2	2	2	2	4	2	2
8	Sewri Metro	359	716	6	12	2	2	2	2	4	2	2
9	BPT Hospital	5684	4514	95	75	4	3	5	2	4	2	2
10	Ganesh Nagar	2232	1010	37	17	2	2	2	2	4	2	2
11	Wadala RTO (Bhatkti Park Metro)	2208	12224	37	204	2	8	2	2	4	2	2
12	Wadala TT	5297	7239	88	121	4	5	4	2	4	2	2
13	Anik Nagar (Anik Nagar Bus Dept)	1483	1440	25	24	2	2	2	2	4	2	2
14	Suman Nagar	2505	2101	42	35	2	2	2	2	4	2	2
15	Siddharth Colony	4373	6210	73	104	3	4	4	2	4	2	2
16	Pestom Sagar (Amar Mahal Junction)	2979	2885	50	48	2	2	3	2	4	2	2
17	Garodia Nagar	851	670	14	11	2	2	2	2	4	2	2
18	Pant Nagar	307	190	5	3	2	2	2	2	4	2	2
19	Laxmi Nagar	965	983	16	16	2	2	2	2	4	2	2
20	Amrut Nagar (Shreyas Cinema)	17365	9502	289	158	12	6	14	2	4	2	2
21	Ambewadi (Godrej Company)	1836	1493	31	25	2	2	2	2	4	2	2
22	Vikhroli Metro	2272	2217	38	37	2	2	2	2	4	2	2
23	Surya nagar	773	601	13	10	2	2	2	2	4	2	2

Sr. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
24	gandhinagar	3875	3868	65	64	3	3	3	2	4	2	2
25	Naval Kousing	170	41	3	1	0	2	2	2	4	2	2
26	Bhandup mahapalika	2452	3032	41	51	2	2	2	2	4	2	2
27	Bhandup Metro	1407	668	23	11	2	2	2	2	4	2	2
28	Nahur Metro (Shagrila)	4449	5742	74	96	3	4	4	2	4	2	2
29	Sonapur	1455	1254	24	21	2	2	2	2	4	2	2
30	Mulund Fire Station	375	93	6	2	2	2	2	2	4	2	2
31	Mulund naka	1209	1818	20	30	2	2	2	2	4	2	2
32	Teen Hath naka	2377	1805	40	30	2	2	2	2	4	2	2
33	RTO Thane	5290	4517	88	75	4	3	4	2	4	2	2
34	Thane Mahapalika Marg (Mahapalika Marg)	2442	1957	41	33	2	2	2	2	4	2	2
35	Siddheshwar Lake (Cadbury Junction)	547	837	9	14	2	2	2	2	4	2	2
36	Majiwada	2955	2295	49	38	2	2	2	2	4	2	2
37	KapurBawdi	2514	2757	42	46	2	2	2	2	4	2	2
38	Manpada	2406	1709	40	28	2	2	2	2	4	2	2
39	Patli Pada (Tikuji Ni wadi)	4187	2937	70	49	3	2	4	2	4	2	2
40	Dongari pada	3392	3514	57	59	2	2	3	2	4	2	2
41	Kavesar Gaon (Vijay Garden)	3405	2372	57	40	2	2	3	2	4	2	2
42	kasarvadavali	3113	2348	52	39	2	2	3	2	4	2	2
43	Gowniwada	2332	2198	39	37	2	2	2	2	4	2	2
44	Gaimukh	9115	6898	152	115	6	5	8	2	4	2	2
	TOTAL					**110**	**114**	**124**	**88**	**176**	**88**	**88**

Annexure 3.2

Table 3.5

AFC Equipments for Mumbai Metro Line 11 i.e. from Bhakti Park (Wadala) to CSMT Metro (Projection for 2031)

Sr. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
1	CSMT Metro	4713	7211	79	120	3	5	4	2	4	2	2
2	Carnac Bunder	593	310	10	5	2	2	2	2	4	2	2
3	Clock Tower	510	578	9	10	2	2	2	2	4	2	2
4	Wadi Bunder	1034	995	17	17	2	2	2	2	4	2	2
5	Darukhana	827	1492	14	25	2	2	2	2	4	2	2
6	Coal Bunder	138	155	2	3	2	2	2	2	4	2	2
7	Hay Bunder	972	240	16	4	2	2	2	2	4	2	2
8	Sewri Metro	2136	1543	36	26	2	2	2	2	4	2	2
9	BPT Hospital	5332	4927	89	82	4	3	4	2	4	2	2
10	Ganesh Nagar	2125	1078	35	18	2	2	2	2	4	2	2
11	Wadala RTO (Bhatkti Park Metro)	3665	13551	61	226	2	9	3	2	4	2	2
12	Wadala TT	3428	7050	57	118	2	5	3	2	4	2	2
13	Anik Nagar (Anik Nagar Bus Dept)	2050	1404	34	23	2	2	2	2	4	2	2
14	Suman Nagar	7220	3054	120	51	5	2	6	2	4	2	2
15	Siddharth Colony	6706	8303	112	138	4	6	6	2	4	2	2
16	Pestom Sagar (Amar Mahal Junction)	8629	1505	144	25	6	2	7	2	4	2	2
17	Garodia Nagar	579	3107	10	52	2	2	2	2	4	2	2
18	Pant Nagar	947	764	16	13	2	2	2	2	4	2	2
19	Laxmi Nagar	5387	1889	90	31	4	2	5	2	4	2	2
20	Amrut Nagar (Shreyas Cinema)	9456	16643	158	277	6	11	8	2	4	2	2
21	Ambewadi (Godrej Company)	3591	4537	60	76	2	3	3	2	4	2	2
22	Vikhroli Metro	2097	3026	35	50	2	2	2	2	4	2	2
23	Surya nagar	2282	1931	38	32	2	2	2	2	4	2	2

Sr. No.	Station Name	Hourly Boarding	Hourly Alighting	Peak min. Boarding	Peak min. Alighting	Entry Gate	Exit Gate	TOM	EFO	TR	TVM	RCTM
24	Gandhinagar	5022	7184	84	120	3	5	4	2	4	2	2
25	Naval Kousing	1842	1220	31	20	2	2	2	2	4	2	2
26	Bhandup mahapalika	1446	808	24	13	2	2	2	2	4	2	2
27	Bhandup Metro	9845	3955	164	66	7	3	8	2	4	2	2
28	Nahur Metro (Shagrila)	1447	2982	24	50	2	2	2	2	4	2	2
29	Sonapur	2210	570	37	10	2	2	2	2	4	2	2
30	Mulund Fire Station	1011	1461	17	24	2	2	2	2	4	2	2
31	Mulund naka	2848	879	47	15	2	2	2	2	4	2	2
32	Teen Hath naka	3056	3370	51	56	2	2	3	2	4	2	2
33	RTO Thane	2662	3789	44	63	2	3	2	2	4	2	2
34	Thane Mahapalika Marg (Mahapalika Marg)	3838	3673	64	61	3	2	3	2	4	2	2
35	Siddheshwar Lake (Cadbury Junction)	4440	4279	74	71	3	3	4	2	4	2	2
36	Majiwada	1888	3510	31	59	2	2	2	2	4	2	2
37	KapurBawdi	10727	1944	179	32	7	2	9	2	4	2	2
38	Manpada	12008	13187	200	220	8	9	10	2	4	2	2
39	Patli Pada (Tikuji Ni wadi)	4158	5651	69	94	3	4	3	2	4	2	2
40	Dongari pada	4326	4645	72	77	3	3	4	2	4	2	2
41	Kavesar Gaon (Vijay Garden)	13	2074	0	35	2	2	2	2	4	2	2
42	kasarvadavali	3221	738	54	12	2	2	3	2	4	2	2
43	Gowniwada	19147	2748	319	46	13	2	16	2	4	2	2
44	Gaimukh	0	15609	0	260	2	10	2	2	4	2	2
	TOTAL					**138**	**140**	**162**	**88**	**176**	**88**	**88**

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. Thoughput 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 a Mass Rapid 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 3.6.

Table 3.6 - Size of the coach

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

**Maximum length of coach over couplers/buffers = 23 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 Heavy Rolling Stock 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/Motor car is envisaged.

Following train composition is recommended:

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

8-car Train (from the year 2031 onwards): DMC+TC+MC+MC+TC+MC+TC+DMC

Table 3.7 shows the carrying capacity of Heavy Rolling Stock.

Table 3.7 - Carrying Capacity of Medium Rail Vehicles

Particulars	**Driving Motor car**		**Trailer car / Motor car**		**6 Car Train**		**8 Car Train**	
	Normal	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**	**Normal**	**Crush**
Seated	42	42	50	50	284	284	384	384
Standing	120	240	124	248	736	1472	984	1968
Total	162	282	174	298	1020	1756	1368	2352

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

3.6.4 Weight

The weights of driving motor car, trailer car and motor car have been estimated as in Table 3.8, referring to the experiences in Delhi Metro. The average passenger weight has been taken as 65 kg.

Table 3.8 - Weight of Light Rail Vehicles (TONNES)

	DMC	**TC**	**MC**	**8 Car Train**
TARE (maximum)	42	43	42	338
Passenger				
(Normal)	10.53	11.31	11.31	88.92
(Crush @6p/sqm)	18.33	19.37	19.37	152.88
(Crush @8p/sqm)	23.40	24.70	24.70	195.00
Gross				
(Normal)	52.53	54.31	53.31	426.92
(Crush @6p/sqm)	60.33	62.37	61.37	490.88
(Crush @8p/sqm)	65.40	67.70	66.70	533.00
Axle Load @6 person/sqm	15.08	15.59	15.34	15.34
Axle Load @8 person/sqm	16.35	16.92	16.68	16.65

The axle load @ 6persons/sqm of standing area works out in the range of 15.08T to 15.59T. 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.**

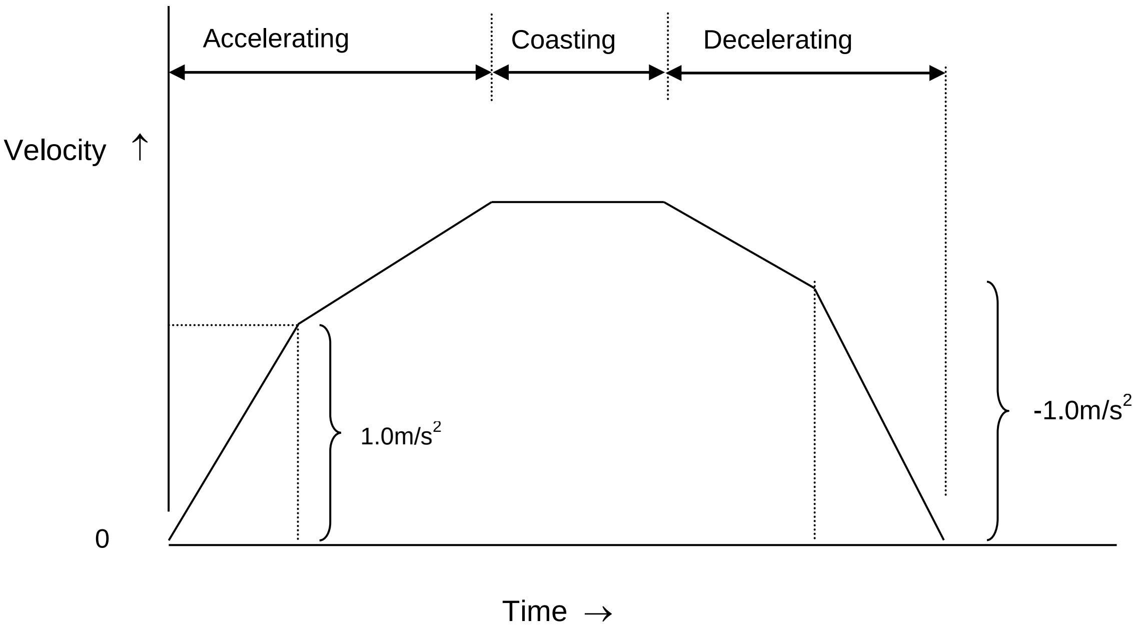
3.6.5 Performance Parameters

The recommended performance parameters are:

Maximum Design Speed: 90 kmph
Maximum Operating Speed: 80 kmph
Max. Acceleration: 1.0 m/s^2 (with AW3 load)
1.2 m/s^2 (with AW2 load)
Max. Deceleration: 1.0 m/s^2 (with AW3 load)
1.1 m/s^2 (with AW2 load)
>1.35 m/s^2 (Emergency brake)

Here AW3 load mean 8 persons per square meter of standee area

AW2 load mean 6 persons per square meter of standee area



Traction in constant speed

The above performance parameters are broad and may be finalized during design stage.

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

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-.

3.6.7.1Car 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 aluminium car body.

The car bodies with aluminium require long and complex extruded sections which are still not manufactured in India, while stainless steel sections are available in India. However both stainless steel (SS) and Aluminium car body construction can be mentioned in the technical specification. Both Aluminium and stainless steel car body construction has its advantages and disadvantages, e.g. Aluminium is lightweight compared to SS, though it requires periodic painting for upto 4-5 times during service life, whereas SS is having high strength and has better aesthetic look, but it is heavier in weight compared to Aluminium.

3.6.7.2 Bogies

Bolster less lightweight fabricated bogies with helical coil spring/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 improves the curve running performance by reducing lateral forces through application of helical coil spring/ conical rubber spring. Helical springs are preferred over conical rubber spring based upon DMRC experience. A smooth curving performance with better ride index is being ensured by provision of above type of bogies.

3.6.7.3 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 tread brake.

3.6.7.4 Propulsion System Technology

In modern trains, cars with microprocessor controlled three phase induction motor drive with VVVF control are recommended. The drive consists of self-ventilated 3-phase AC squirrel cage induction motor and a power converter-inverter system with microprocessor control gate drive. 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 AC 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.

The AC catenary voltage is stepped down through a transformer and fed to power converter-inverter (CI). In CI, AC voltage output of transformer is converted to DC voltage through converter connected 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. IGBT incorporates its own over current protection, short circuit protection, over temperature protection and low power supply detection. In addition also have provision for over current, phase unbalance, over temperature protection for traction motor.

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.

3.6.7.5 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. Some equipments may be mounted in the under seat cubicles to have more standing capacity in the gangway.

Interior View

3.6.7.6 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

3.6.7.7 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 60% 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.

3.6.7.8 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

In Standard Gauge (3.2 m wide stock) cars, an emergency door for easy detrainment of the passenger on the track has been provided at the center of the front side of each cabin which has an easy operation with one handle type master controller.

3.6.7.9 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.

3.6.7.10 Noise and Vibration

The trains will pass through heavily populated urban area. The noise and vibration for a metro railway become an important criterion from public acceptance view point. The sources 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.
- Provision of wheel flange and top of rail lubrication to reduce squealing noise.
- Provision of noise attenuators (Hypno dampers) on wheels to reduce noise due to rail wheel interaction.

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

3.6.7.11 Passenger Safety Features

(i) ATP/ATO/UTO

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. There shall be provision for fire/heat detectors in electrical cubicles inside the train. Also, as per MoHUA guidelines para-9 two fire extinguishers per car in saloon area. One fire extinguisher per cab to be provided.

(iii) Emergency door

In Standard Gauge(3.2 m wide stock) cars, 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

(vi) Obstruction deflection device(ODD):

ODD shall be mounted on front bogie of each driving car(DMC) which shall be able to deflect obstacles such as metal block, wooden block or plastic bottle with water etc. After detection and deflection of obstacle emergency brake shall be applied to stop the train automatically.

The salient features of the proposed Rolling Stock are enclosed as Annexure-3.2

Annexure-3.3

Salient Features of 3.2m wide SG Rolling Stock for MRTS

S.No.	Parameter	Details
1	**Gauge** (Nominal)	1435mm
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 set 8 car train set (from year 2031 onwards)	DMC+TC+MC+ MC+TC+DMC DMC+TC+MC+MC+TC+MC+TC+DMC
4	**Coach Body**	Stainless Steel/Aluminum
5	**Coach Dimensions**	
5.1	Height	3.9 m
5.2	Width	3.2 m
5.3	Length over body (approx)	
	- 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 23m (depending upon Kinematic Envelop and SOD)*
5.4	Locked down Panto height (if applicable)	4048 mm
5.5	Floor height	1100mm
6	**Designed - Passenger Loading**	
6.1	Design of Propulsion equipment	8 Passenger/ m^2
6.2	Design of Mechanical systems	10 Passenger/ m^2
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	
	6 Car Train 8 Car Train (In year 2031)	1756 (seating – 284, standing – 1472) 2352 (seating - 384; standing - 1968)
8	**Weight (Tonnes)**	
8.1	Tare weight (maximum)	
	DMC	42
	TC	43
	MC	42
8.2	Passenger Weight in tons	@ 0.065 T per passenger

<table>
<tr><th>S.No.</th><th>Parameter</th><th colspan="3">Details</th></tr>
<tr><td></td><td>DMC</td><td colspan="3">18.33 (@ 6 persons per sqm of standee area)</td></tr>
<tr><td></td><td>TC</td><td colspan="3">19.37 (@ 6 persons per sqm of standee area)</td></tr>
<tr><td></td><td>MC</td><td colspan="3">19.37 (@ 6 persons per sqm of standee area)</td></tr>
<tr><td>8.3</td><td>Gross weight in tons (@ 6 persons per sqm of standee area)</td><td colspan="3"></td></tr>
<tr><td></td><td>DMC</td><td colspan="3">60.3</td></tr>
<tr><td></td><td>TC</td><td colspan="3">62.4</td></tr>
<tr><td></td><td>MC</td><td colspan="3">61.4</td></tr>
<tr><td>**9**</td><td>**Axle load(T) (@ 8 persons per sqm of standee area)**</td><td colspan="3">**17 (System should be designed for 17T axle load)**</td></tr>
<tr><td>**10**</td><td>**Maximum Train Length - Approximate**</td><td colspan="3"></td></tr>
<tr><td>10.1</td><td>6 car train set
8 car train set (In year 2031)</td><td colspan="3">≈138
≈184</td></tr>
<tr><td>**11**</td><td>**Speed**</td><td colspan="3"></td></tr>
<tr><td>10.1</td><td>Maximum Design Speed</td><td colspan="3">90 Kmph</td></tr>
<tr><td>10.2</td><td>Maximum Operating Speed</td><td colspan="3">80 Kmph</td></tr>
<tr><td>**12**</td><td>**Wheel Profile**</td><td colspan="3">UIC 510-2/RDSO wheel profile</td></tr>
<tr><td>**13**</td><td colspan="4">**Noise Limits (ISO 3381 and 3095 - 2005)**
Vibration (ISO-2631-1 1997, ISO 2631-4 2001), as per MoHUA circular on Standardisation of Broad Parameters of Rolling Stock for Metro Railways in India</td></tr>
<tr><td>13.1</td><td>Interior Noise Level ($L_{PAeq20sec}$)</td><td colspan="3"></td></tr>
<tr><td rowspan="3"></td><td rowspan="3">**Location(Section)**</td><td colspan="3">**Interior Noise Measurements in Maximum dBA**</td></tr>
<tr><td colspan="2">**Stationary**</td><td>**Running (Elevated and At Grade)**</td></tr>
<tr><td>**Elevated**</td><td>**Underground**</td><td>**Elevated**</td></tr>
<tr><td></td><td>All cars except in driving cab(Elevated and at grade)</td><td>68</td><td>75</td><td>68</td></tr>
<tr><td></td><td>Driving cab(Elevated and at grade)</td><td>68</td><td>72</td><td>68</td></tr>
<tr><td>13.2</td><td>Exterior Noise Levels ($L_{PAeq20sec}$)</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="4">Maximum Level of Exterior Noise in dBA @ 7.5 m from centre of track on either side LpAEq 20sec 75 dB(A)</td></tr>
<tr><td></td><td>**Stationary**</td><td colspan="3">**Running at 75 kmph**</td></tr>
<tr><td></td><td>67</td><td colspan="3">82</td></tr>
<tr><td>**14**</td><td>**Traction Motors Ventilation**</td><td colspan="3">Self</td></tr>
</table>

S.No.	Parameter	Details
15	**Acceleration on level tangent track**	1.0 m/sec^2 @ AW3 1.2 m/sec^2 @ AW2
16	**Deacceleration on level tangent track**	1.0 m/sec^2 @ AW3 1.1 m/sec^2 @ AW2 (>1.35 m/sec^2 during emergency)
17	**Type of Bogie**	Fabricated
18	**Secondary Suspension springs**	Air
19	**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 - Brake Electronic Control Unit (BECU) - Independent for each bogie
20	**Coupler**	
	Driving Cab end of cars (DMC)	Automatic coupler with mechanical & pneumatic coupling but without electrical coupling head
	Between cars of same Unit	Semi-permanent couplers
21	**Detrainment Door**	Front
22	**Type of Doors**	Sliding
23	**Lighting**	LED based with dimmer control
24	**Passenger Seats**	Stainless Steel
25	**Cooling**	
25.1	Transformer	Forced
25.2	CI & SIV	Self/Forced
25.3	TM	Self-ventilated
26	**Control System**	Train based Monitor & Control System (TCMS)
27	**Traction Motors**	3 phase VVVF controlled
28	**Temperature Rise Limits**	
28.1	Traction Motor	Temperature Index **minus** 70°C
28.2	CI & SIV	10°C temperature margin for Junction temperature
28.3	Transformer	IEC specified limit **minus** 20° C

S.No.	Parameter	Details
29	**HVAC**	- Cooling, Heating & Humidifier (As required) - Automatic controlling of interior temperature throughout the passenger area at 25°C with 60% RH all the times under varying ambient conditions up to full load.
30	**PA/PIS including PSSS (CCTV)**	Required
31	**Passenger Surveillance**	Required
32	**Battery**	Ni-Cd
33	**Headlight type**	LED
34	**Coasting**	8% (Run time with 8% coasting shall be the 'Run Time in All out mode **plus** 8%')
35	**Gradient (max)**	4%
36	**Sharpest Radius**	Bogie shall be able to negotiate 100m(in Mainline) and 90m (in depot)
37	**Train Operation**	UTO(GoA4) with CBTC signaling system

CHAPTER - 4

CIVIL ENGINEERING

4.1 GEOMETRIC DESIGN NORMS

4.1.1 General

The proposed extension 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 wherever possible 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 underground tracks will be carried in separate tunnels to be drilled by Tunnel Boring Machine. Stations will, however, be constructed by cut and cover method.

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. On elevated section minimum radius of 125m has been used at two locations having speed potential upto40 km/h. However in underground section desirable minimum radius of curve shall be 300 m for ease of working of Tunnel Boring Machine (TBM). For maximum permissible speed on curve with various radii,

Table 4.1 may be referred.

Horizontal Curves:

Table 4.1- Horizontal Curves

Description	Elevated Section	Underground Section
Desirable Minimum radius	200m	300 m
Absolute minimum radius	120m*	200 m (only c/c)
Minimum curve radius at stations	1000m	1000 m
Maximum permissible cant (C_a)	125 mm	125 mm
Maximum desirable cant	110mm	110 mm
Maximum cant deficiency (C_d)	85mm	85 mm

* 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) Underground Sections

Rail level at midsection in tunneling portion shall be kept at least 12.0 m below the ground level. At stations, the desirable depth of rail below ground level is atleast 13.5 m, so that station concourse can be located above the platforms.

Track center in underground sections are follows:

Track center in underground sections are follows: Sections where stations are to be constructed by cut & cover and running section by TBM to Accommodate 12 m wide platform	15.35 m (for lesser width of platform, track center to be reduced)
Sections where stations are to be constructed by NATM and running section by TBM to facilitate Construction of stations	22.00 m
Sections where stations as well as running section both are to be constructed by cut and cover method	4.50 m

(c) 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.

(d) 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.

(e) 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 DISTANCE BETWEEN ADJACENT TRACKS	
			UNDERGROUND	ELEVATED AND AT-GRADE
meters	mm	kmph	mm	mm
3000	15	80	3500	3650
2800	15	80	3500	3650
2400	20	80	3500	3650
2000	20	80	3500	3650
1600	25	80	3500	3650
1500	30	80	3500	3650
1200	35	80	3500	3650
1000	45	80	3500	3700
800	55	80	3550	3700
600	70	80	3550	3750
500	85	80	3600	3750
450	95	80	3600	3800
400	105	80	3650	3800
350	110	75	3650	3800
300	110	70	3700	3850
200	110	55	3800	3950
150	110	45	4000	4050
150*	0	30	4000	4050
120	110	40	4000	4150
120*	0	25	4000	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 of this extension is named as Chhatrapati Shivaji Maharaj Terminus Metro and last station is Ganesh Nagar. Since this corridor is South-West extension of Mumbai Metro corridor from Gaimukh to Wadala (Bhakti Park), thus Ganesh Nagar is not a terminal station rather it is followed by Wadala (Bhakti Park) Station.

4.2.1.2 Chainage of Chhatrapati Shivaji Maharaj Terminus proposed station is taken as 0.0 for reference and dead end chainage of this station as (-) 530 m.

4.2.1.3 Total length of this extension is 12.774 km. It is proposed as partly elevated and partly underground.

4.2.1.4 Ten stations have been proposed on this extension of Gaimukh to Wadala (Bhakti Park) corridor. Names of stations are Chhatrapati Shivaji Maharaj Terminus, Carnac Bunder, Clock Tower, Wadi Bandar, Darukhana, Coal Bunder, Hay Bunder, Sewri Metro, BPT Hospital and Ganesh Nagar. 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 2098.1 m and 851.1 m respectively. No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

4.2.1.5 This is an extension of Gaimukh to Wadala (Bhakti Park) corridor towards South-West direction.

4.2.2 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.

All stations will be two level stations. For elevated stations, the concourse comprising of passenger facilities and station facilities will be at lower level and the platforms on the higher level, whereas, for underground stations, the concourse will be at higher level and the platforms on the lower level. Stations on the road have been planned cantilever leaving 10.5m road width either side of the median.

4.2.3 Terminals

Since this is an extension of Gaimukh to Wadala (Bhakti Park) corridor on Wadala (Bhakti Park) end. Thus this section has only one terminal station as mentioned below:

Chhatrapati Shivaji Maharaj Terminus

This Station is proposed to be underground. Scissors cross overs are proposed at the rear end of station.

4.2.4 Scissors Crossovers

Scissors Crossovers will be provided at the terminal station viz. Chhatrapati Shivaji Maharaj Terminus and before Wadala (Bhakti Park) station.

4.2.5 Depot

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

4.2.6 Switch Over Ramp (SOR)

Vertical alignment of this corridor changes from underground to elevated or vice versa at one locations, as described below:-

Table 4.8 - Details of Switch over Ramp

S. No.	Chainage (m)		Length (m)	Remarks
	From	to		
1	8022.436	8449.563	427.127	SOR is proposed off the road on right side of Messent Road

4.2.7 Description of Alignment

4.2.7.1 Horizontal Alignment

The proposed alignment is an extension of Gaimukh to Wadala (Bhakti Park) corridor of Mumbai Metro. Though this is a South-West extension at Wadala (Bhakti Park) end but since chainage of main line was started at southern end which increases towards north direction, thus for this extension also 0.0 chainage is considered at the southern end(at terminal station) i.e. Chhatrapati Shivaji Maharaj Terminus. The chainages increases towards north direction. Dead end chainage of Chhatrapati Shivaji Maharaj Terminus is taken as (-) 530 m.

First station is Chhatrapati Shivaji Maharaj Terminus at 0.0 chainage. This is an underground station proposed adjacent to under construction station of Colaba-Bandra-SEEPZ line. From chainage (-) 530 m till 8235.99 m the alignment is underground and beyond this it is elevated. Next station is Carnac Bunder at chainage 1584.597 m. This station is proposed below MBPT area. Next station is Clock Tower at chainage 2473.963m which also below MBPT area. Alignment continues to be underground and it goes parallel to Eastern Freeway (on right side). Next station is Wadi Bunder. It is proposed before crossing Nawab Tank Road at chainage 3620.461 m. Alignment runs underground and crosses Nawab Tank Road around chainage 3850m. Next station is Darukhana at chainage 4598 m. It is on a straight alignment and is located near SSK Engineering Works. The alignment turns right from Sant Savata Mali Marg and thereafter it runs beneath 4th Ln Road. From chainage 5414.312 m it turns left with a radius on 320m and comes beneath Forsberry Road. Next Station is Coal Bunder at ch.5780.57 beneath Forsberry Road. The alignment continues beneath this road and next station is Hay Bunder at ch.6805.016 m. Near junction of Forsberry Road and Haji Bunder Road, the alignment turns left and comes beneath Haji Bunder Road. Next station is Sewri Metro at chainage 7656.128 m. It is proposed beneath the occupied land, adjacent to Eastern Freeway on right side. After this station from chainage 7786.128 m alignment shall be constructed by cut and cover method till Switch over ramp. Switch over ramp is proposed off the road (right side of Messent Road) and it starts from chainage 8022.436m and ends at chainage 8449.563m. Here onwards the alignment is elevated and it takes a left turn from ch. 8410.952 m with a curve of radius 125 m to align itself along the median of Sewri-Chembur Road. It crosses Eastern Freeway around ch. 9300 m. Next station is BPT Hospital at chainage 9754.193 m. It is an elevated station, proposed near Mumbai Port Trust Hospital and is on straight alignment. After this station, from chainage 9494.808 m it turns right and aligns onto Antop Hill road. It crosses Chathrapati Shivaji Maharaj Chowk around chainage 10350 m, after this it turns right with 125 m radius and comes onto Sewri-Chembur Road. Few meters from this turn, Ganesh Nagar station is proposed at chainage 10722.095 m. After this station, the alignment turns left, goes off the road and run parallel to Eastern Freeway on its left side. From chainage 11890.318 m, it turns left to negotiate road junction and runs off the Sewri-Chembur Road (on its right side). This extension is detailed till 12244.115 m, since beyond this point upto Gaimukh, separate DPRs have already been submitted.

All underground stations are proposed to be constructed by cut and cover method.

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 3.7% and has been used at one location.

The proposed rail levels are given in **Table 4.4** and abstracts of gradients are given in **Table4.5.**

Table 4.4:Proposed Gradients

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
1	-530	140	670.000	-23.6	-23.6	0.000%	LEVEL
2	140	740	600.000	-23.6	-25.1	-0.250%	FALL
3	740	1390	650.000	-25.1	-17.5	1.169%	RISE
4	1390	1785.818	395.818	-17.5	-17.5	0.000%	LEVEL
5	1785.818	2340	554.182	-17.5	-18	-0.090%	FALL
6	2340	2610	270.000	-18	-18	0.000%	LEVEL
7	2610	3045	435.000	-18	-19.175	-0.270%	FALL
8	3045	3480	435.000	-19.175	-16	0.730%	RISE
9	3480	3740	260.000	-16	-16	0.000%	LEVEL
10	3740	4070	330.000	-16	-17.9	-0.576%	FALL
11	4070	4403.079	333.079	-17.9	-17	0.270%	RISE
12	4403.079	4730	326.921	-17	-17	0.000%	LEVEL
13	4730	5140	410.000	-17	-18.75	-0.427%	FALL
14	5140	5540	400.000	-18.75	-17	0.438%	RISE
15	5540	5910	370.000	-17	-17	0.000%	LEVEL
16	5910	6290	380.000	-17	-18.95	-0.513%	FALL
17	6290	6670	380.000	-18.95	-17	0.513%	RISE
18	6670	7050	380.000	-17	-17	0.000%	LEVEL
19	7050	7440	390.000	-17	-11	1.538%	RISE
20	7440	7800	360.000	-11	-11	0.000%	LEVEL
21	7800	8000	200.000	-11	-5.4	2.800%	RISE
22	8000	8590	590.000	-5.4	16.43	3.700%	RISE
23	8590	9349.692	759.692	16.43	20	0.470%	RISE
24	9349.692	9630	280.308	20	16.1	-1.391%	FALL
25	9630	9966.055	336.055	16.1	16.1	0.000%	LEVEL
26	9966.055	10490	523.945	16.1	16	-0.019%	FALL
27	10490	10884.06	394.060	16	16	0.000%	LEVEL
28	10884.06	11540	655.940	16	12.7	-0.503%	FALL

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
29	11540	12200	660.000	12.7	20	1.106%	RISE
30	12200	12450	250.000	20	23	1.200%	RISE
31	12450	13139.7995	689.800	23	23	0.000%	LEVEL

Table 4.5: Abstract of Gradients

S. No.	Description	Nos. Occurrences	Length (m)	% w. r. t. total Alignment length
1	Level	11	4452.654	32.57%
2	> 0% to = 1%	13	6196.838	45.33%
3	> 1% to = 2%	5	2230.308	16.32%
4	> 2% to = 3%	1	200.000	1.46%
5	> 3% to = 4%	1	590.000	4.32%
	Total	**31**	**13669.8**	**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 27curves have been provided in this extension. The details of curves and abstracts of horizontal curves are indicated in Table 4.6 and 4.7 respectively.

Table 4.6 A: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		66.5
1	Left	310	59.542	55	55	11	00	17	29.863	611.879
2	Left	320	683.895	55	55	122	27	03	582.691	0
3	Right	1010	286.109	30	30	16	13	49	144.019	253.275
4	Right	320	39.076	55	57.781	06	59	47	19.562	0
5	Left	320	45.602	57.781	55	08	09	53	22.84	1195.706
6	Right	1010	104.196	30	30	05	54	39	52.144	230.982
7	Left	1200	320.76	25	25	15	18	54	161.342	332.475
8	Left	600	94.882	40	40	09	03	37	47.54	413.846
9	Right	320	299.992	55	55	53	42	48	162.041	99.953
10	Left	320	109.372	55	55	19	34	58	55.225	1314.519
11	Left	320	193.308	55	55	34	36	41	99.705	0
12	Right	320	170.336	55	55	30	29	54	87.237	370.408
13	Right	300	258.872	55	55	49	26	27	138.115	139.825
14	Left	125	154.119	55	55	70	38	34	88.575	0
15	Right	1750	30.505	25	25	00	59	55	15.253	40.91
16	Right	175	31.21	55	55	10	13	05	15.646	205.719
17	Right	400	40.615	50	50	05	49	03	20.325	0
18	Left	450	31.326	50	50	03	59	18	15.669	479.453
19	Right	175	32.494	55	55	10	38	19	16.294	0
20	Left	275	26.865	55	55	05	35	50	13.443	17.245
21	Right	2500	26.74	20	20	00	36	46	13.37	117.466
22	Right	125	98.969	55	55	45	21	50	52.242	189.751

Curve No.	Hand of Arc	Radius (m)	Arc Length (m)	Transition Length (m)		Included Angle			Tangent (m)	Straight Length (m)
23	Right	5000	41.105	20	20	00	28	15	20.553	57.233
24	Left	500	167.783	45	55	19	13	35	84.688	0
25	Left	200	104.872	55	55	30	02	36	53.671	549.986
26	Left	1010	324.746	30	30	18	25	20	163.787	564.292
27	Right	300	41.773	55	55	07	58	40	20.92	148.67

Table 4.7:Abstract of Horizontal Curves

S. No.	Radius (m)	Nos. Occurrences	Curved Length With TL (m)	% w. r. t. total curved length
1	>125m - 500m	19	4655.583	73.61%
2	>500m - 1020m	4	1069.933	16.92%
3	>1020m - 1500m	1	370.76	5.86%
4	>1500m - 2500m	2	147.245	2.33%
5	>2500m - 5000m	1	81.105	1.28%
	Total	**27**	**6324.626**	**100.00%**

4.3 CIVIL STRUCTURE AND CONSTRUCTION METHODOLOGY

4.3.1 Underground Construction

For the underground section running under the road, cut and cover method of the underground construction can be employed for the construction of the underground sections. However keeping in view the inconvenience to the traffic movement, it is proposed to tunnel through by using Tunnel Boring Machine (TBM) or New Austrian Tunneling Method (NATM) in the overburden soil mass. Tunnel excavation for a major length of underground section is expected to be carried out by Tunnel Boring Machines. There is some length along the underground alignment where Cut & Cover method has been considered for construction before Switch Over Ramp (SOR). Tunnel boring machines (TBMs) capable of drilling through rock with a finished internal diameter of 5.6 m can be successfully employed for boring tunnels through this stratum. The tunnels are proposed with a minimum cushion cover of 6.0m.

4.3.2 Underground Stations

Underground stations have been proposed to be constructed by cut and cover with top-down method. The diaphragm walls for such station constructions would be 80 to 100 cm thick and will function as a permanent side wall of the station. It is, therefore, necessary to construct the diaphragm walls absolutely watertight and with the required concrete strength. By resorting to top-down method the surface could be restored quickly and further excavations and construction of the station will not hamper the surface activity.

4.3.3 Cut and Cover Method of Construction of Underground Stations

Cut and Cover mainly consists of following steps:

1. Diversion of utilities

2. Construction of support walls
3. Excavation between the support walls along with the installation of struts between the two walls to keep them in position.
4. Construction of tunnel/structure and removal of temporary struts.
5. Back filling and restoration of the surface

4.3.3.1 Utility Diversion:

It is suggested that all utilities falling within excavation area are diverted away in advance to avoid damage to such utilities during the excavation/ construction phase. The cross utilities, however has to be kept supported. It is suggested that pressure water pipelines crossing the proposed cut area are provided with valves on both sides of the cut so that the cut area can be isolated in case of any leakage to the pipeline to avoid flooding of the cut/damage to the works.

4.3.3.2 Support Walls:

Most commonly used support wall is RCC Diaphragm Wall. The advantage of diaphragm wall is that the same can be used as part of permanent structure. The modern techniques are now available where water-stop can be inserted at the joints of two diaphragm wall panels to avoid seepage through the joints. It is also now possible to ensure the verticality of the diaphragm wall panels to avoid any infringement problem later on. Typically the diaphragm wall of 80 cm to 1 meter thickness is sufficient to do the cut and cover construction. The various advantages of diaphragm wall are as follows.

(a) It is rigid type of support system and therefore ensures the maximum safety against settlement to the adjacent structures.

(b) Can be used as part of the permanent structure and, therefore, considered economical.

(c) With diaphragm wall it is possible to construct an underground structure by top down method. In this method top slab is cast once the excavation is reached to the top slab level with rigid connections to the diaphragm wall which can be achieved by leaving couplers in the diaphragm wall reinforcement at appropriate level. This top slab then acts as strut between the two support walls and gives much more rigidity and safety to the construction. Excavation thereafter can be completed. This also helps in restoration of the surface faster without waiting for full structure to be completed.

The other support walls which can be used depending on the site conditions are as follows:

(a) Sheet Piles

‘Z’/‘U’ sheet piles can be used as temporary support wall. This can be advantageous where it is possible to re-use the sheet pile again and again and therefore, economy can be achieved. However the main concern remains, driving of sheet piles causes vibrations/noise to the adjacent buildings. This may sometimes lead to damage to the building and most of the time causes inconvenience to the occupants of the building. Situation becomes more critical if sensitive buildings are adjacent to the alignment like hospitals, schools, laboratories, etc. Silent pile driving equipments however are now available and can be used where such problems are anticipated.

(b) Retaining Casing Piles

This is suitable for situation where the cut and cover is to be done in partly soil and partly rock. The top soil retaining structure can be done with the help of Casing pile which is then grouted with cement slurry. This is considered suitable in case of shallow level, non-uniform, uneven nature of rock head surface which render the construction of sheet piles/diaphragm wall impracticable. These are suitable up to 7-meter depth. The common diameter used for such casing pile is 2.00-2.50 m dia.

(c) Soldier Piles and Lagging

Steel piles (H Section or I section) are driven into the ground at suitable interval (normally 1-1.5 m) center-to-center depending on the section and depth of excavation. The gap between two piles is covered with suitable lagging of timber planks/shot-creting /steel sheets/GI sheets during the process of excavation.

(d) Secant Piles

Secant Piles are cast-in-situ bored piles constructed contiguously to each other so that it forms a rigid continuous wall. This is considered an alternative to diaphragm wall where due to soil conditions it is not advisable to construct diaphragm wall from the consideration of settlement during the trenching operation. 800 to 1000 mm dia piles are commonly used. Two alternate soft piles are driven and cast in such a way that the new pile partly cuts into earlier constructed piles. This new pile is constructed with suitable reinforcement. With this, alternate soft and hard pile is constructed. This has got all the advantages of diaphragm wall. However, this wall cannot be used as part of permanent structure and permanent structure has to be constructed in- side of this temporary wall.

4.3.3.3 Anchors

As an alternative to the struts, soil/rock anchors can be used to keep these support walls in position. This gives additional advantage as clear space is available between two support walls and progress of excavation & construction is much faster as compared to the case where large number of struts is provided which create hindrance to the movement of equipments and material & thus affects the progress adversely.

The combination of all the type of retaining walls, struts/anchors may be necessary for the project to suit the particular site. Based on the above broad principle, the support walls system for cut and cover shall be chosen for particular locations.

4.3.4 Viaduct – Elevated Structure

4.3.4.1 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 extension of Gaimukh to Wadala (Bhakti Park) 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.

4.3.5 Pre-Cast Construction

4.3.5.1 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.

4.3.5.2 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.

4.3.6 Structural System of Viaduct

4.3.6.1Superstructure

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.

4.3.6.2Substructure

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.

4.3.7 Construction of Stations

At 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.

For underground stations, platform will be at lower level and concourse will be at upper level. All the underground stations are proposed to be constructed by cut and cover method.

4.3.8 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.

4.3.9 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).

4.3.10 Road width required during construction

As most of the elevated 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 relevant data available in the DPR prepared by M/s RITES for fast rail corridor from CSTM to Panvel has been reproduced, as part of that corridor is more or less same as this extension and ground profile does not changes for smaller deviation in corridor route.

It is recommended that fresh Geotechnical Investigation may be got done before implementation of this project.

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 meter 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 Bore Hole Details

The boreholes details are provided below:

Table 4.22: Details of Boreholes

BH No.	Ground level (m)	Ground Water Table Depth (m)	In Soil	In rock (soft/ hard)	Total
1	4.98	2.60	7.25	7.25	14.50
2	4.79	2.10	7.00	7.00	14.00
3	3.96	3.10	3.45	9.65	13.10
4	3.73	2.80	3.55	9.55	13.10
5	5.72	3.00	4.80	9.70	14.40
6	7.09	3.10	4.40	10.50	14.90
7	5.67	2.80	4.80	8.50	13.30
8	4.10	3.10	6.05	7.45	13.50
9	4.09	2.80	6.05	7.45	13.50
10	3.66	3.20	11.05	8.45	19.50
11	3.25	2.90	11.05	7.25	18.30
12	3.85	2.80	7.60	6.80	14.40
13	4.81	3.10	6.50	8.30	14.80
14	3.95	2.70	5.80	8.70	14.50
15	3.43	2.90	6.00	8.00	14.00
16	3.20	2.50	5.45	7.65	13.10
17	3.17	2.30	5.05	7.55	12.60
18	3.49	2.70	5.65	6.70	12.35

4.4.4 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 below.

BH No.	S. No.	Depth of test (m)	N’ VALUE No. of blows per 30cm	Remarks
1	1	1.75−2.20	02−02−03−0	05−Greyish stiff marine clay.
	2	4.00−4.60	01−02−03−03	05−Greyish stiff marine clay.
	3	5.40−6.00	02−03−01−04	04−Greyish stiff marine clay.
	4	6.80−7.25	03−02−05−0	07− Greyish stiff marine clay.
2	1	1.75−2.20	02−03−01−0	04−Dark greyish soft marine clay with few gravels.
	2	4.25−4.70	01−02−01−0	03−Dark greyish marine clay.
	3	5.50−5.95	02−02−03−0	05− Dark greyish marine clay.
	4	6.75−7.00	26−0−0−0	R−refusal.
3	1	1.75−2.20	03−05−05−0	10−Greyish Silty sandy with little gravels.
	2	3.00−3.45	03−04−04−0	08− Greyish Silty sandy with little gravels.
4	1	1.75−2.20	03−02−03−0	05−Brownish greyish soft marine clay.
	2	3.10−3.55	03−03−05−0	08−Greyish soft marine clay with little gravels.
5	1	1.75−2.20	01−02−01−0	03−Brownish greyish soft marine clay.
	2	3.10−3.55	02−02−02−0	04− Brownish greyish soft marine clay.
	3	4.35−4.80	03−02−04−0	06−Greyish soft marine clay with few gravels.
6	1	1.75−2.20	03−04−03−0	07−Brownish greyish soft marine clay.
	2	3.10−3.55	04−02−04−0	06−−Brownish greyish soft marine clay.
	3	4.35−4.40	37−0−0−0	R−refusal.
7	1	1.75−2.20	01−03−03−0	06−Brownish greyish soft marine.
	2	4.35−4.80	04−05−06−0	11−greyi h soft marine clay.
8	1	1.75−2.20	06−07−09−0	16−Brownish stiff sandy clay soil.
	2	4.35−4.50	08−05−09−0	14−Brownish stiff sandy clay.
	3	5.60−6.05	08−07−07−0	14− Brownish stiff sandy clay with few gravels.
9	1	1.85−2.30	07−09−06−0	15−Brownish stiff sandy clay.
	2	4.35−4.80	09−08−11−0	19−Brownish stiff sandy clay with few gravels.
	3	5.60−6.05	08−09−08−0	17− Brownish stiff sandy clay with few gravels.
10	1	1.75−2.20	07−05−06−0	11−Brownish stiff sandy clay with little gravels.
	2	4.35−4.80	08−09−06−0	15− Brownish stiff sandy clay with little gravels.
	3	6.85−7.30	08−07−07−0	14− Brownish stiff sandy clay soil .
	4	8.10−8.55	07−10−10−0	20− Brownish stiff sandy clay soil

BH No.	S. No.	Depth of test (m)	N' VALUE No. of blows per 30cm	Remarks
11	1	1.75–2.20	06–08–07–0	15–Brownish stiff sandy clay with little gravels.
	2	4.35–4.80	07–06–08–0	14– Brownish stiff sandy clay with little gravels.
	3	6.85–7.30	08–07–09–0	16– Brownish stiff sandy clay with little gravels.
	4	9.35–9.80	07–10–12–0	22– Brownish stiff sandy clay soil
	5	10.60–11.05	09–08–09–0	17–Brownish stiff sandy clay soil.
12	1	1.75–2.20	08–07–07–0	14–Brownish soft sandy clay soil.
	2	4.50–4.95	07–08–09–0	17–Brownish soft sandy clay soil.
	3	5.75–6.20	09–08–07–0	15–Brownish soft sandy clay.
	4	7.00–7.60	05–07–08–09	15–Brownish soft sandy clay.
13	1	1.75–2.20	03–02–03–0	05–Greyish silty sandy soil.
	2	4.25–4.70	02–01–03–0	04– Greyish silty sandy soil.
	3	5.50–5.95	02–02–03–0	05– Greyish silty sandy soil.
14	1	1.75–2.20	07–09–11–0	20–Brownish stiff sandy clay with few gravels.
	2	4.25–4.70	08–07–10–0	17–Brownish stiff sandy clay with few gravels.
	3	5.50–5.80	25–31–0–0	R–weak greyish red weathered rock with few rde patches.
15	1	0.95–1.40	07–10–12–0	22–Drak brownish stiff sandy clay with little gravels.
	2	3.45–3.90	06–09–11–0	20– Drak brownish stiff sandy clay with little gravels.
	3	4.75–5.20	08–07–09–0	16– Drak brownish stiff sandy clay with little gravels.
	4	6.00–6.30	15–25–0–0	R–Dark brownish grey with few pieces o weathered rock
16	1	1.75–2.20	08–09–12–0	21–Brownish stiff sandy clay s il with few gravels.
	2	4.25–4.70	07–10–08–0	18– Bro nish stiff sandy clay soil with few gravels.
	3	5.45–5.50	42–0–0–0	R–completely weathered basalt rock.
17	1	1.75–2.55	04–05–07–0	12– Brownish soft sandy clay with little gravels.
	2	3.55–3.80	05–07–08–0	15– Brownish soft sandy clay with little gravels.
	3	4.60–5.05	07–09–18–0	27–Brownish soft sandy clay.
18	1	1.75–2.35	07–09–08–12	17–Brownish soft sandy clay with little gravels.
	2	4.40–4.85	07–07–09–0	16– Brownish soft sandy clay with little gravels.

4.4.5 Conclusion and Recommendations

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

Depth of Foundation-A foundation must have an adequate depth from considerations of adverse environmental influences. It must also be economically feasible in terms of overall structure. Keeping in view the type of the proposed structure and the subsoil strata, the length of pile may be about 7.5 to 15 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 1200 to 1500 mm diameter may be adopted.

Piles transmit foundation loads through soil strata of low bearing capacity to deeper soil having a higher bearing capacity value. Piles carry loads as a combination of side friction and point bearing resistance. The minimum diameter of pile should be 1000mm.

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

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

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.

4.5.2 Utilities owning Organizations/Departments agencies along the corridors

Organizations/Departments with concerned utility services in Mumbai are mentioned in **Table 4.28.**

Table 4.28: UTILITY RESPONSIBILITY DEPARTMENTS

S. No.	Name of Utility	Organizations/Departments
1	WATER SUPPLY	Office of the Hydraulic Engineer, MCGM
2	SEWERAGE	Office of Sewer Operations, Eastern and western Suburb, MCGM
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 (MGL)
7	MOBILE PHONE	Vodafone TTML TATA Communications Airtel Bharat 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. 4.29: Details of the HT towers

S.No.	LocationChainage(m)	Position w.r.t alignment	Remarks
1	10174.167	Across	110kV
2	10202	Across	110kV
3	10595.833	Across	110kV
4	10605	Across	110kV
5	12023	Across	110kV
6.	12050	Across	110kV

Table No. 4.30: Other Affected Services

S. No	Description	Number
1.	Lamp Post	45
2.	Manhole	88
3.	Telephone Pole	37

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.

Drawings submitted to concerned departments for marking of underground utilities. The same will be incorporated in the report after its receipt from the concerned departments.

4.5.5 Underground Stretch and Switch Over Ramp

The details of underground sections are also given in this chapter. As indicated in the previous paras due to various reasons, the entire length of underground section is proposed to be constructed with tunneling keeping a minimum cover of about 6m above the tunnel, except at stations which will be constructed by cut and cover method. Hence, the utility services existing in above ground or below ground position are not likely to be affected in underground stretch of the alignment except at station and ramp location.

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 for Underground stretches

No land at surface is required permanently for underground section, except for small areas for entry/exit structures, traffic integration, chilling plant and ventilation shafts at stations. These will be located either on footpath edge or in front marginal open setback of the building along the road.

4.6.3 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.

4.6.4 Land for Switch-over Ramps

Switch-over ramps are required for transition from the underground to elevated section or *vice versa*. The ramp covers a stretch at ground for the whole width of structure for two tracks (about 10.5m including the protection works). The length of ramp above ground depends on the existing ground slope and the gradient provided on Metro alignment (normally 3% to 4%). Thus the ramp is to be located in an area where sufficient road width is available or in an open area. On this corridor, one such ramp is provided.

4.6.5 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.

4.6.6 Land for Depot

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

4.6.7 Land for Traction and Receiving Substation and Radio Towers

One RSS near Sewri Metro Station is proposed to be located for this extension. Hence, an area of 5,600m^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.

4.6.8 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 (underground and elevated) were planned out of ROW of Road. But, for locating other station facilities such as chiller plants, ventilation shafts, underground water tanks, generator set room etc., land acquisition is proposed. Details of land permanently required for depot, stations and running sections are indicated in Table 4.31 and 4.32.

Table 4.31RUNNING SECTION

S.No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
1	RS-1	134	Pvt.
2	RS-2	1369	Pvt.
3	RS-3	107	Pvt.
4	RS-4	281	Pvt.
5	RS-5	115	Pvt.
6	RS-6	321	Pvt.
7	RS-7	37	Pvt.
8	RS-8	16	Pvt.
9	RS-9	21	Pvt.
10	RS-10	2	Pvt.
11	RS-11	145	Pvt.
12	RS-12	648	Pvt.
13	RS-13	290	Pvt.
14	RS-14	2166	Pvt.
15	RS-15	91	Pvt.
16	RS-16	2	Pvt.
17	RS-17	6	Pvt.
18	RS-18	8	Pvt.
19	RS-19	1	Pvt.
20	RS-20	3650	Govt.
21	RS-21	1217	Pvt.
22	RS-22	6469	Govt.
23	RS-23	10465	Govt.
***TOTAL = 27561*m^2**			
***GOVT. =20584*m^2**			
***PVT. =6977*m^2**			

Table 4.32LAND REQUIRED FOR STATIONS

S. No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
1	CSMT-1	1030.87	Govt.
2	CSMT -2	450	Govt.
3	CSMT -3	1044	Govt.
4	CSMT -4	85.14	Govt.
5	CSMT -5	48.96	Govt.
6	CSMT -6	85.14	Govt.
7	CB-1	85.14	Govt.
8	CB-2	400	Govt.
9	CB-3	450	Govt.
10	CB-4	85.14	Govt.
11	CB-5	400	Govt.
12	CB-6	400	Govt.
13	CT-1	85.14	Govt.
14	CT-2	400	Govt.
15	CT-3	85.14	Govt.
16	CT-4	400	Govt.
17	CT-5	450	Govt.
18	CT-6	400	Govt.
19	WB-1	400	Govt.
20	WB-2	85.14	Govt.
21	WB-3	400	Govt.
22	WB-4	450	Govt.
23	WB-5	400	Govt.
24	WB-6	85.14	Govt.
25	D-1	85.14	Pvt.
26	D-2	400	Pvt.
27	D-3	400	Pvt.
28	D-4	450	Pvt.
29	D-5	85.14	Pvt.
30	COB-1	400	Govt.
31	COB-2	450	Govt.
32	COB-3	400	Govt.
33	COB-4	400	Govt.
34	COB-5	85.14	Govt.
35	COB-6	85.14	Govt.
36	COB-7	400	Govt.
37	HB-1	400	Govt.
38	HB-2	85.14	Govt.
39	HB-3	85.14	Govt.
40	HB-4	400	Govt.
41	HB-5	450	Govt.
42	HB-6	400	Govt.
43	S-1	400	Govt.

S. No.	PLOT NO	AREA PROPOSED TO BE ACQUIRED (Sqm.)	OWNERSHIP
44	S-2	85.14	Govt.
45	S-3	400	Govt.
46	S-4	400	Govt.
47	S-5	450	Govt.
48	S-6	85.14	Govt.
49	BPTH-1	612	Govt.
50	BPTH-2	593	Govt.
51	GN-1	509	Pvt.
52	GN-2	77	Pvt.
53	GN-3	329	Govt.
Total Land = 17606.07 m^2 (including 3600 m^2 land for Ancillary Structure)			
Govt. Land = 15599.79 m^2(including 3150 m^2 land for Ancillary Structure)			
Pvt. Land = 2006.28 m^2(including 450 m^2 land for Ancillary Structure)			

4.6.9 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. Metro Operation Control Centre (OCC) will be same for complete Chhatrapati Shivaji Maharaj Terminus to Gaimukh corridor, it is already considered in the DPR of Wadala - Ghatkopar – Mulund – Thane - Kasarvadavali corridor and therefore no separate OCC is proposed for this extension. It is proposed to keep the provision of **0.5 ha** of government land for staff quarters for this extension. Exact location of land has not been identified at this stage. It may be decided at the time of project implementation.

4.6.10 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 4.33 Details of Temporary Land office accommodation

S. No.	Corridor	AREA (m^2)	OWNER-SHIP
1	Chhatrapati Shivaji Maharaj Terminus to Wadala (Bhakti Park)	4000	Government
	Total	**4000**	

4.6.11 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 two casting yards for the proposed extension. Accordingly a provision of **4ha** land has been proposed on temporary basis considering 2.0 ha of land for each casting yard for a period of four years.

4.6.12 Summary of Land Requirements

Abstract of land requirements for different components of this proposed extension are given in **Table 4.34 and Table 4.35**.

Table 4.34 Summary of Permanent Land Requirement (All figures in Sq. m)

S.No.	Description	Govt.	Pvt.
1	Stations	12449.79	1556.28
2	Running Section	20584	6977
3	Ramp	3957	0
4	Depot	0	0
4	Staff Quarters	5000	0
5	Office Complex and OCC	0	0
6	RSS	5600	0
7	Ventilation Shaft	800	0
8	Mid Shaft	0	0
9	Ancillary Structure	3150	450
	Total	**51540.79**	**8983.28**

Total Permanent Land = 6.0524ha
Permanent Land (Govt.) = 5.1541 ha
Permanent Land (Pvt.) = 0.8983 ha

Table 4.35 - Summary of Temporary Land Requirement(All figures in Sq. m)

S. No.	Description	Govt.	Pvt.
1	Temporary Office/ Site Office	4000	0
2	Segment Casting Yard	40000	0
3	For construction of UG Stations by cut and cover method	0	7674
4	Portion of alignment before start of Ramp by cut and cover method	4772	0
	Total	**48772**	**7674**

Total land required for temporary acquisition is **4.8772ha (Govt.) and 0.7674 ha (Pvt.)**.

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.

4.7.2.4Addressable 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.

4.7.2.5Intelligent 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.

4.7.2.6Addressable 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.

4.7.2.7Isolator 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:

4.7.3.1General

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.

4.7.3.2Scope

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.

4.7.3.3System 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.

4.7.3.5Hoses

Hose is a flexible tube used to carry water

4.7.3.6Hose 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.

4.7.3.7Coupling

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.

4.7.3.8Fire 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

4.7.4.1A 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

4.7.5.1General

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

4.7.5.2Scope

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.

4.7.5.3Description

Carbon Di Oxide (CO_2) Fire Extinguishers

The cylinder filled with carbon dioxide (CO2), 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.

4.7.5.4ABC 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.

4.7.5.5Water 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.

4.7.5.6Glow 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

4.7.6.1General

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

4.7.6.2Description:

CCTV comprises of the following components:

i. Integrated Port Camera (IP Cameras)
ii. Computer
iii. Software

4.7.6.3Integrated 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.

4.7.6.4Computer

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.

4.7.6.5Software

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

4.7.6.6Server 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)

4.7.6.7Client 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.

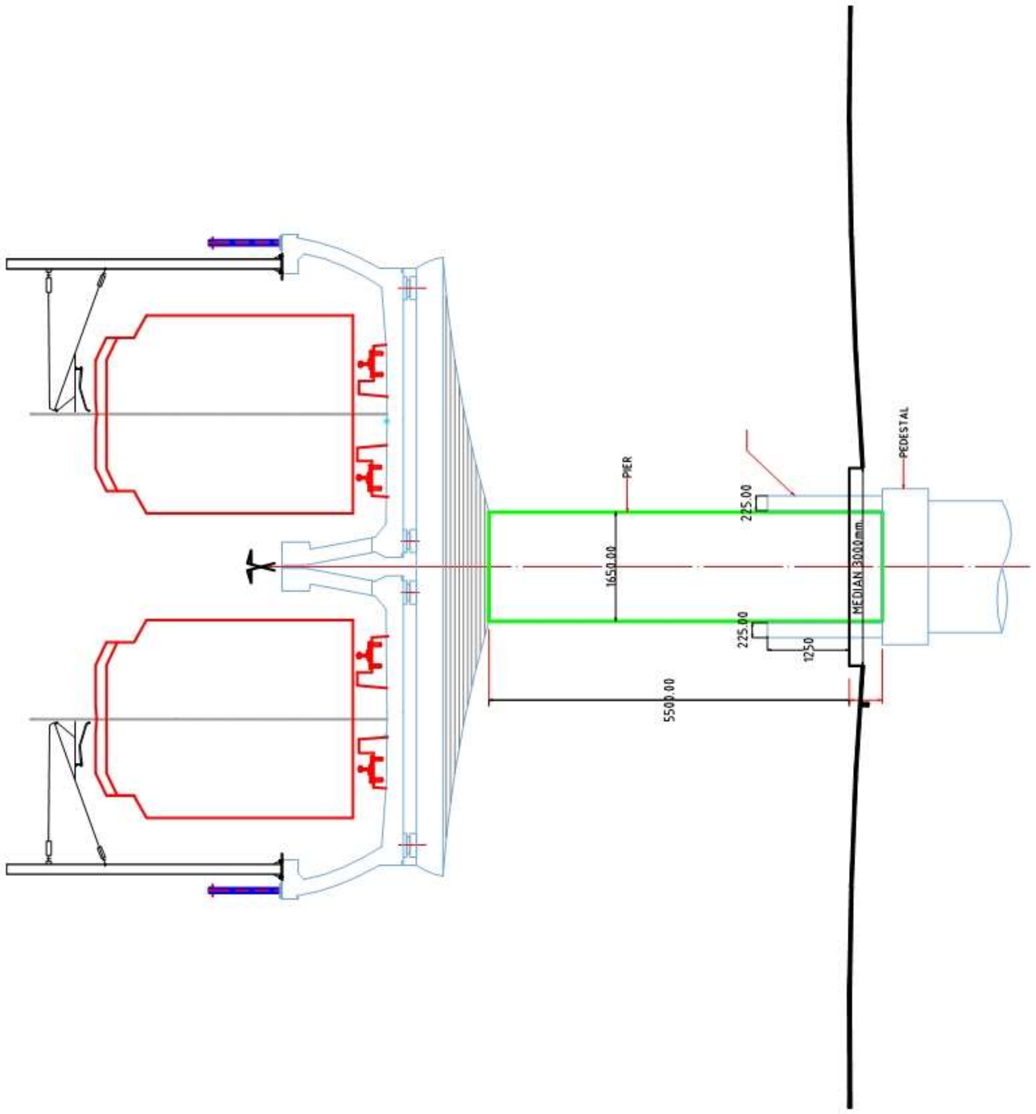
Client application is to control pan-tilt-zoom, iris, focus, presets and dome patterns of the PTZ camera for correct functioning of the system.
Software provides utility to play multiple exported clips simultaneously. It also provides the ability to play multiple clips in time sync with each other to 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.

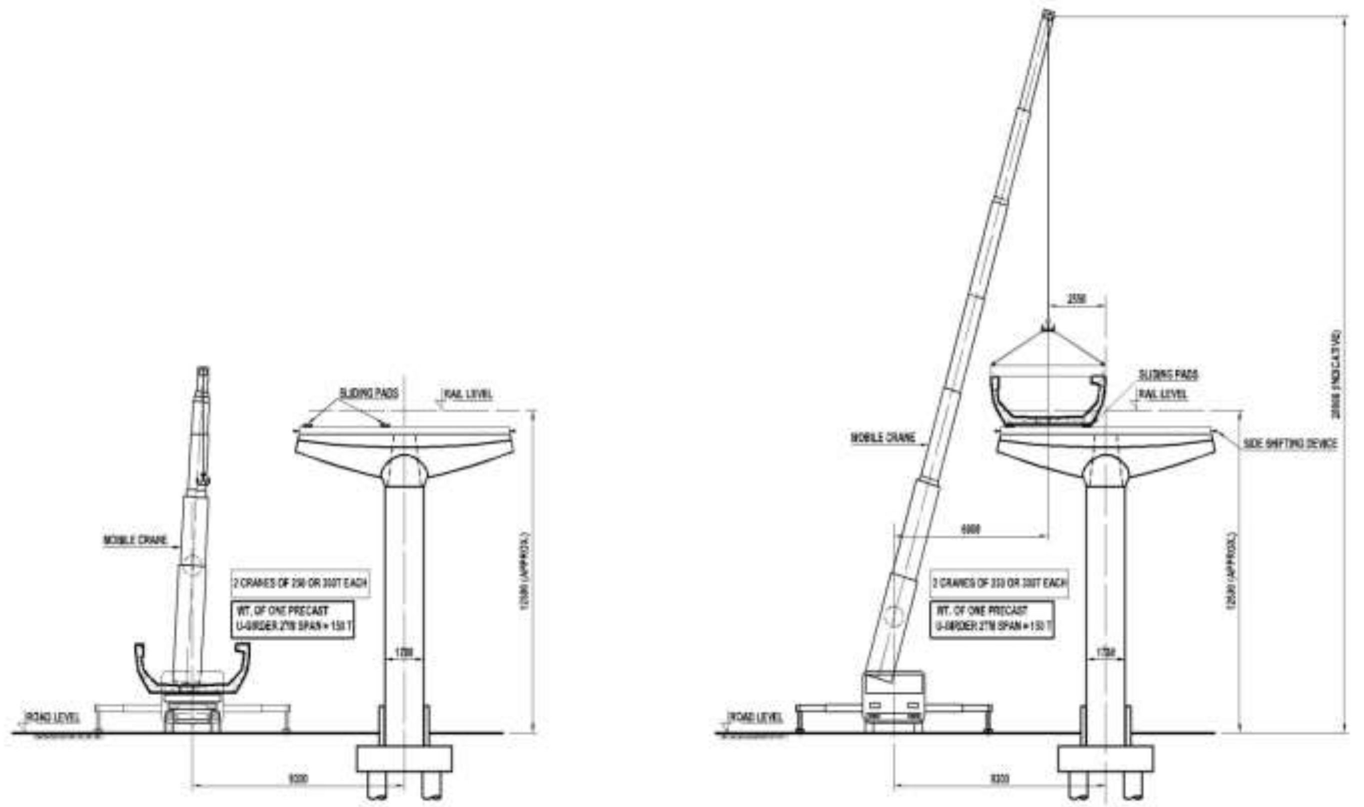
Figure 4.1

TYPICAL CROSS SECTION OF THE VIADUCT WITH DOUBLE U GIRDER



SCALE:- NTS

Figure 4.2(a): Erection of Girder using Crane

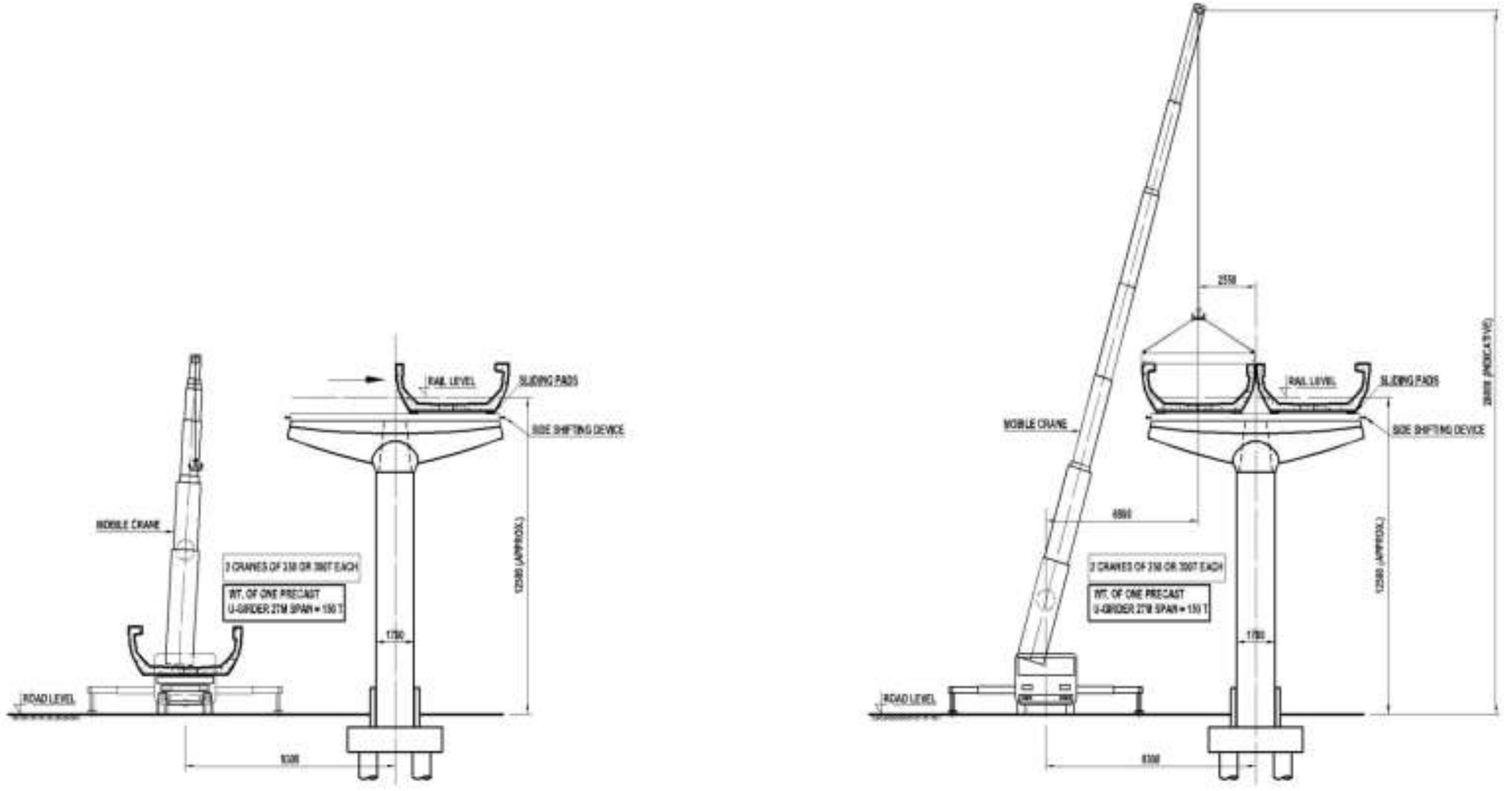


STAGE 1- LIFTING OF U-BEAM FROM TRAILER
SECTION A-A
SCALE : 1:100

STAGE 2 - INSTALLATION OF U-BEAM ON PIER CAP
SECTION B-B
SCALE : 1:100

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

Figure 4.2(b): Erection of Girder using Crane



STAGE 3 - SIDE SHIFTING OF U-GIRDER

SECTION C-C

SCALE : 1/100

STAGE 4 - LIFTING AND INSTALLATION OF OTHER U-GIRDER

SECTION D-D

SCALE : 1/100

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

Figure 4.3: Bored Tunnel & Underground Station

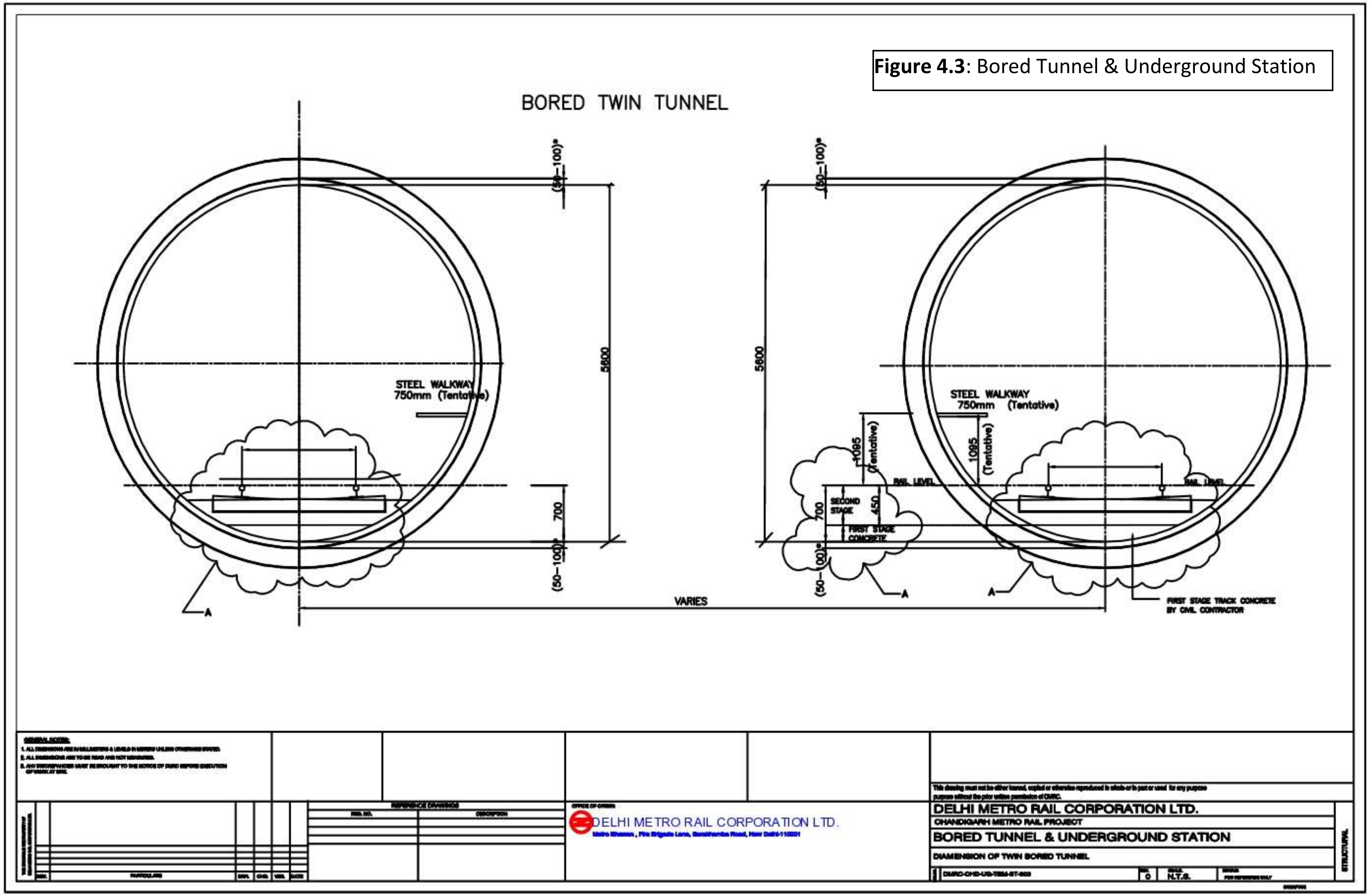


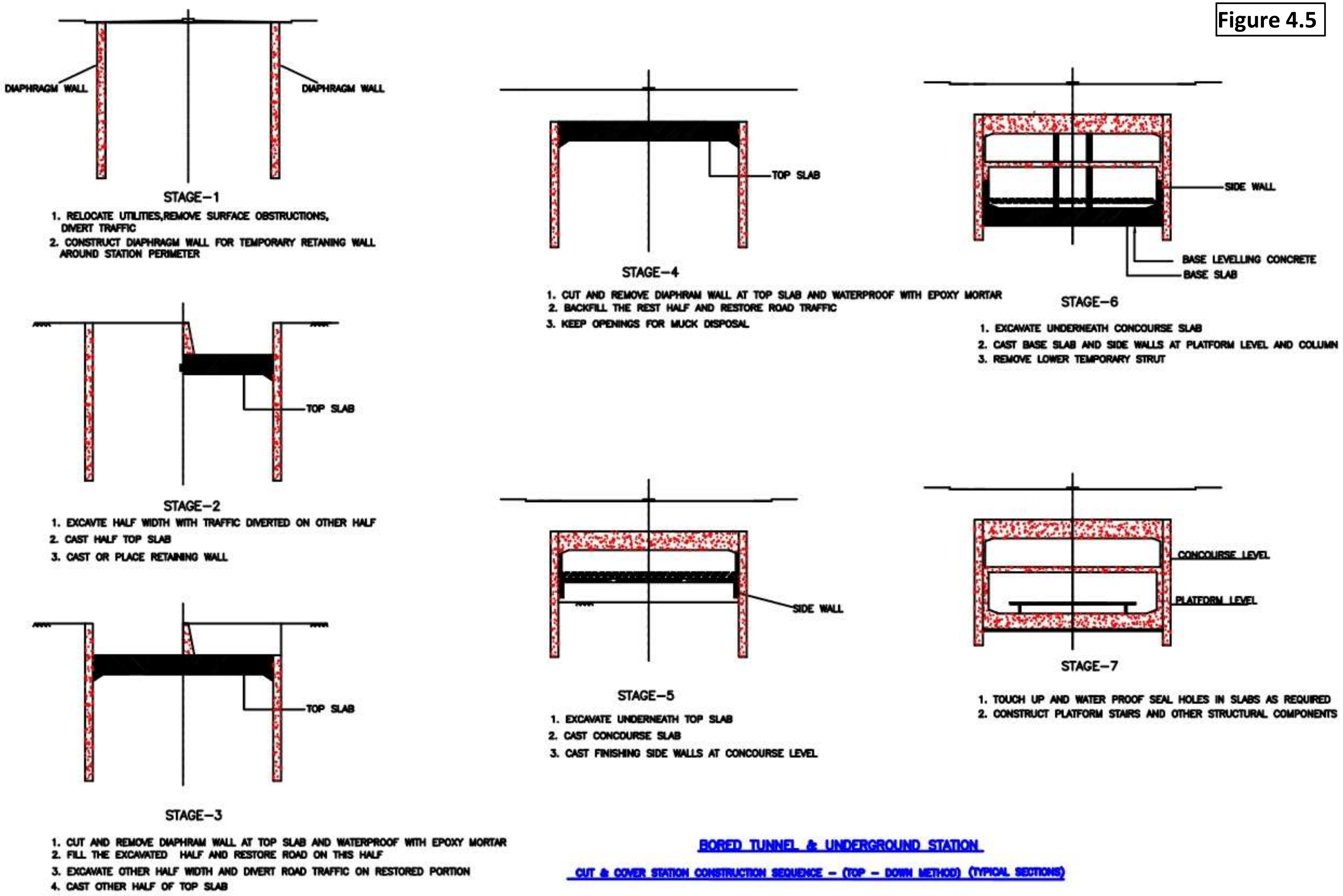
Figure 4.4

NOTE :
Thickness of walls, slab & intermediate walls are indicative only.

TUNNEL

DIMENSIONS OF TUNNEL SECTION (TYPICAL SECTIONS)

Figure 4.5



STAGE-1

1. RELOCATE UTILITIES,REMOVE SURFACE OBSTRUCTIONS, DIVERT TRAFFIC
2. CONSTRUCT DIAPHRAGM WALL FOR TEMPORARY RETANING WALL AROUND STATION PERIMETER

STAGE-2

1. EXCAVTE HALF WIDTH WITH TRAFFIC DIVERTED ON OTHER HALF
2. CAST HALF TOP SLAB
3. CAST OR PLACE RETAINING WALL

STAGE-3

1. CUT AND REMOVE DIAPHRAM WALL AT TOP SLAB AND WATERPROOF WITH EPOXY MORTAR
2. FILL THE EXCAVATED HALF AND RESTORE ROAD ON THIS HALF
3. EXCAVATE OTHER HALF WIDTH AND DIVERT ROAD TRAFFIC ON RESTORED PORTION
4. CAST OTHER HALF OF TOP SLAB

STAGE-4

1. CUT AND REMOVE DIAPHRAM WALL AT TOP SLAB AND WATERPROOF WITH EPOXY MORTAR
2. BACKFILL THE REST HALF AND RESTORE ROAD TRAFFIC
3. KEEP OPENINGS FOR MUCK DISPOSAL

STAGE-5

1. EXCAVATE UNDERNEATH TOP SLAB
2. CAST CONCOURSE SLAB
3. CAST FINISHING SIDE WALLS AT CONCOURSE LEVEL

STAGE-6

1. EXCAVATE UNDERNEATH CONCOURSE SLAB
2. CAST BASE SLAB AND SIDE WALLS AT PLATFORM LEVEL AND COLUMN
3. REMOVE LOWER TEMPORARY STRUT

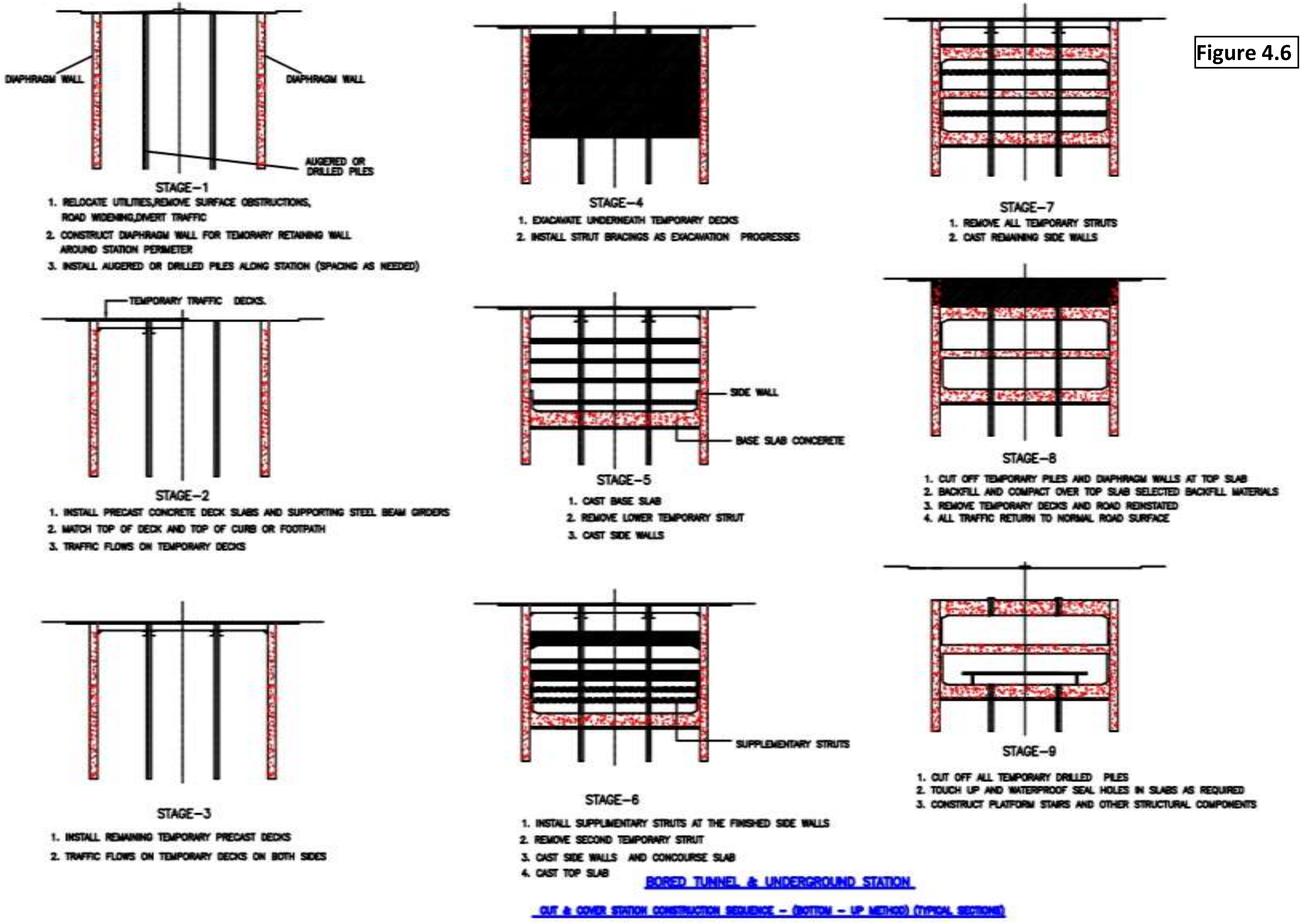
STAGE-7

1. TOUCH UP AND WATER PROOF SEAL HOLES IN SLABS AS REQUIRED
2. CONSTRUCT PLATFORM STAIRS AND OTHER STRUCTURAL COMPONENTS

BORED TUNNEL & UNDERGROUND STATION

CUT & COVER STATION CONSTRUCTION SEQUENCE – (TOP – DOWN METHOD) (TYPICAL SECTIONS)

Figure 4.6



STAGE-1

1. RELOCATE UTILITIES,REMOVE SURFACE OBSTRUCTIONS, ROAD WIDENING,DIVERT TRAFFIC
2. CONSTRUCT DIAPHRAGM WALL FOR TEMORARY RETAINING WALL AROUND STATION PERIMETER
3. INSTALL AUGERED OR DRILLED PILES ALONG STATION (SPACING AS NEEDED)

STAGE-2

1. INSTALL PRECAST CONCRETE DECK SLABS AND SUPPORTING STEEL BEAM GIRDERS
2. MATCH TOP OF DECK AND TOP OF CURB OR FOOTPATH
3. TRAFFIC FLOWS ON TEMPORARY DECKS

STAGE-3

1. INSTALL REMAINING TEMPORARY PRECAST DECKS
2. TRAFFIC FLOWS ON TEMPORARY DECKS ON BOTH SIDES

STAGE-4

1. EXACAVATE UNDERNEATH TEMPORARY DECKS
2. INSTALL STRUT BRACINGS AS EXACAVATION PROGRESSES

STAGE-5

1. CAST BASE SLAB
2. REMOVE LOWER TEMPORARY STRUT
3. CAST SIDE WALLS

STAGE-6

1. INSTALL SUPPLMENTARY STRUTS AT THE FINISHED SIDE WALLS
2. REMOVE SECOND TEMPORARY STRUT
3. CAST SIDE WALLS AND CONCOURSE SLAB
4. CAST TOP SLAB

STAGE-7

1. REMOVE ALL TEMPORARY STRUTS
2. CAST REMAINING SIDE WALLS

STAGE-8

1. CUT OFF TEMPORARY PILES AND DIAPHRAGM WALLS AT TOP SLAB
2. BACKFILL AND COMPACT OVER TOP SLAB SELECTED BACKFILL MATERIALS
3. REMOVE TEMPORARY DECKS AND ROAD REINSTATED
4. ALL TRAFFIC RETURN TO NORMAL ROAD SURFACE

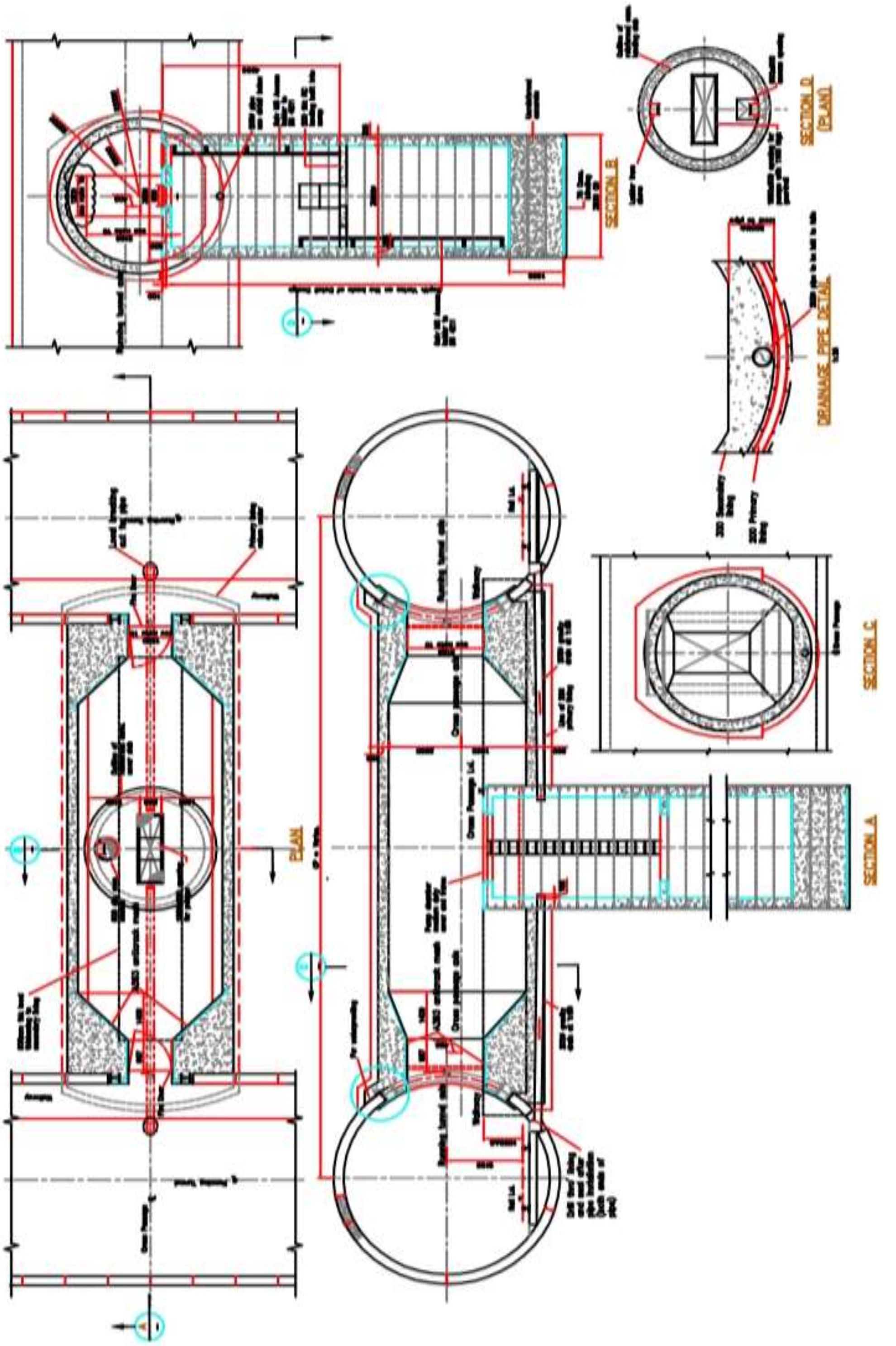
STAGE-9

1. CUT OFF ALL TEMPORARY DRILLED PILES
2. TOUCH UP AND WATERPROOF SEAL HOLES IN SLABS AS REQUIRED
3. CONSTRUCT PLATFORM STAIRS AND OTHER STRUCTURAL COMPONENTS

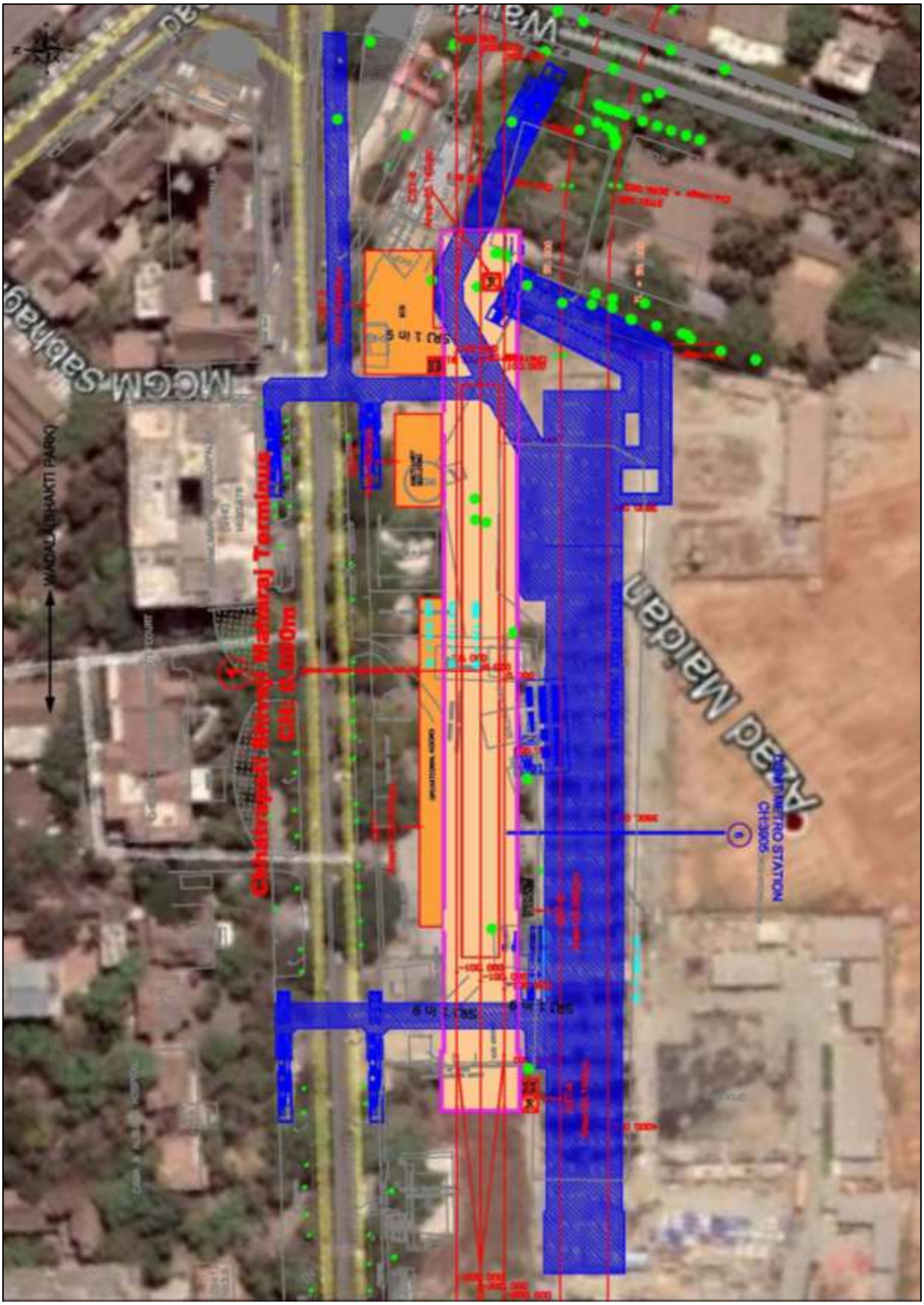
BORED TUNNEL & UNDERGROUND STATION

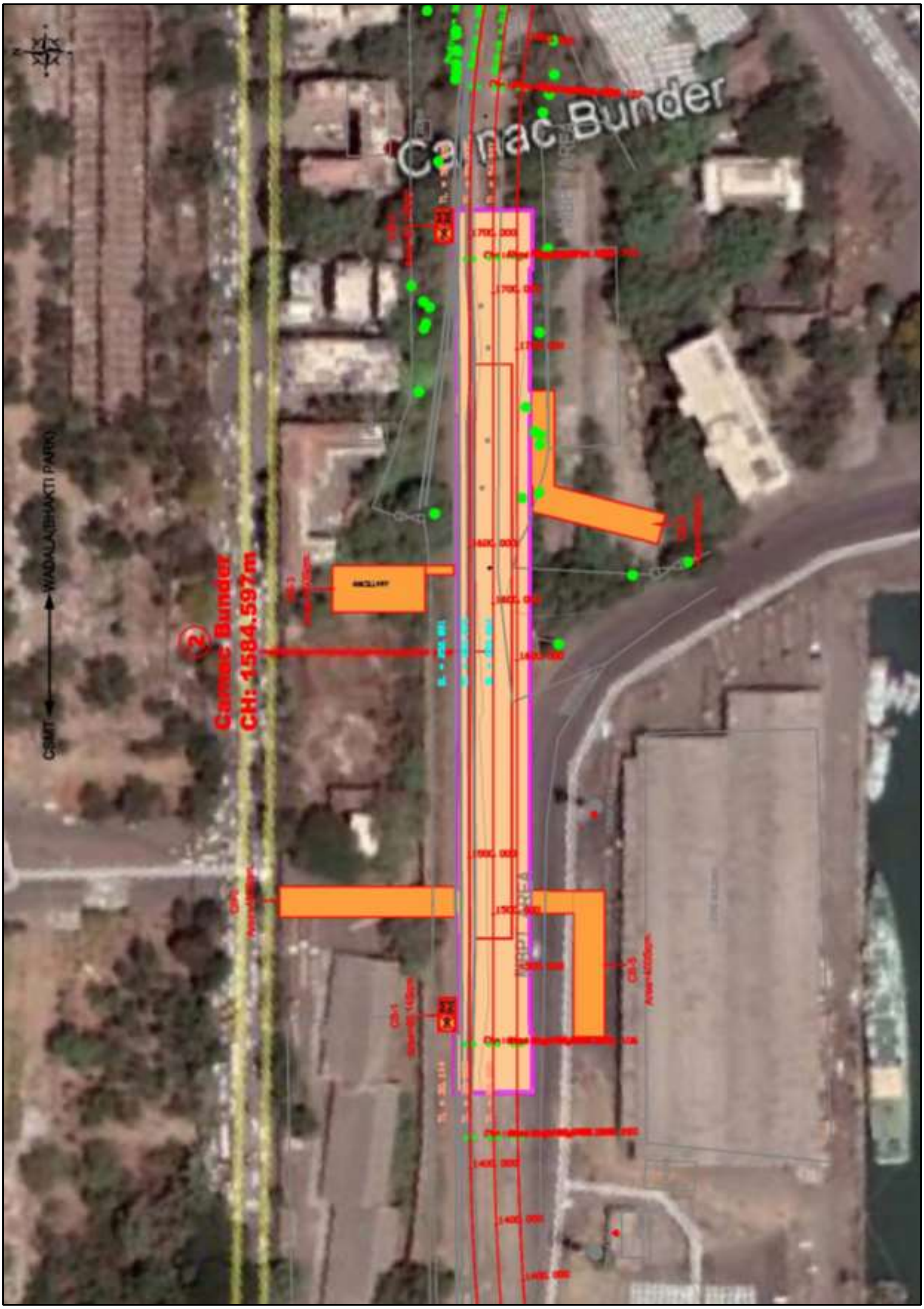
CUT & COVER STATION CONSTRUCTION SEQUENCE - (BOTTOM - UP METHOD) (TYPICAL SECTIONS)

Figure 4.7

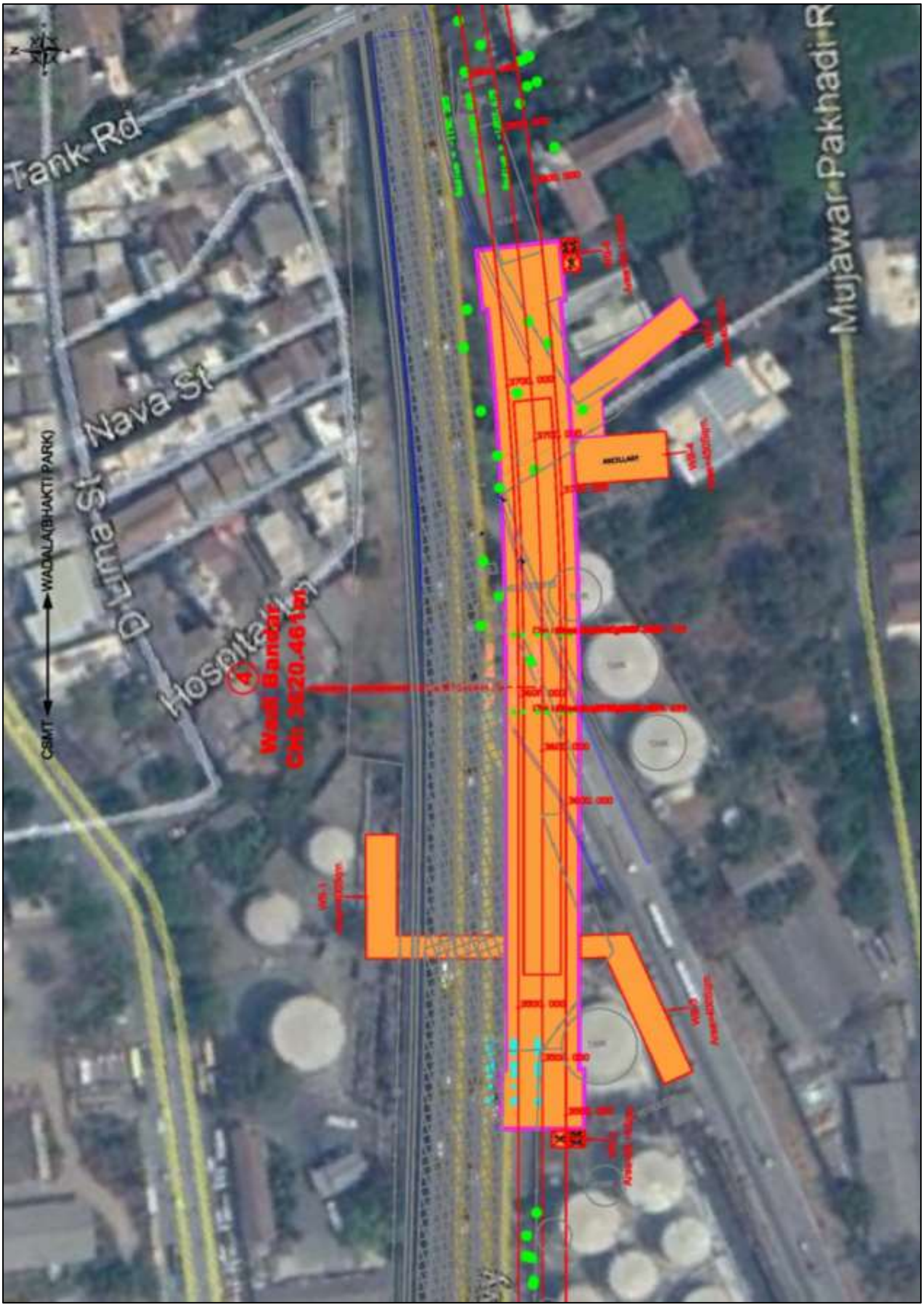


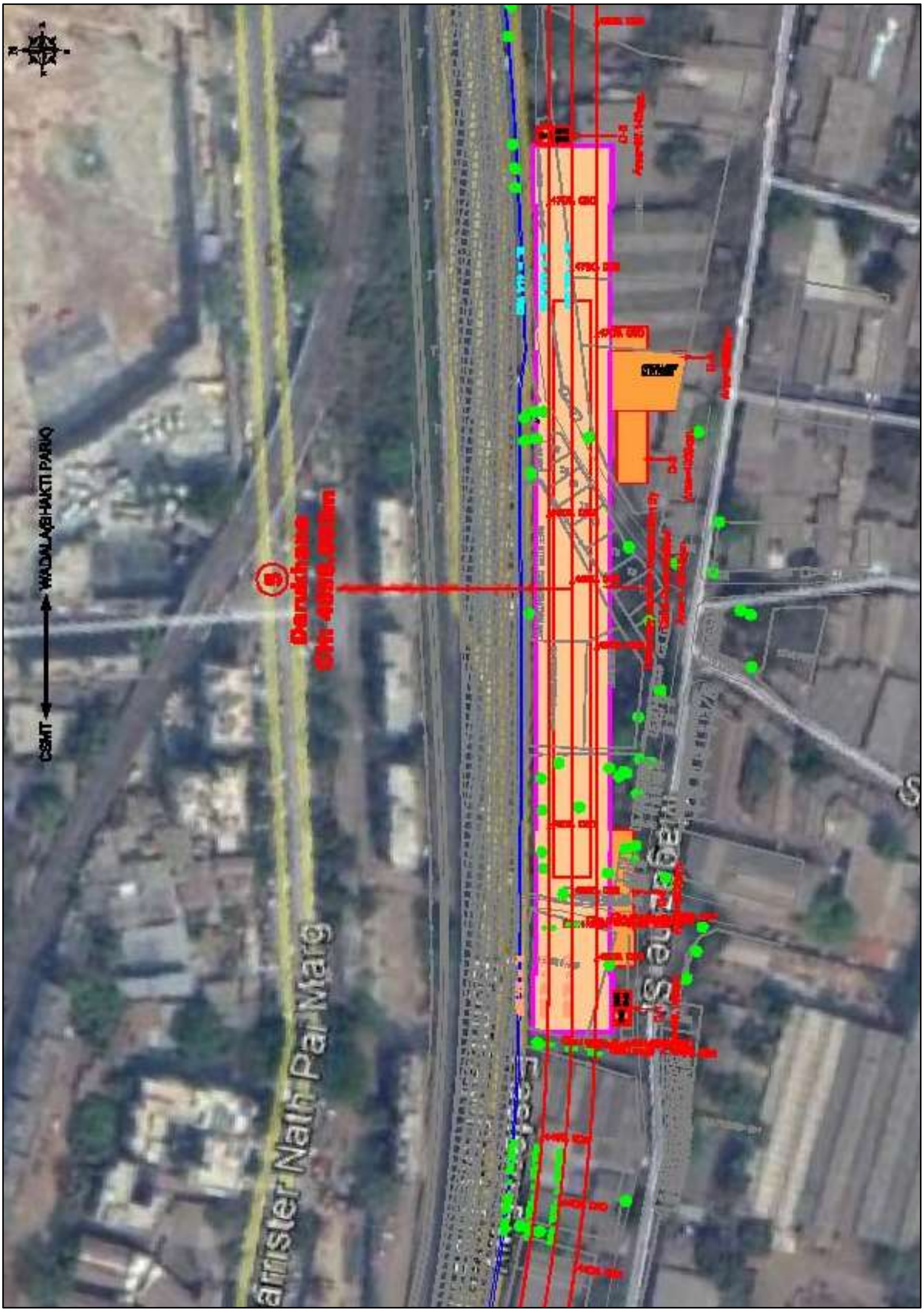
BORED TUNNEL & UNDERGROUND STATION CROSS PASSAGE WITH SUMP (TYPICAL SECTION)


WADALA (BHAKTI PARK)
MCGM Sabhagr
Chhatrapati Shivaji Maharaj Terminus
CH: 0.000m
SRJ 1 in 5
SRJ 1 in 6
Azad Maidan
CSMT METRO STATION
CH:13906

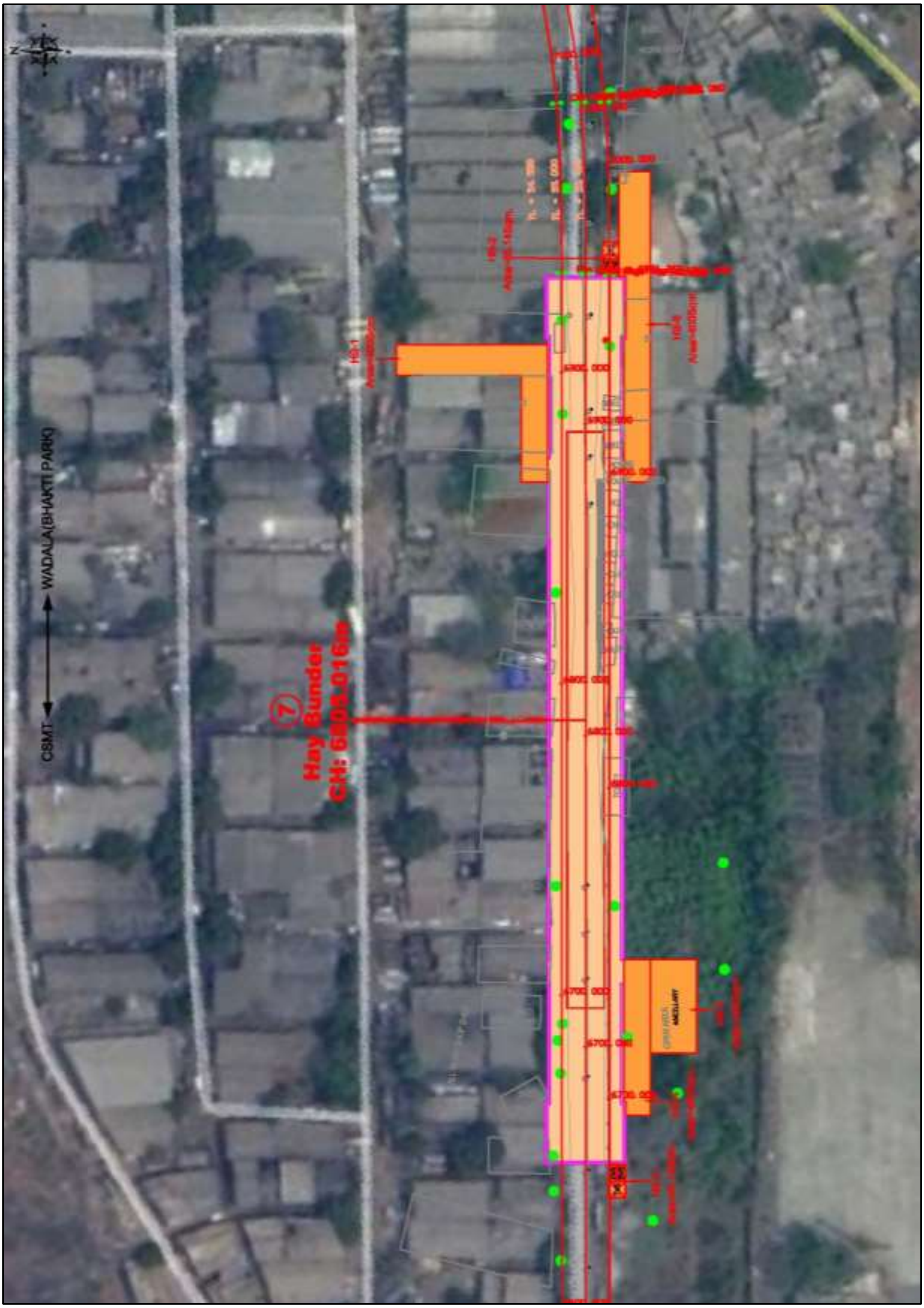

Carnac Bunder
WADALA (SHAKTI PARK)
CSMT
2
Carnac Bunder
CH: 1584.597m
ANCILLARY

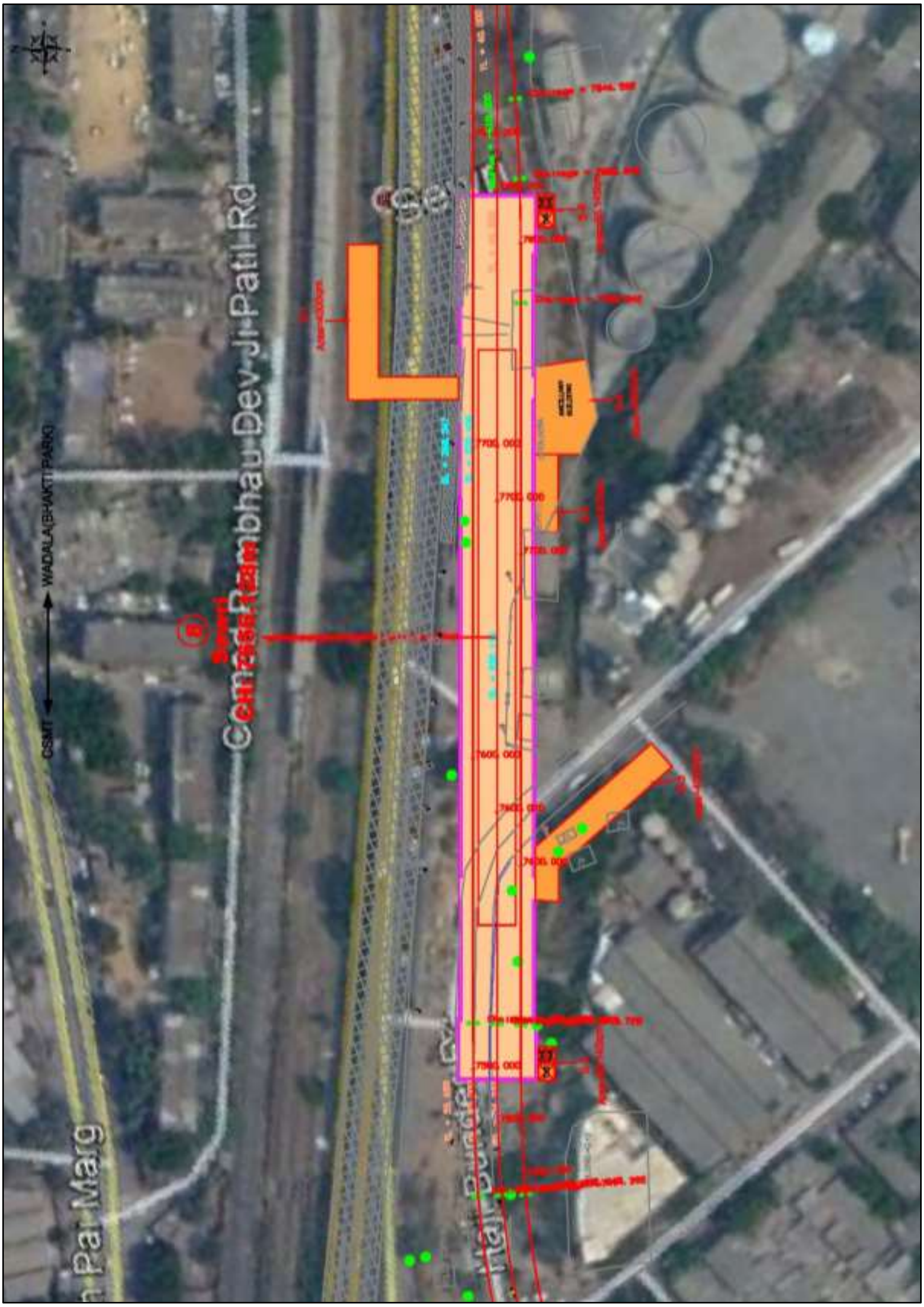

CSMT
WADALA(BHAKTI PARK)
Frere Rd
Braf Hmadelkahoi Rd
Mansion Road
③
Clock Tower
CH: 2473.983m
CT-1
CT-2
Area=4005m
CT-3
Area=4005m
CT-4
Area=4005m
CT-5
Area=4005m
CT-6
Area=4005m
ANCILLARY


Tank Rd
Nava St
D Lima St
Hospital
Mujawar Pakhadi R
WADALA(BHAKTI PARK)
CSMT
4
Wadi Bandar
CH: 3620.461m
ANCILLARY

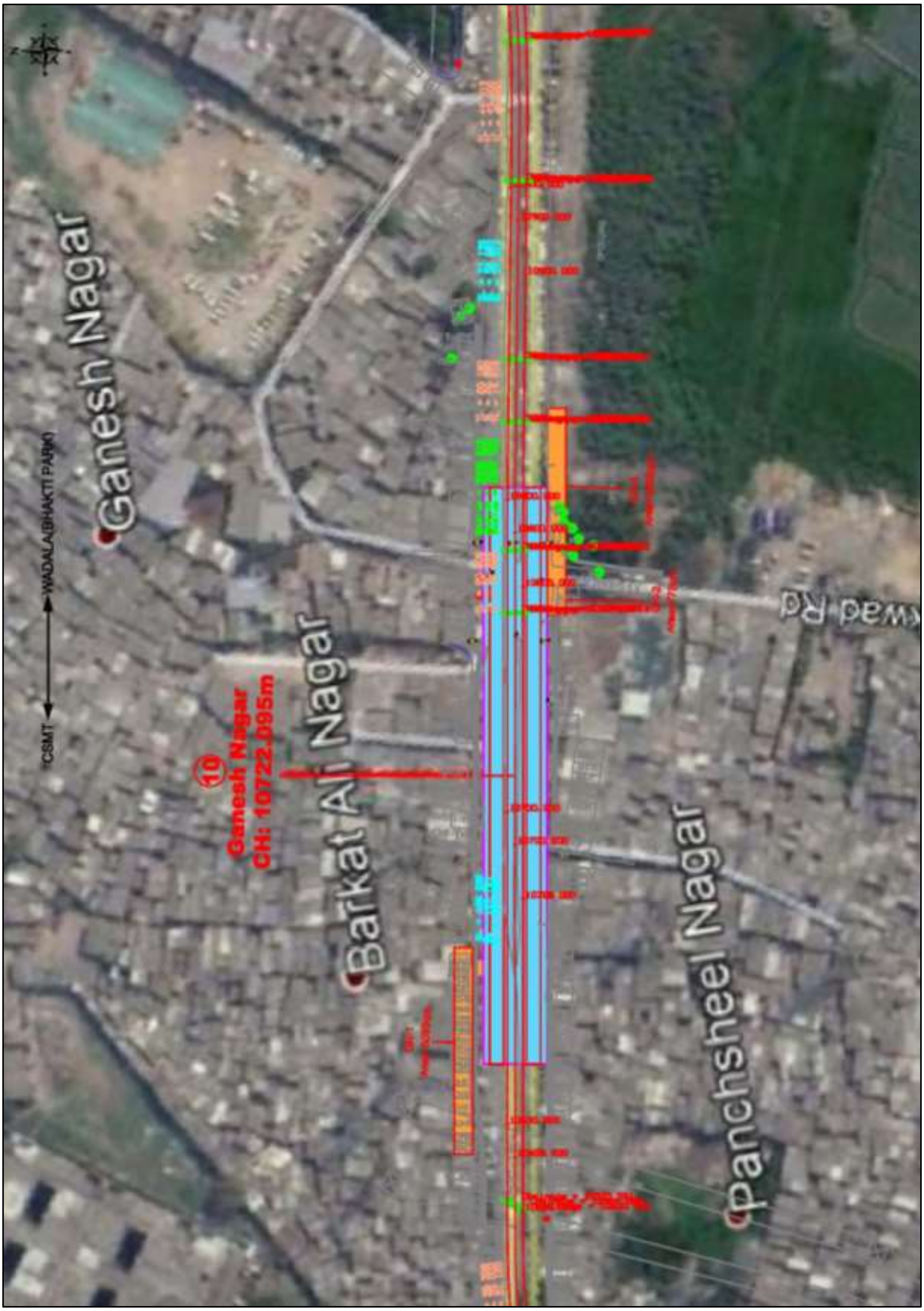

CSMT
WADALA(BHAKTI PARK)
Barrister Nath Pai Marg


WADALA(BHAKTI PARK)
CSMT
⑥
Coal Bunder
CH: 5780.570m
ANCILLARY


CSMT
WADALA(BHAKTI PARK)
N
7
Hay Bunder
CH: 6805.016m
HB-1
HB-2
HB-4
ANCILLARY


WADALA(BHAKTI PARK)
CSMT
Dev-Ji-Patil-Rd
Pai Marg
Bunder


BPT Hospital
CH: 9754.193m
BPT Colony
WADALA(BHAKTI PARK)
CSMT


Ganesh Nagar
WADALA(BHAKTI PARK)
CSMT
⑩
Ganesh Nagar
CH: 10722.095m
Barkat Ali Nagar
Panchsheel Nagar
wad Rd

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-4.8& Figure-4.9 to this appendix.

Figure -4.8Typical Elevated Station Layout

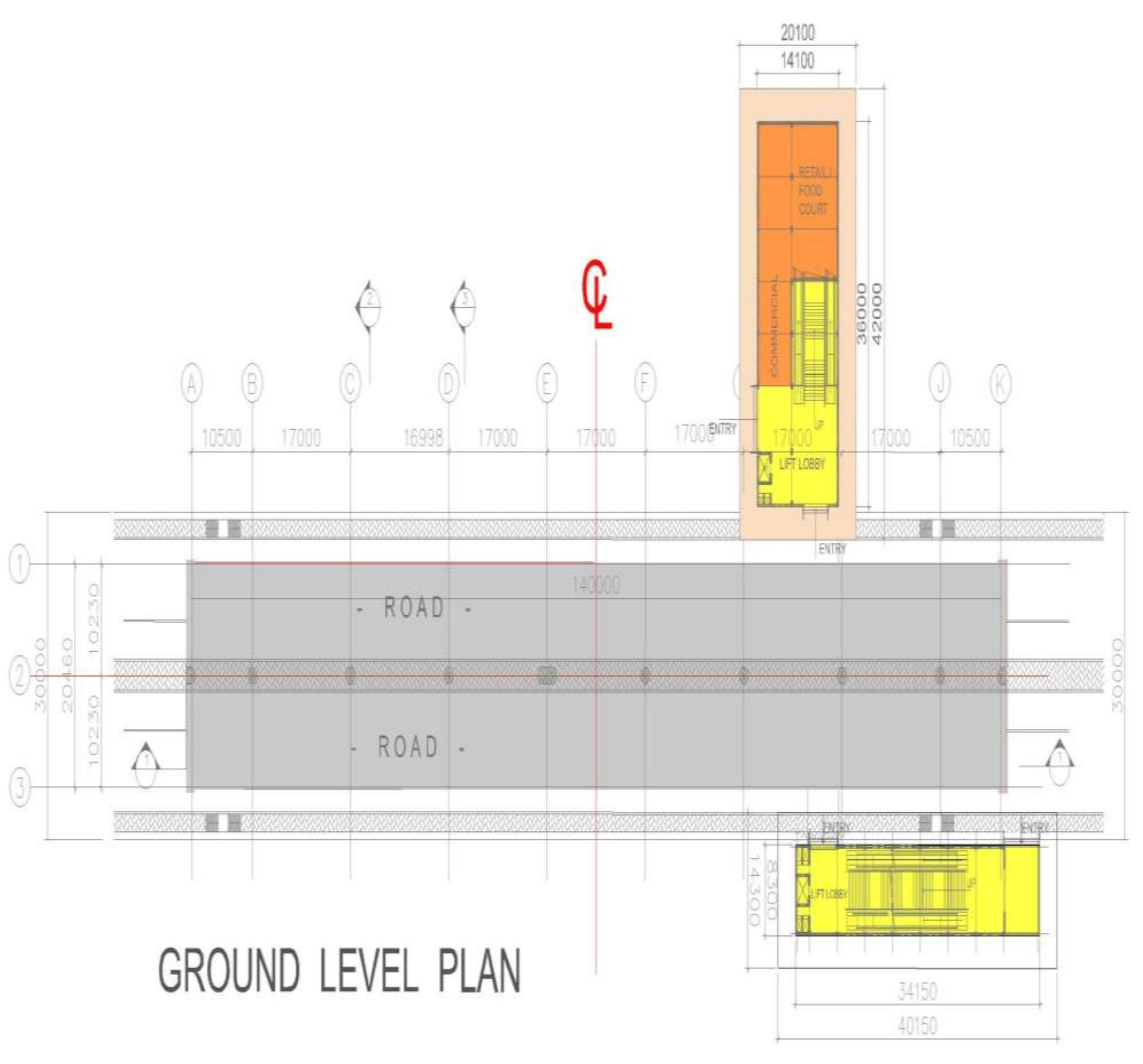
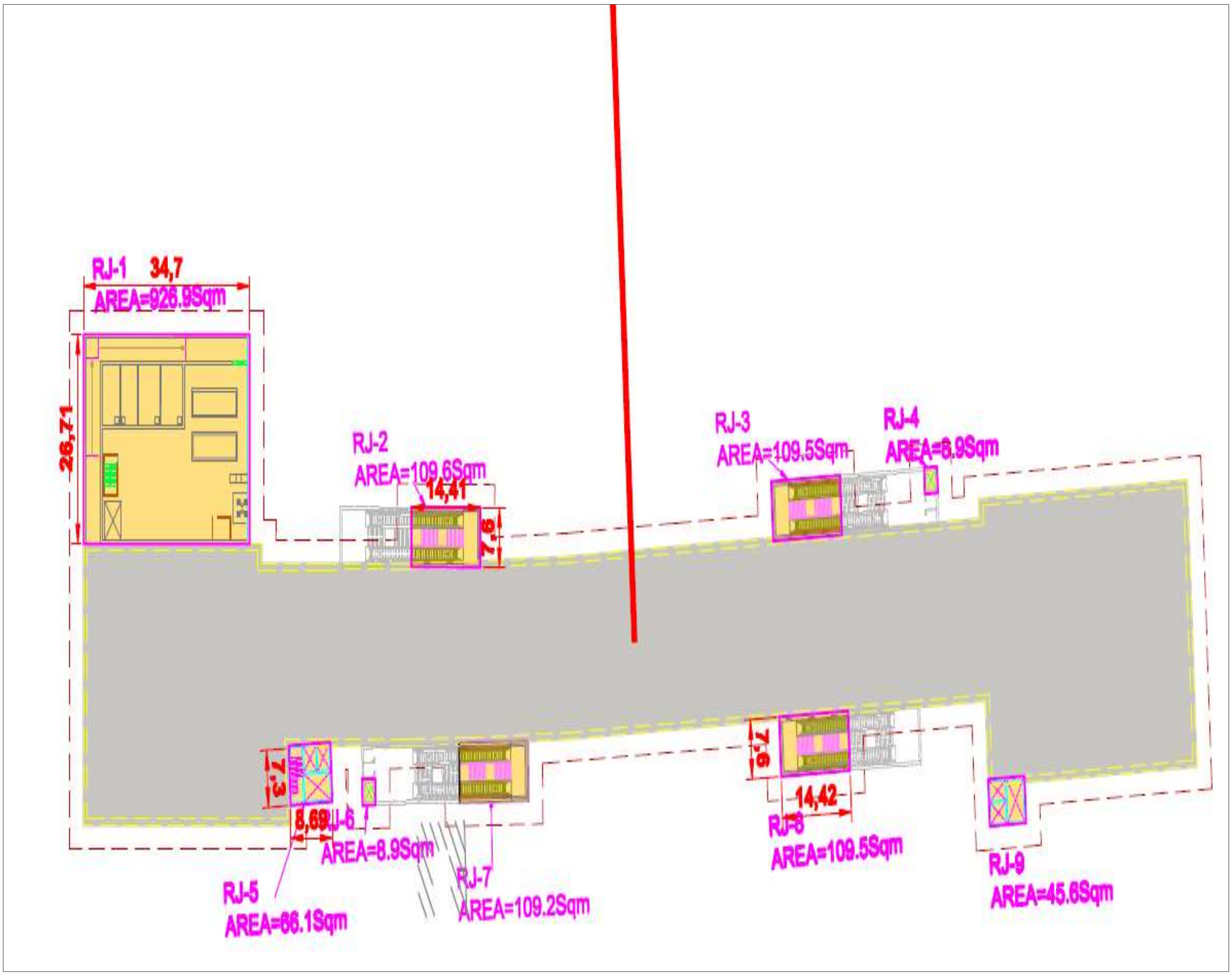


Figure-4.9 Typical Underground Station Layout

Ground Level Plan



CHAPTER - 5

STATION PLANNING

5.1 GENERAL

The proposed Metro Corridor is from Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park). It is in the southern portion of the Mumbai. In fact this corridor is the southward extension of Gaimukh-Kasarvadavali-Wadala Corridor of Mumbai Metro.

This proposed extension of Gaimukh to Wadala Corridor consists of ten stations. Out of these ten stations, eight are underground and two are elevated. CSMT metro station is proposed will be an Interchange Station. The placement of these stations has been done considering Right of way, land availability, location, proximity to the Institutions for better ridership and connectivity.

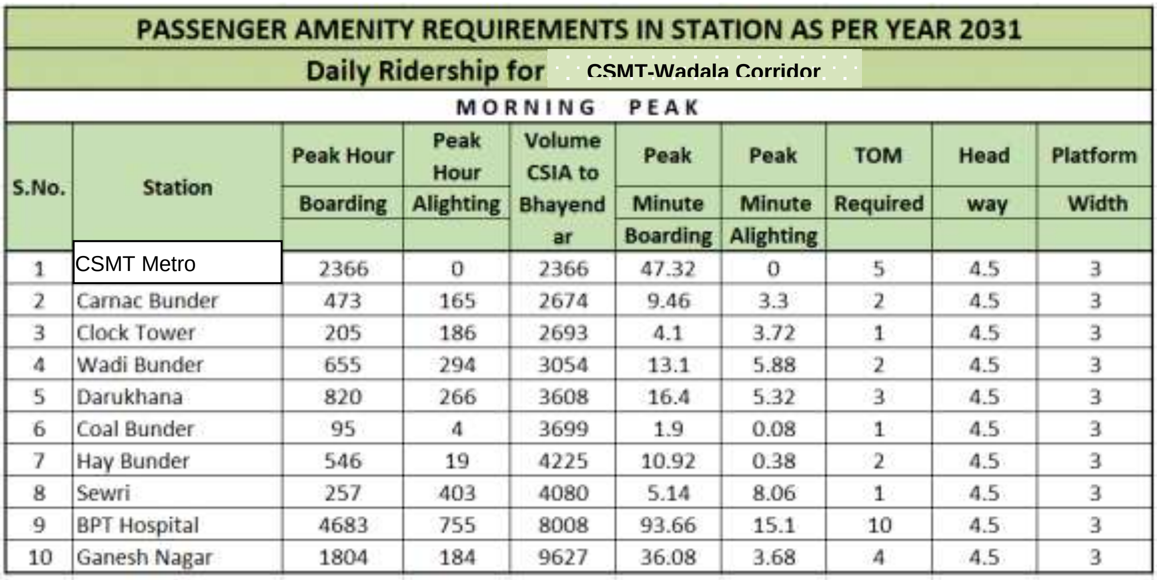
CSMT Metro station (underground) is proposed adjoining to an under-construction underground station. At this location concourse of both the stations are planned to be merged by entry structure connections. To attract maximum pedestrian traffic, station locations are finalised at the traffic nodal points.

5.2 STATION TYPES

Total Ten Stations have been planned on this extension. Out of Ten Stations, Eight are Underground and Two are Elevated. Concourse of all elevated stations is proposed along the roads with sufficient Right of way. The stations accommodate the passengers from the eastern port area of Mumbai.

Average inter-station distance is 1.27 km approximately varying from 0.85 km to 2.1 km depending upon the site, operational and traffic constraints. The sequence of stations with their respective location and platform characteristics is presented in Table 5.4.

Table 5.1: Passenger Amenity Requirements (Morning Peak)



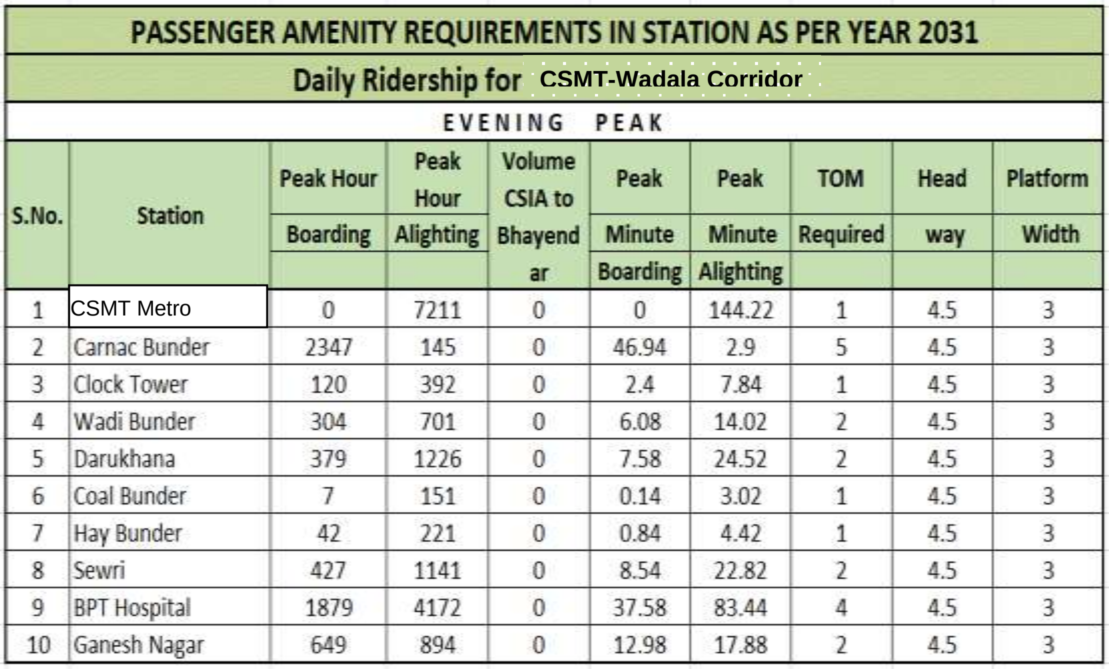
PASSENGER AMENITY REQUIREMENTS IN STATION AS PER YEAR 2031

Daily Ridership for CSMT-Wadala Corridor

MORNING PEAK

S.No.	Station	Peak Hour Boarding	Peak Hour Alighting	Volume CSIA to Bhayendar	Peak Minute Boarding	Peak Minute Alighting	TOM Required	Head way	Platform Width
1	CSMT Metro	2366	0	2366	47.32	0	5	4.5	3
2	Carnac Bunder	473	165	2674	9.46	3.3	2	4.5	3
3	Clock Tower	205	186	2693	4.1	3.72	1	4.5	3
4	Wadi Bunder	655	294	3054	13.1	5.88	2	4.5	3
5	Darukhana	820	266	3608	16.4	5.32	3	4.5	3
6	Coal Bunder	95	4	3699	1.9	0.08	1	4.5	3
7	Hay Bunder	546	19	4225	10.92	0.38	2	4.5	3
8	Sewri	257	403	4080	5.14	8.06	1	4.5	3
9	BPT Hospital	4683	755	8008	93.66	15.1	10	4.5	3
10	Ganesh Nagar	1804	184	9627	36.08	3.68	4	4.5	3

Table 5.2: Passenger Amenity Requirements (Evening Peak)



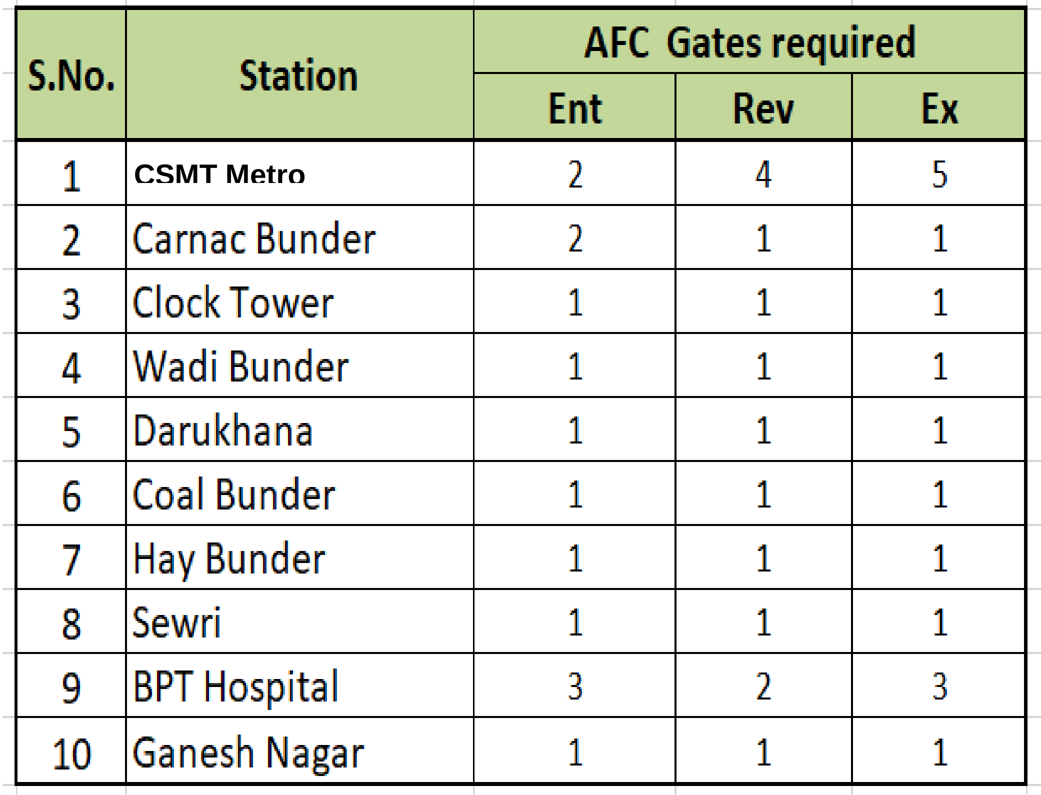
PASSENGER AMENITY REQUIREMENTS IN STATION AS PER YEAR 2031

Daily Ridership for CSMT-Wadala Corridor

EVENING PEAK

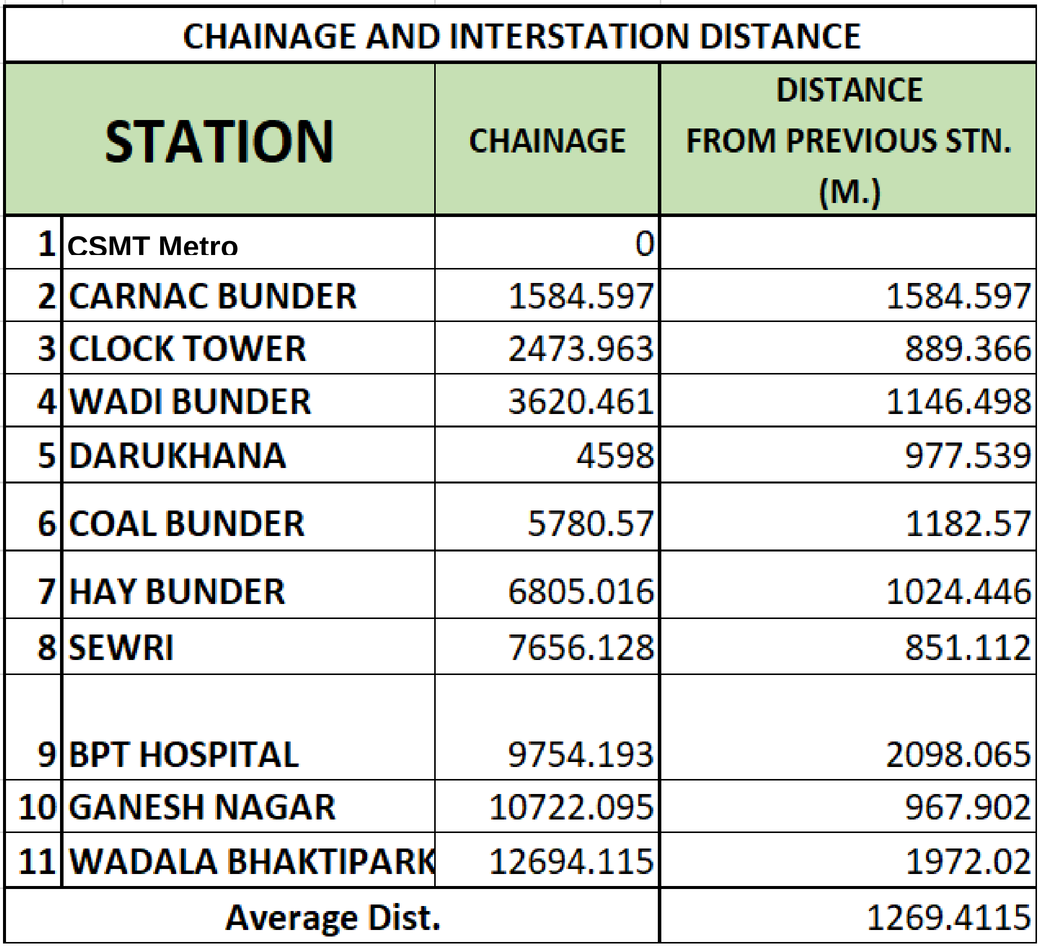
S.No.	Station	Peak Hour Boarding	Peak Hour Alighting	Volume CSIA to Bhayendar	Peak Minute Boarding	Peak Minute Alighting	TOM Required	Head way	Platform Width
1	CSMT Metro	0	7211	0	0	144.22	1	4.5	3
2	Carnac Bunder	2347	145	0	46.94	2.9	5	4.5	3
3	Clock Tower	120	392	0	2.4	7.84	1	4.5	3
4	Wadi Bunder	304	701	0	6.08	14.02	2	4.5	3
5	Darukhana	379	1226	0	7.58	24.52	2	4.5	3
6	Coal Bunder	7	151	0	0.14	3.02	1	4.5	3
7	Hay Bunder	42	221	0	0.84	4.42	1	4.5	3
8	Sewri	427	1141	0	8.54	22.82	2	4.5	3
9	BPT Hospital	1879	4172	0	37.58	83.44	4	4.5	3
10	Ganesh Nagar	649	894	0	12.98	17.88	2	4.5	3

Table 5.3: AFC Gates Required



S.No.	Station	AFC Gates required		
		Ent	Rev	Ex
1	CSMT Metro	2	4	5
2	Carnac Bunder	2	1	1
3	Clock Tower	1	1	1
4	Wadi Bunder	1	1	1
5	Darukhana	1	1	1
6	Coal Bunder	1	1	1
7	Hay Bunder	1	1	1
8	Sewri	1	1	1
9	BPT Hospital	3	2	3
10	Ganesh Nagar	1	1	1

Table 5.4: Sequence of Stations with chainages and interstation distance



CHAINAGE AND INTERSTATION DISTANCE			
STATION		CHAINAGE	DISTANCE FROM PREVIOUS STN. (M.)
1	CSMT Metro	0	
2	CARNAC BUNDER	1584.597	1584.597
3	CLOCK TOWER	2473.963	889.366
4	WADI BUNDER	3620.461	1146.498
5	DARUKHANA	4598	977.539
6	COAL BUNDER	5780.57	1182.57
7	HAY BUNDER	6805.016	1024.446
8	SEWRI	7656.128	851.112
9	BPT HOSPITAL	9754.193	2098.065
10	GANESH NAGAR	10722.095	967.902
11	WADALA BHAKTIPARK	12694.115	1972.02
Average Dist.			1269.4115

1. CSMT Metro Station

Chainage	0 m.
Inter-Station Distance (From Dhahisar station)	0 m.
Rail Level	-12.200 m.
Platform Depth from Ground	17.742 m.
Location	Located on Dadabhai Naoroji Road in Mumbai
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Taj Palace Tower Hotel, Gateway of India, Municipal Corporation of Greater Mumbai.
Remarks	Vent shafts of the Existing under construction station will come above the station box of the proposed station. These shafts can be shifted if needed in future. Entry Exits of the under construction station will be merged to the unpaid area of the proposed station.

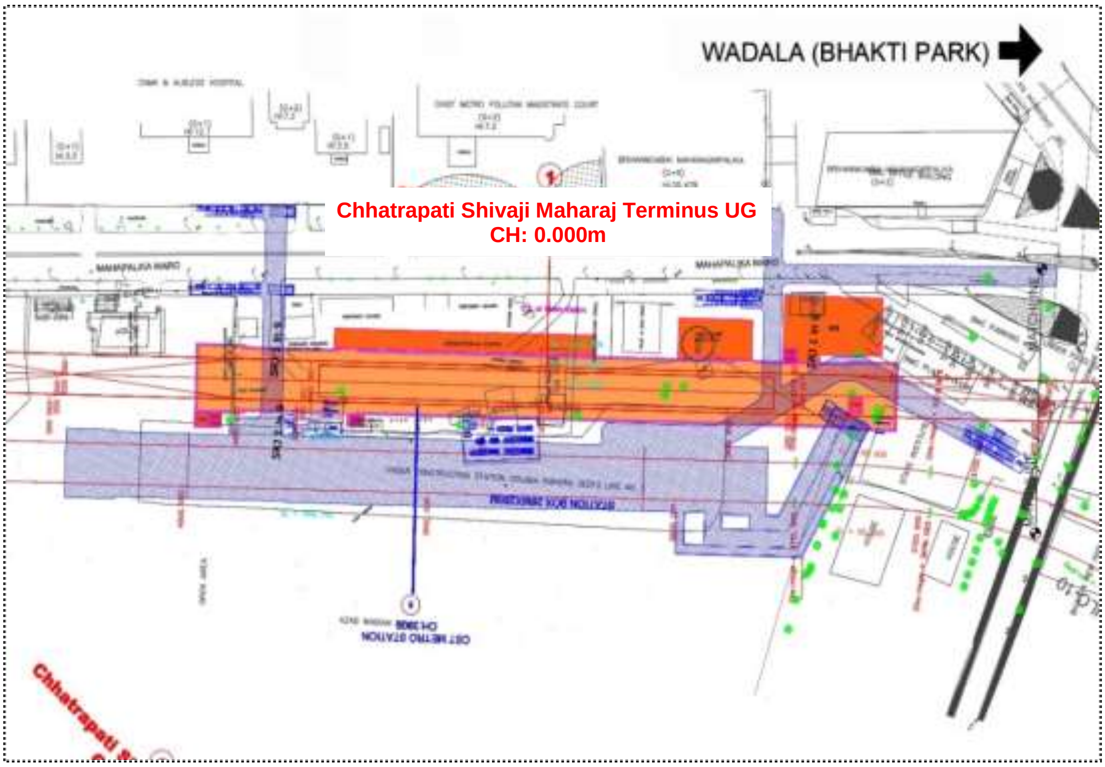


Figure 5.1 Site Photographs showing site conditions – CSMT Station

2. Carnac Bunder

Chainage	1584.597 m
Inter-Station Distance	1584.597 m
Rail Level	-17.500
Platform Depth from Ground	19.145
Location	Located on eastern port area of the Mumbai near Mumbai Port Trust.
Entry / Exit Stairs	Entry Exit stairs proposed in the proximity of the Mumbai Port area
Catchment Area	Chhatrapati Shivaji Maharaj Terminus, Mumbai Port trust Building, Indira Docks, Victoria Docks.

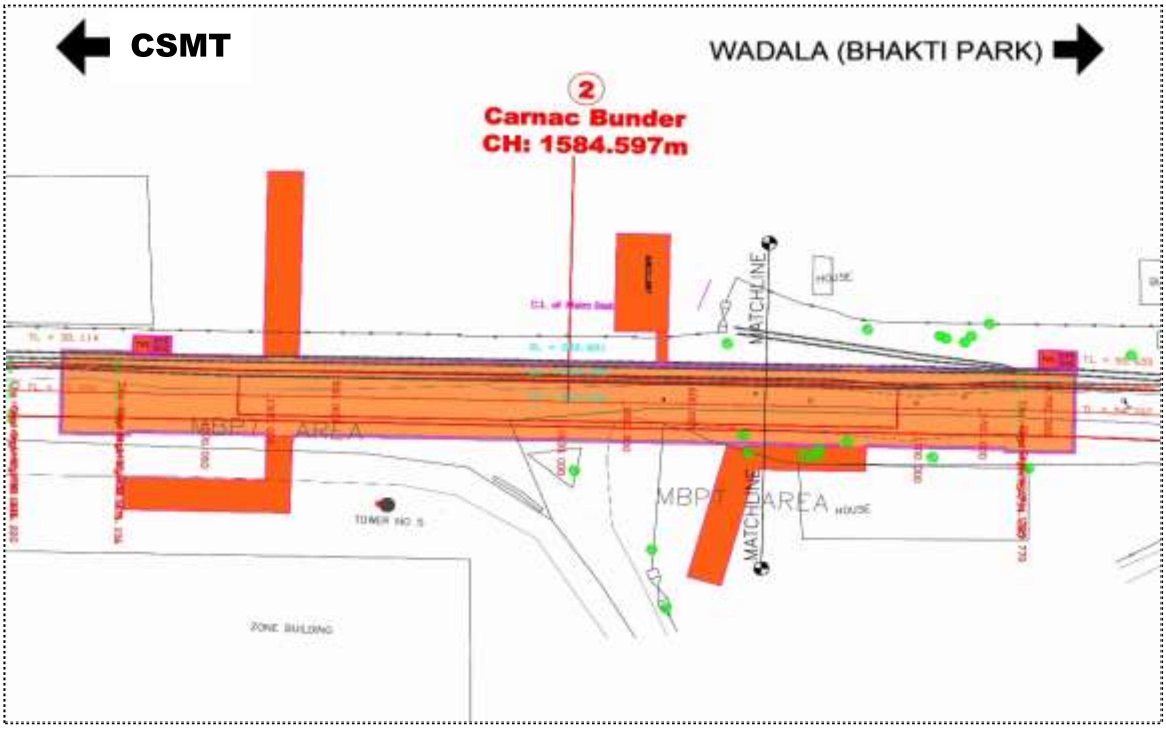


Figure 5.2 Site Photographs showing site conditions – Carnac Bunder

3. Clock Tower

Chainage	2473.963 m
Inter-Station Distance	889.366 m.
Rail Level	-18.00 m.
Platform Depth from Ground	20.123 m.
Location	Located besides Braf hammadelkahoi Road near Mumbai port Trust
Entry / Exit Stairs	Entry Exit stairs proposed in the proximity of the Mumbai Port area
Catchment Area	Dana Bandar, Masjid bandar east, Victoria Docks

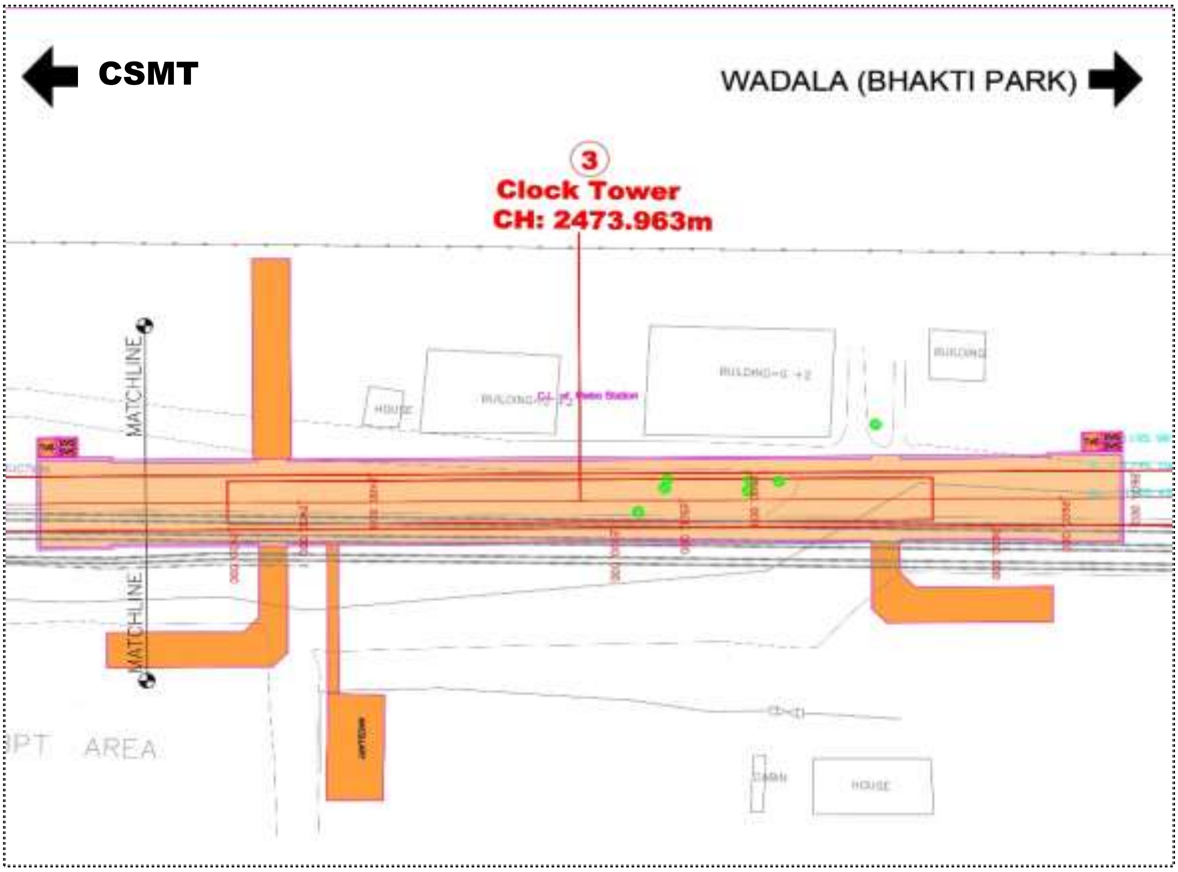


Figure 5.3 Site Photographs showing site conditions – Clock Tower

4. Wadi Bunder

Chainage	3620.461 m.
Inter-Station Distance	1146.49 m.
Rail Level	-16.00 m.
Platform Depth from Ground	18.966 m.
Location	Located beside Bombay Port Trust Road
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Wadi Bunder, Mazgaon, Ekta Nagar, Central Railway Godown

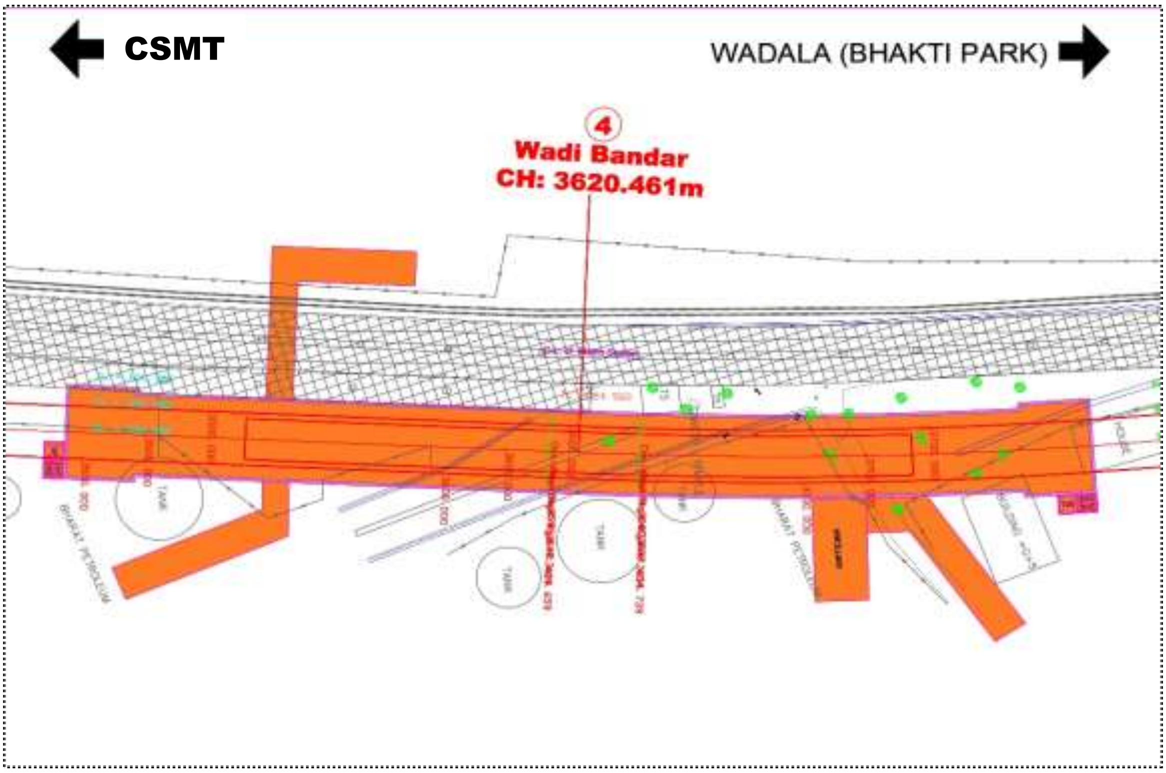


Figure 5.4 Site Photographs showing site conditions – Wadi Bunder

5. Darukhana

Chainage	4598.0 m.
Inter-Station Distance	977.539 m.
Rail Level	-17.00 m.
Platform Depth from Ground	19.91 m.
Location	Located beside Bombay Port Trust Road
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Darukhana, Railway Colony, Byculla, Narial wadi, Thakkar Estate

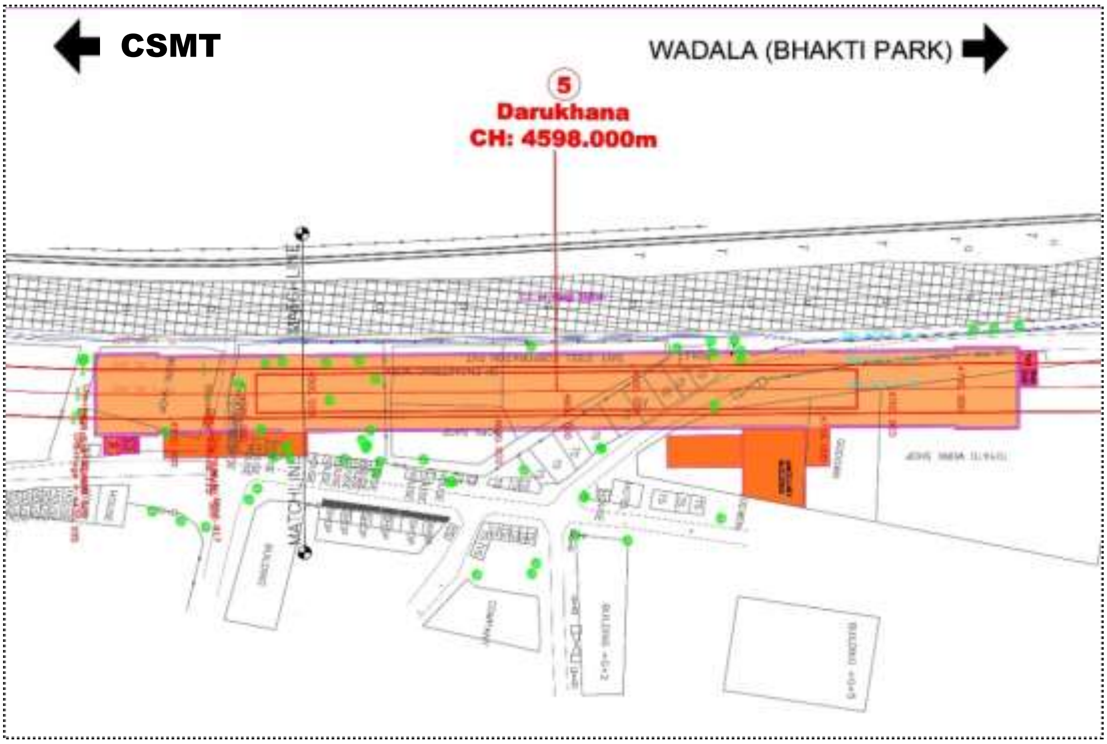


Figure 5.5 Site Photographs showing site conditions – Darukhana

6. Coal Bunder

Chainage	5780.57m.
Inter-Station Distance	1182.57 m.
Rail Level	-17.00 m.
Platform Depth from Ground	18.935 m.
Location	Located on Fosbery Road.
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Coal Bunder, Darukhana, Hay Bunder, Abhyudaya Nagar

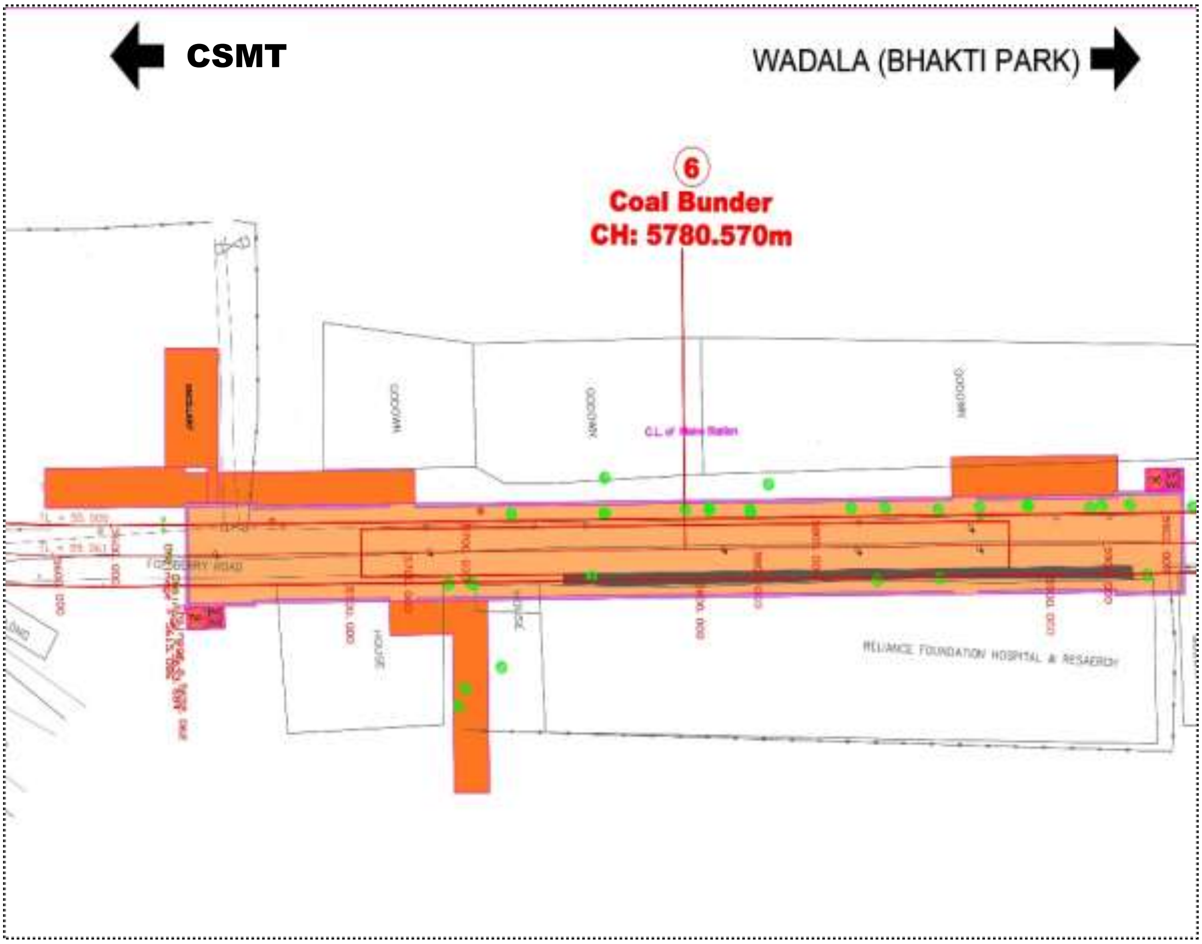


Figure 5.6 Site Photographs showing site conditions – Coal Bunder

7. Hay Bunder

Chainage	6805.016m.
Inter-Station Distance	1024.446 m.
Rail Level	-17.00 m.
Platform Depth from Ground	19.061 m.
Location	Located on Fosbery Road.
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Coal Bunder, Hay Bunder, Abhyudaya Nagar

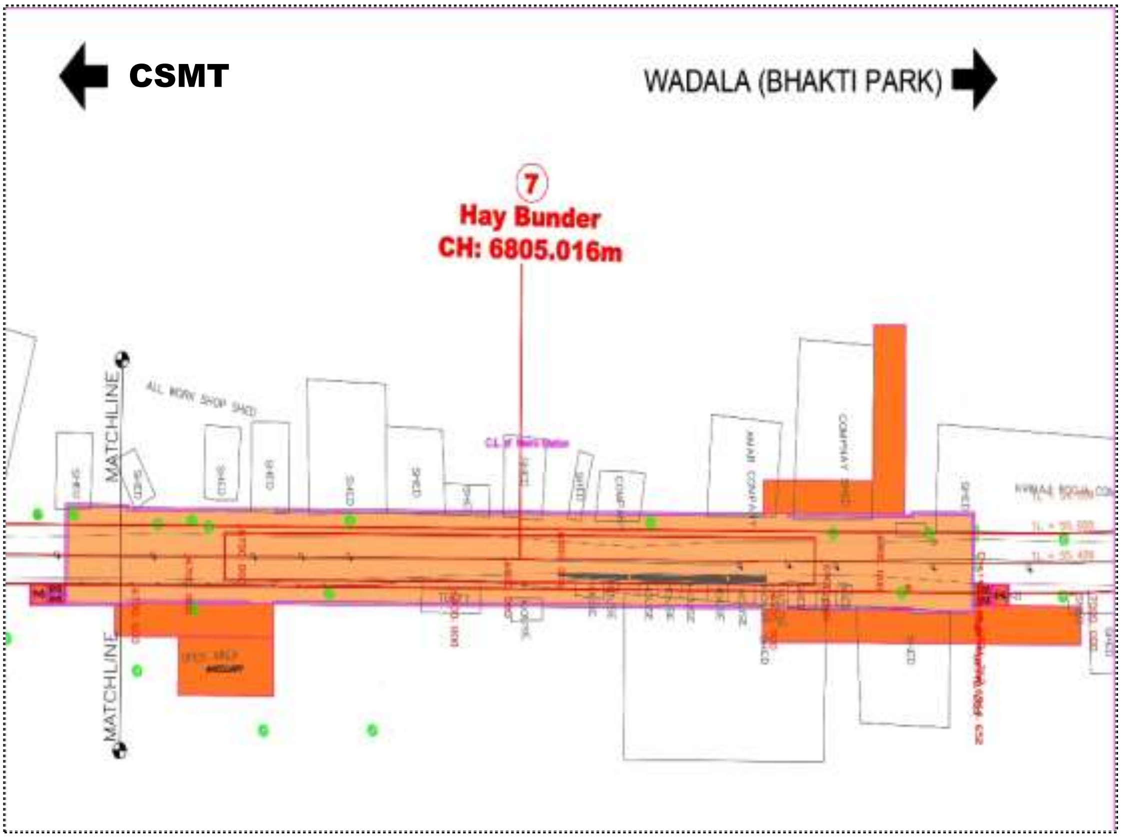


Figure 5.7 Site Photographs showing site conditions – Hay Bunder

8. Sewri Metro

Chainage	7656.128 m.
Inter-Station Distance	851.112 m.
Rail Level	-11.00 m.
Platform Depth from Ground	14.219 m.
Location	Located besides Eastern Flyway(Bombay Port Trust Road)
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Priydarshini Ambika Nagar, Sewri west,Gandhi Nagar,Shivaji Nagar

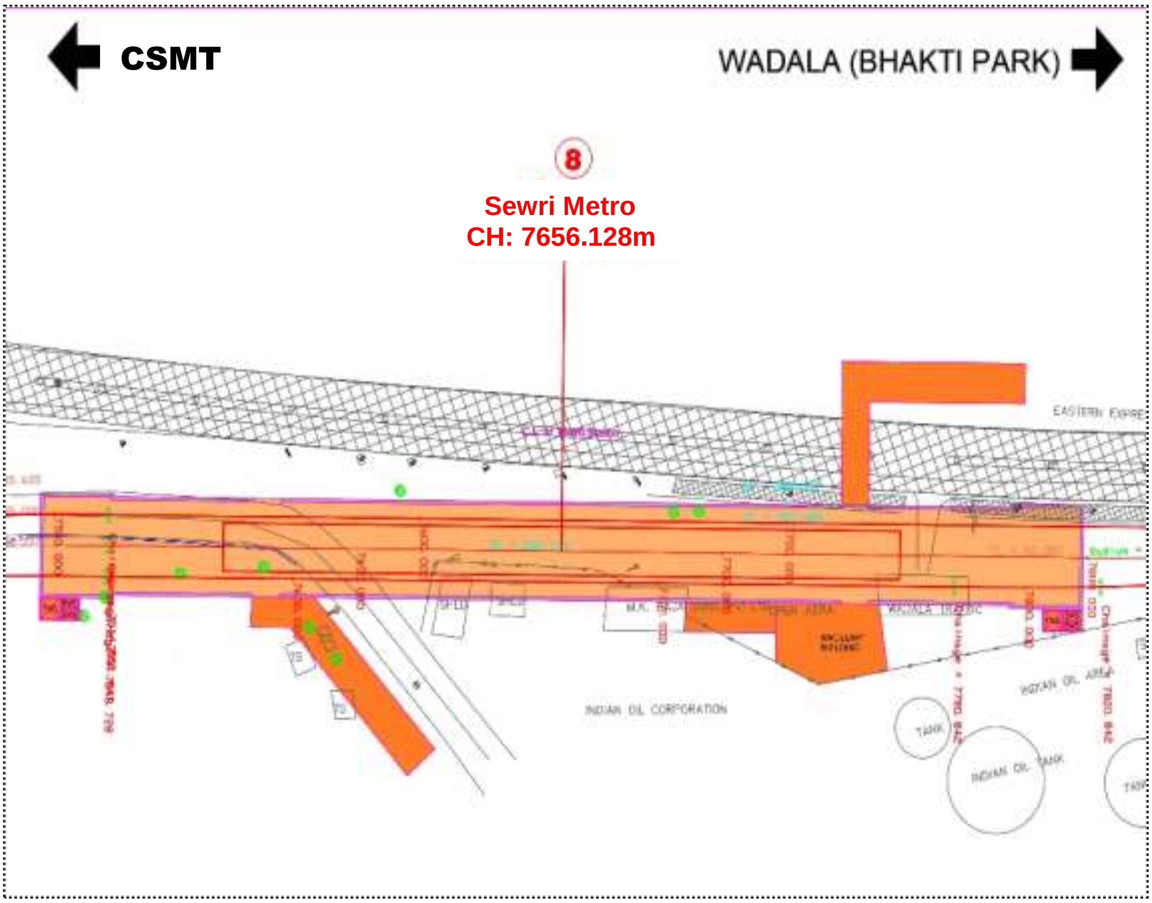


Figure 5.8 Site Photographs showing site conditions – Sewri

9. BPT Hospital

Chainage	9754.193m.
Inter-Station Distance	2098.065 m.
Rail Level	16.100 m.
Platform Height from Ground	14.884 m.
Location	Located on L.M. Nadkarni Marg
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	BPT Colony, Tejas Nagar Colony, BPCL Terminal, Pratikash Nagar

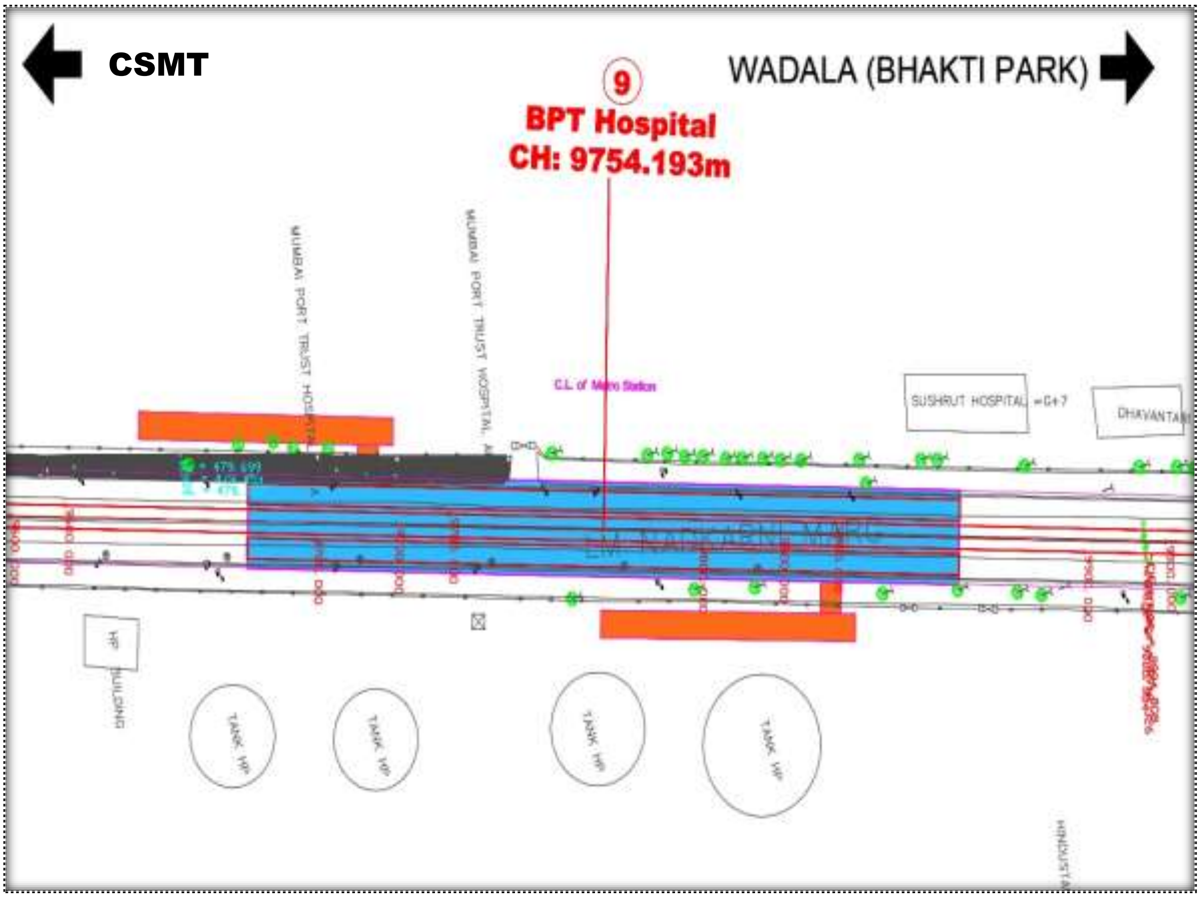


Figure 5.9 Site Photographs showing site conditions – BPT Hospital

10. Ganesh Nagar

Chainage	10722.095 m.
Inter-Station Distance	967.902 m.
Rail Level	16.00 m.
Platform Height from Ground	14.702 m.
Location	Located on the Sewri Chembur Road
Entry / Exit Stairs	Entry Exit stairs proposed on footpath besides main carriageway.
Catchment Area	Ganesh Nagar, Kalaram Nagar, Panchsheel Nagar, Siddharth Nagar

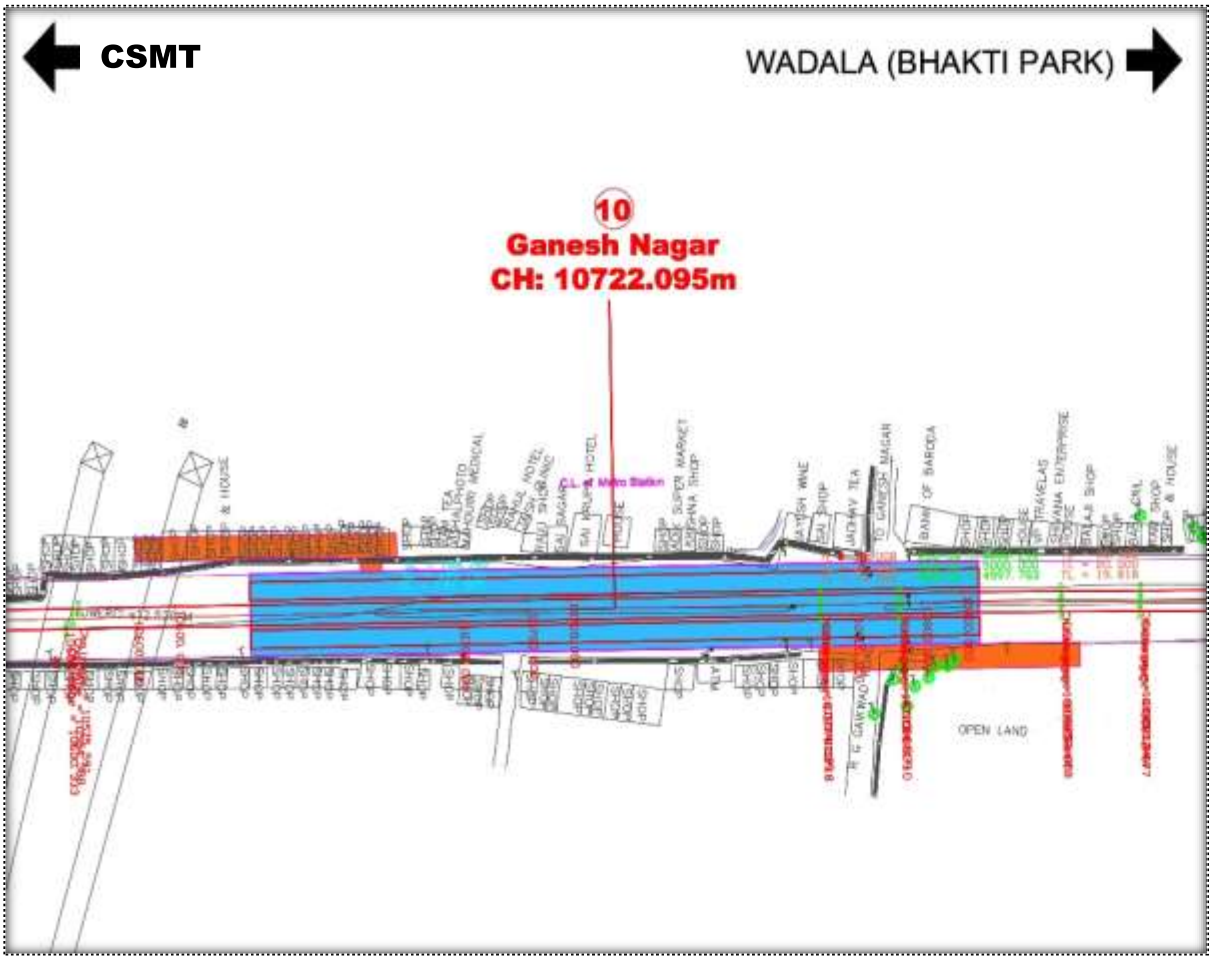


Figure 5.10 Site Photographs showing site conditions – Ganesh Nagar

5.3 PLANNING AND DESIGN CRITERIA FOR STATIONS

Salient features of a typical metro 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 at elevated stations is determined by a critical clearance of 5.50-m under the concourse above the road intersection, allowing 3.00-m for the concourse height, about 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 at least 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.

9. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.

10. 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 and between platforms for transfer between lines.
    - Adequate capacity for passenger movements.

- Convenience, including good signage relating to circulation and orientation.
- Safety and security, including a high level of protection against accidents.

11. Following requirements have been taken into account:

    a. Minimum capital cost is incurred consistent with maximizing passenger attraction.
    b. Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
    c. 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.
    d. Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
    e. Provision of display of passenger information and advertising.

12. 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

13. 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**.**

14. 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 – at Station	
Station Control Room	Fire Tank & Pump room
Platform Supervisor’s Booth	Staff Area
Station Master’s Office	UPS and Battery Room
Traction Substation	Cleaner’s Room
Information & Enquiries	Security Room
Signaling Room	Staff Toilets
Ticket Office	Refuse Store
Communication Room	Miscellaneous Operations Room
Ticket Hall Supervisor & Excess Fare Collection (Passenger Office	First Aid Room
Station Substation	

5.4 TYPICAL ELEVATED STATION - APPLICABLE TO THIS CORRIDOR

The station is generally located on the road median, and its footprint is 185-m long and is a three level structure. Passenger area on concourse is spread as the paid and unpaid area 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 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. Area left over in the unpaid zone, after accommodating passenger movement and other station facilities is earmarked for commercial utilization. Station concourse box length and breadth are 185 m. and 20 m. respectively. 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 14.0-m from the road. With respect to its spatial quality, an elevated MRT structure makes a great impact on the viewer as compared to an *At-grade* station. 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 High-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 slopping roof. 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.

5.5 CSMT METRO INTERCHANGE STATION

CSMT Metro interchange station is the combination of the two separate Island platforms dedicated to the tracks of two separate corridors. This station consist two separate concourse areas connected by common unpaid corridors and contain service areas dedicated to separate corridors.

Entry exits have been planned to provide easy access to the station for all passengers, from each side of the intersection, without having to cross vehicular traffic on the busy road. The integrated entrances for intersecting lines are at the ground level from where the passengers can access the concourse. Concourse houses ticketing for corridors, lifts, stairs and escalators to reach both the platforms dedicated to different lines.

5.6 PASSENGER AMENITIES

Passenger amenities such as ticketing counters / automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Adequate numbers of these facilities have been provided for system wide requirements, 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 2031has been adopted for normal operation regarding all stations. For this purpose, peak minute traffic is assumed to be 2% of the peak hour traffic.

5.7 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 away 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.

5.8 TICKETING GATES

Ticketing gates' requirement has been calculated taking the gate capacity as 28 persons per minute per gate. Passenger forecast for the horizon year 2031 has been used to compute the maximum design capacity. At least three (one entry, one exit and one reversible) ticketing gates or AFC gates shall be provided at any station. Uniform space has been provided in all stations where gates can be installed as and when required.

5.9 TICKET COUNTERS AND TICKET ISSUING MACHINES (TIMS)

It is proposed to deploy manual ticket issuing in the beginning of the operation of the line. At a later stage, automatic 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 Ticket vending Machines (TVMs) in future. Capacity of manual ticket vending counters is taken to be 5 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 prepaid card. Accordingly, the requirement of ticket counters has been calculated and the same provided for in the plans.

5.10 PLATFORMS

A uniform platform minimum width of 3.0-m wide including staircases and escalators in the central section is proposed for the elevated stations. All platform widths have been calculated for holding capacity of the platform for worst-case scenario (one missed headway and holding section load) in the design year i.e. 2031.

5.11 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 and escalator together provide an escape capacity adequate to evacuate passengers in emergency from platforms to concourse in most stations.

5.12 PASSENGER AMENITIES REQUIREMENT IN STATIONS

Passenger Amenities 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.

5.13 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 function as an integrated network and provides efficient service to the commuter, the following steps have been identified:

- Suitable linkages are proposed so that various corridors of MRTS are integrated within themselves, with existing rail services and with road based modes.
- 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.

Table 5.5: Traffic Integration Requirement for Stations (Projections for Year 2051)

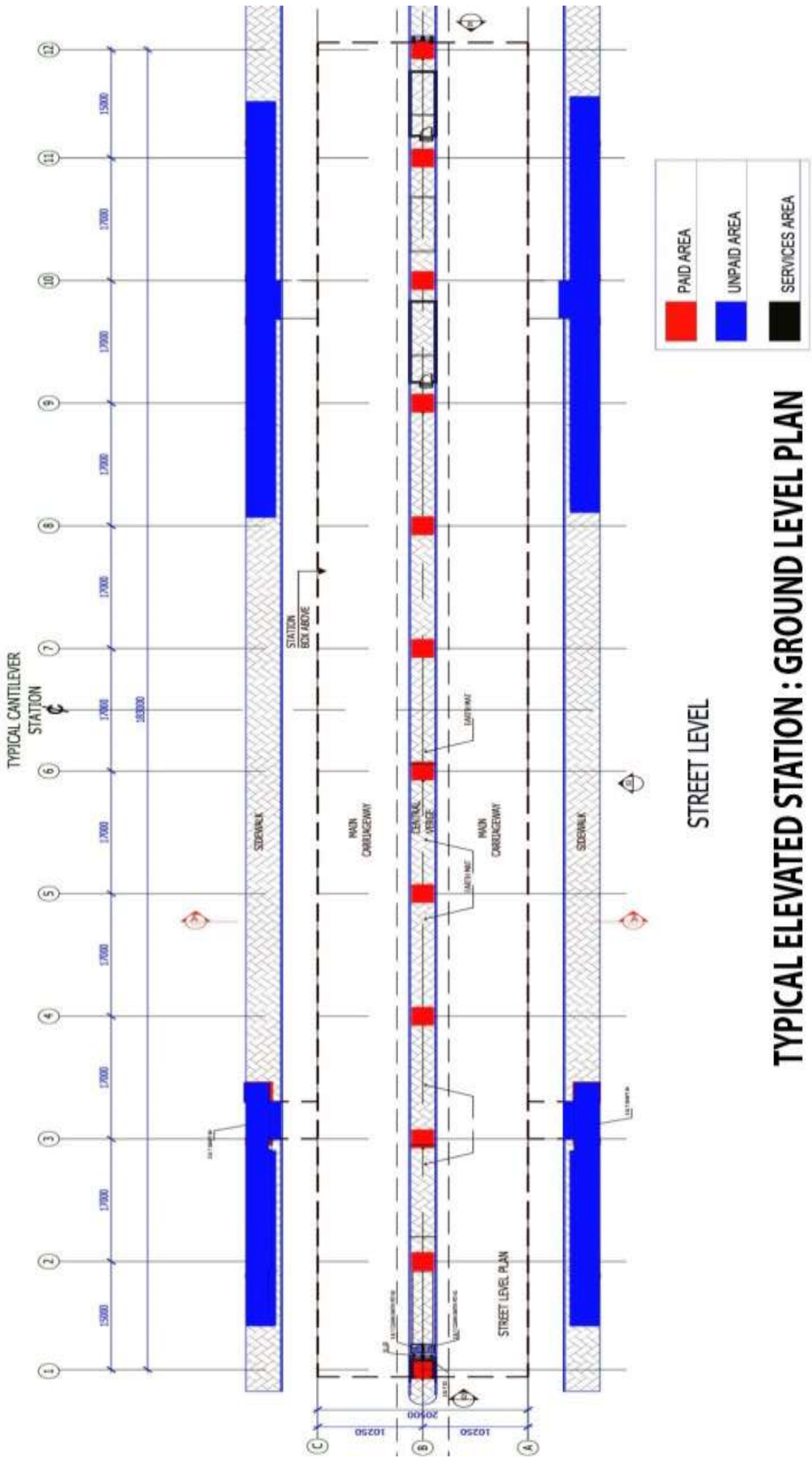
Traffic Integration Requirement for Stations											
S.No.	Name of the Station	Peak Hour Station Load	Number of Bays					Area Required (Sq.M.)			
			Bus	Car	Two Wheelers	Auto	Cycle	Car	Two Wheelers	Cycle	Total
1	CSTM	2366	3	197	592	6	789	7887	2603	1183	11672
2	Carnac Bunder	2347	3	196	587	6	782	7823	2582	1174	11579
3	Clock Tower	205	1	17	51	1	68	683	226	103	1011
4	Wadi Bunder	655	1	55	164	2	218	2183	721	328	3231
5	Darukhana	820	1	68	205	2	273	2733	902	410	4045
6	Coal Bunder	95	1	8	24	1	32	317	105	48	469
7	Hay Bunder	546	1	46	137	1	182	1820	601	273	2694
8	Sewri	427	1	36	107	1	142	1423	470	214	2107
9	BPT Hospital	4683	5	390	1171	12	1561	15610	5151	2342	23103
10	Ganesh Nagar	1804	2	150	451	5	601	6013	1984	902	8900

5.14 APPROACH ADOPTED IN PLANNING TRAFFIC INTEGRATION FACILITIES

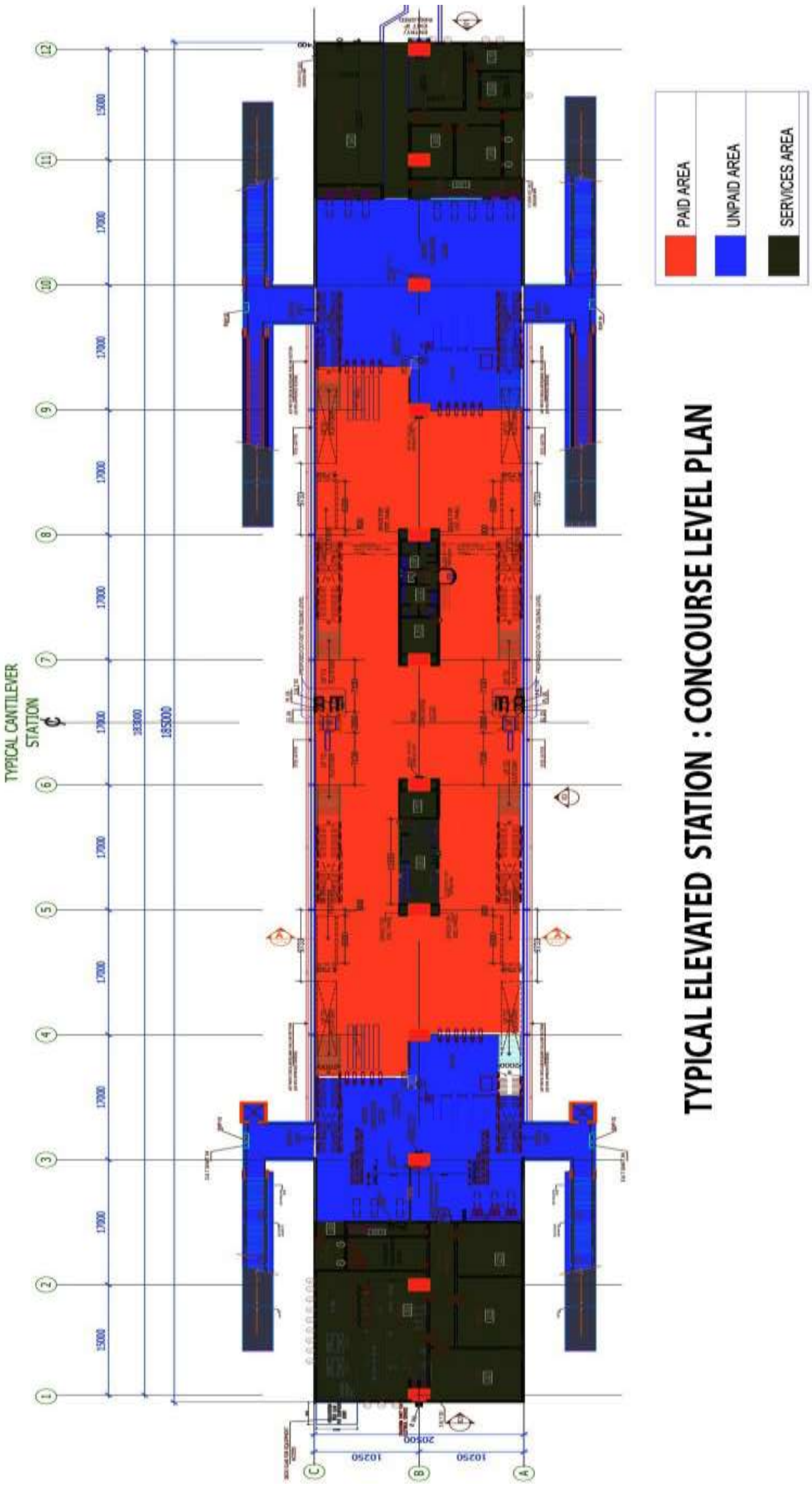
Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate circulation areas for various modes likely to come to important stations including feeder bus/mini-buses. Parking for private vehicles has not been proposed.

5.15 OPERATIONAL INTEGRATION

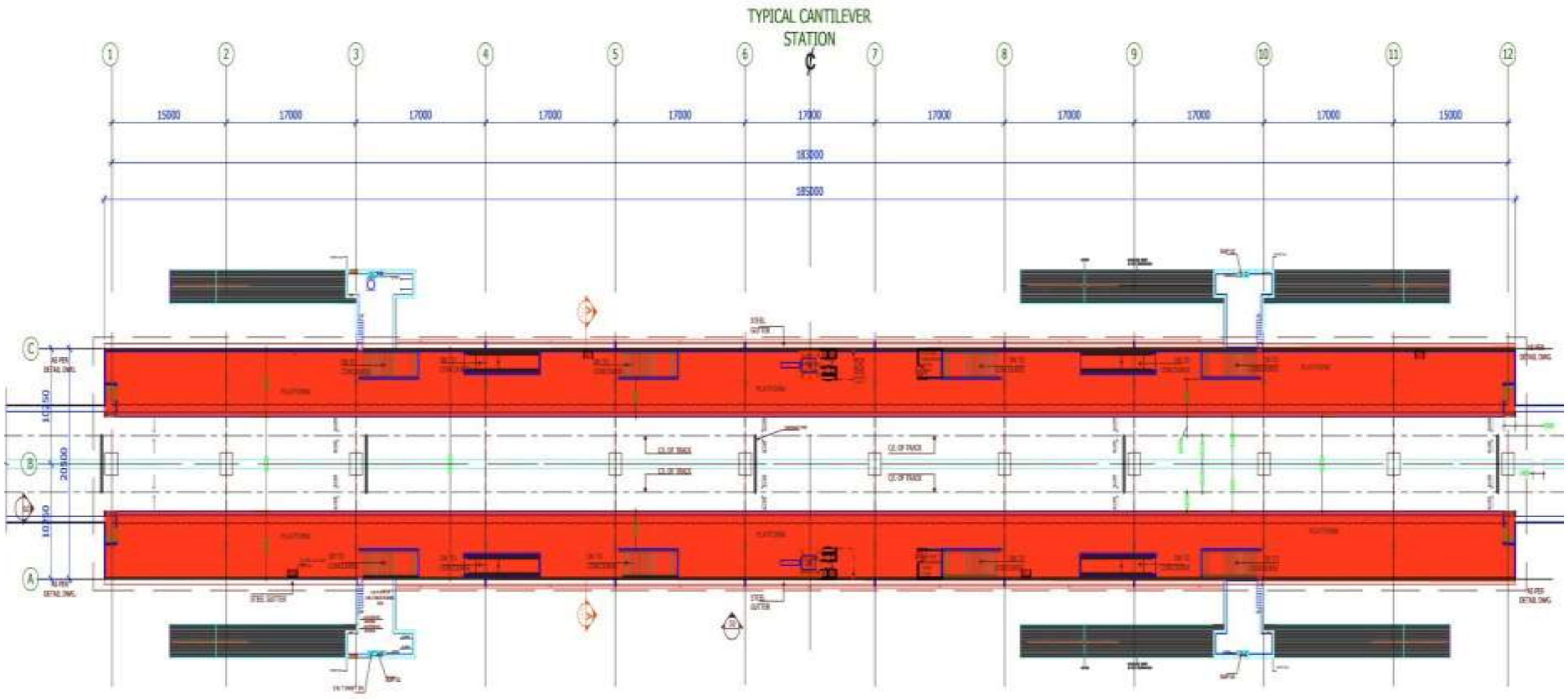
Integration at operational level will be required to synchronize the timings of the MRTS services and the feeder service. For an efficient interchange, walking and waiting time at these stations will need to be minimized. Introduction of common ticketing and their availability at convenient locations 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.



TYPICAL ELEVATED STATION : GROUND LEVEL PLAN

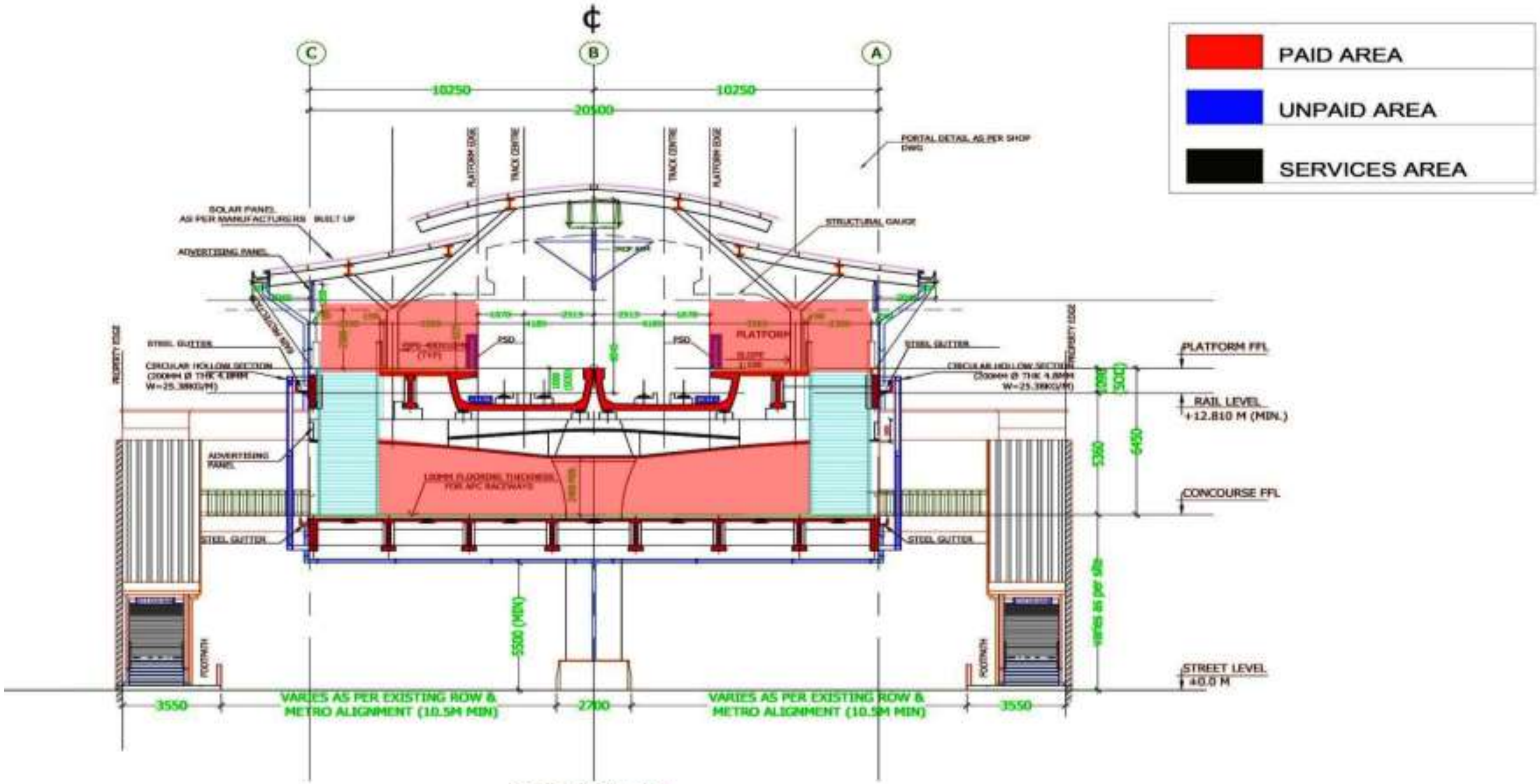


TYPICAL ELEVATED STATION : CONCOURSE LEVEL PLAN



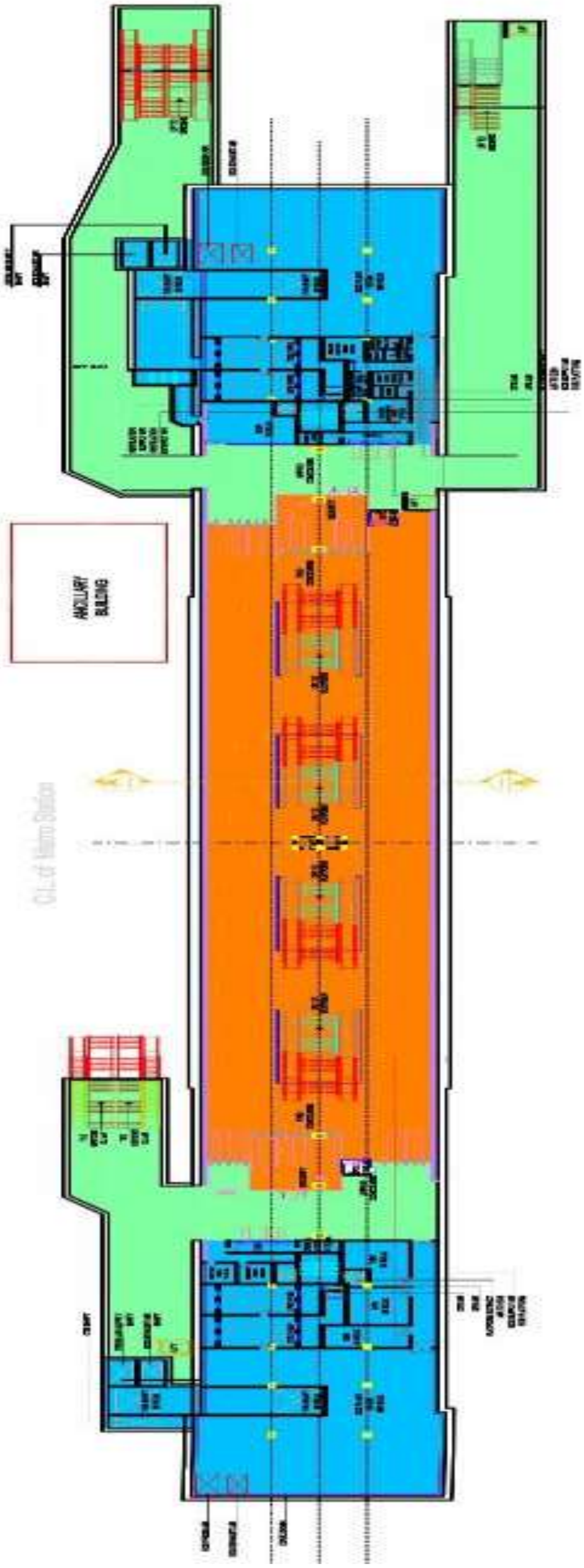
🟥 PAID AREA
🟦 UNPAID AREA
⬛ SERVICES AREA

TYPICAL ELEVATED STATION PLATFORM LEVEL PLAN



SECTION-AA

TYPICAL ELEVATED STATION : SECTION



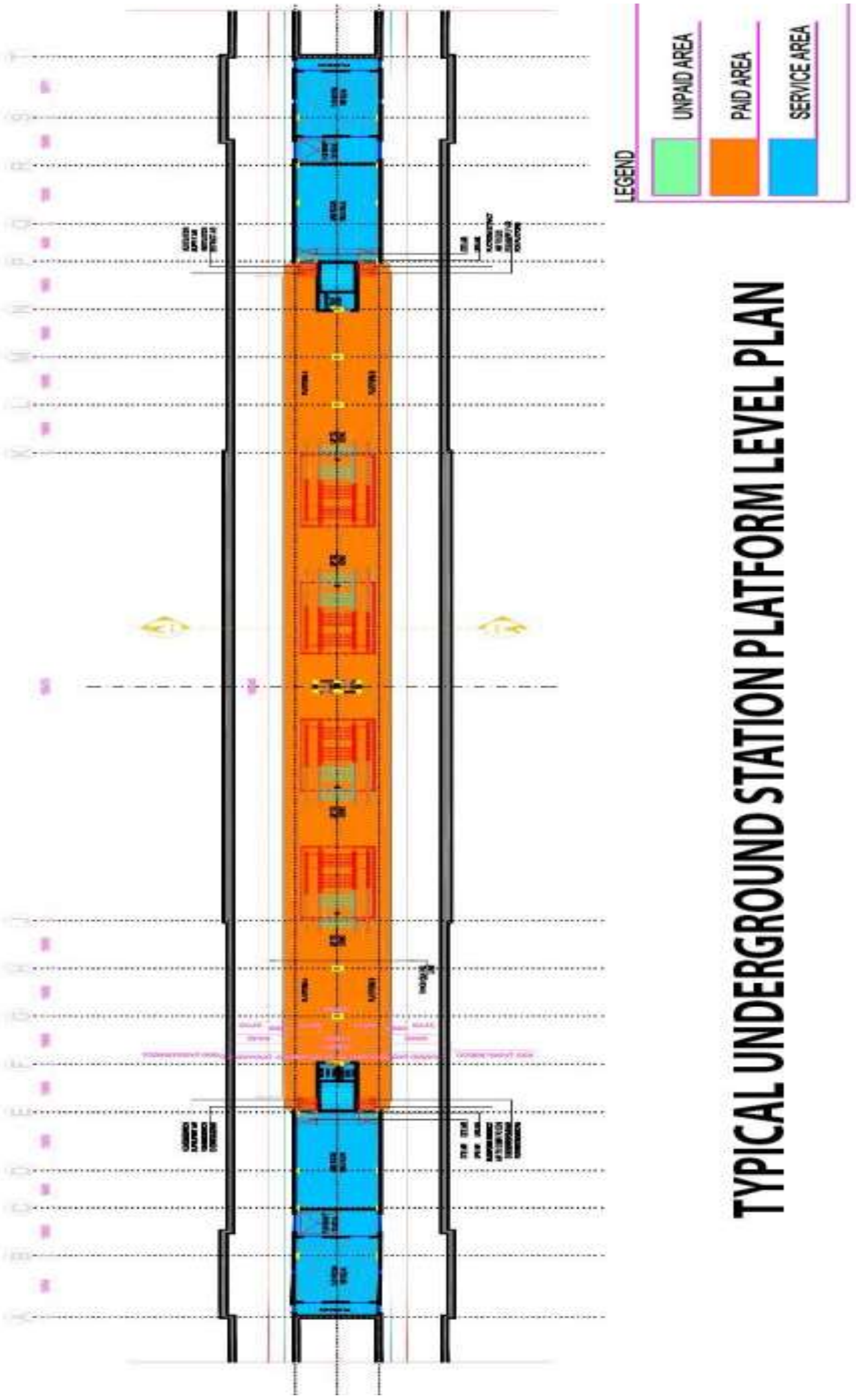
LEGEND

🟩 UNPAID AREA

🟧 PAID AREA

🟦 SERVICE AREA

TYPICAL UNDERGROUND STATION :CONCOURSE LEVEL PLAN



TYPICAL UNDERGROUND STATION PLATFORM LEVEL PLAN

CHAPTER - 6

TRAIN OPERATION PLAN

6.1 OPERATION PHILOSOPHY

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections.
- Economical & optimum train service frequency not only during peak period, but also during off-peak period.
- Optimization of train's reliability for achieving best possible availability on line.
- A train consists of 6 coaches which will be augmented to 8 coaches in future.
- Multi-tasking of train operation and maintenance staff.

6.2 STATIONS

List of stations for the Mumbai Metro Line (CSMT Metro to Gaimukh) is given below:

TABLE- 6.1: STATIONS

CSMT METRO TO GAIMUKH					
S. No.	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
0.	**Dead End**	-530			
1.	CHHATRAPATI MAHARAJ SHIVAJI TERMINUS	0.000	530.000	Underground	Interchange Station
2.	CARNAC BUNDER	1584.597	1584.597	Underground	
3.	CLOCK TOWER	2473.963	889.366	Underground	
4.	WADI BUNDER	3620.461	1146.498	Underground	
5.	DARUKHANA	4598.000	977.539	Underground	
6.	COAL BUNDER	5780.570	1182.570	Underground	
7.	HAY BUNDER	6805.016	1024.446	Underground	
8.	SEWRI METRO	7656.128	851.112	Underground	
9.	BPT HOSPITAL	9754.193	2098.065	Elevated	
10.	GANESH NAGAR	10722.095	967.902	Elevated	
11.	WADALA (BHAKTI PARK)	12694.115	1972.020	Elevated	Interchange Station
12.	WADALA TT	13694.115	1000.00	Elevated	
13.	ANIK NAGAR BUS DEPOT	14555.725	861.61	Elevated	
14.	SUMAN NAGAR	15634.115	1078.39	Elevated	
15.	SIDDHARTH COLONY	16688.545	1054.43	Elevated	

CSMT METRO TO GAIMUKH					
S. No.	**Name of Station**	**Chainage (in m)**	**Inter – Station Distance (in m)**	**Station Type**	**Remarks**
16.	AMAR MAHAL JUNCTION	18032.125	1343.58	Elevated	Interchange Station
17.	GARODIA NAGAR	18630.655	598.53	Elevated	
18.	PANT NAGAR	20263.335	1632.68	Elevated	
19.	LAXMI NAGAR	21340.845	1077.51	Elevated	
20.	SHREYES CINEMA	21961.655	620.81	Elevated	
21.	GODREJ COMPANY	23124.475	1162.82	Elevated	
22.	VIKHROLI METRO	23847.595	723.12	Elevated	
23.	SURYA NAGAR	24852.365	1004.77	Elevated	
24.	GANDHI NAGAR	25854.475	1002.11	Elevated	Interchange Station
25.	NAVAL HOUSING	26546.355	691.88	Elevated	
26.	BHANDUP MAHAPALIKA	27325.695	779.34	Elevated	
27.	BHANDUP METRO	28374.525	1048.83	Elevated	
28.	SHANGRILA	29218.175	843.65	Elevated	
29.	SONAPUR	30608.935	1390.76	Elevated	
30.	MULUND FIRE STATION	31721.915	1112.98	Elevated	
31.	MULUND NAKA	33070.015	1348.10	Elevated	
32.	TEEN HAATH NAKA (THANE)	34306.365	1236.35	Elevated	
33.	RTO THANE	34984.905	678.54	Elevated	
34.	MAHAPALIKA MARG	36020.875	1035.97	Elevated	
35.	CADBURY JUNCTION	36813.585	792.71	Elevated	
36.	MAJIWADA	37637.875	824.29	Elevated	
37.	KAPURBAWDI	39027.135	1389.26	Elevated	
38.	MANPADA	39892.515	865.38	Elevated	
39.	TIKUJI-NI-WADI	40668.165	775.65	Elevated	
40.	DONGARI PADA	42133.765	1465.60	Elevated	
41.	VIJAY GARDEN	43042.635	908.87	Elevated	
42.	KASARVADAVALI	44116.205	1073.57	Elevated	
43.	GOWNIWADA	45501.145	1384.94	Elevated	
44.	GAIMUKH	46784.235	1283.09	Elevated	
45.	**Dead End**	47684.235	450.00		

6.3 TRAIN OPERATION PLAN: 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 these corridors has been considered as: 35 kmph.

6.4 TRAFFIC DEMAND

Peak hour peak direction traffic demands (PHPDT) for the Mumbai Metro 'Line: CSMT Metro - Gaimukh' in the year 2021 & 2031for the purpose of planning are indicated in Attachment I/A & I/B respectively.

6.5 TRAIN FORMATION

To meet the above projected traffic demand, the possibility of running trains with composition of 6 and 8 cars with different headway has been examined.

Composition

DMC : Driving Motor Car
TC : Trailer Car
MC : Motor Car

Capacity (@ 6 passengers per square meter of standee area)

Driving Motor Car (DMC)	- 282 (42 seated + 240 standing)
Trailer Car (TC)	- 298 (50 seated + 248 standing)
Motor Car (MC)	- 298 (50 seated + 248 standing)
6 Car Train	- 1756 (284 seated + 1472 standing)
8 Car Train	- 2352 (384 seated + 1968 standing)

6.6 TRAIN OPERATION PLAN

Based on the projected PHPDT demand, Train operation plan with train carrying capacity @ 6 persons per square meter of standee area for the Mumbai Metro 'Line: CSMT Metro-Gaimukh' for the year 2021 and 2031 is given below:

CSMT Metro-Gaimukh

Train Operation Plan for Line: CSMT Metro-Gaimukh has been planned in such a way that there are two loops of train operation, one is end to end operation from CSMT Metro to Gaimukh and other one is from Bhakti Park (Wadala) to Kapurbawdi. Reversal facility at Bhakti Park (Wadala) and Kapurbawdi would be required for this.

i) Year 2021: Train operation is planned in 2 loops to meet the PHPDT demand. Train on 6.50 minutes headway will run from CSMT Metro to Gaimukh in one loop. In second loop train will run from Bhakti Park (Wadala) to Kapurbawdi with an effective headway of 3.25 minutes.

a) CSMT Metro to Bhakti Park (Wadala) and Kapurbawdi to Gaimukh Section (Refer attachment –I/A)

- 6.50 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 16209@ 6 persons per square meter of standee area.

- Available Peak Hour Peak Direction Capacity of 20677@ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 17460 is in the Section between Kapurbawdi to Manpada and demand in the remaining sections is in the range of 7522 to 16209 only. The planned capacity is slightly less than the PHPDT Demand in only one section i.e Kapurbawdi to Manpada, which can be fulfilled by accommodating 8 persons per square meter of standee area.

b) Bhakti Park (Wadala) to Kapurbawdi (Refer attachment –I/A)

- 3.25 minutes Effective Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 32418@ 6 persons per square meter of standee area.
- Available Peak Hour Peak Direction Capacity of 41354@ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 32460 is in the Section between Garodia Nagar to Pant Nagar and demand in the remaining sections is in the range of 18734 to 32336 only. The planned capacity is slightly less than the PHPDT Demand in only one section i.e Garodia Nagar to Pant Nagar, which can be fulfilled by accommodating 8 persons per square meter of standee area.

Traffic demand and train capacity for this Line in the year 2021 is tabulated and represented on chart enclosed as Attachment I/A.

ii) Year 2031: Train operation is planned in 2 loops to meet the PHPDT demand. Train on 6.50 minutes headway will run from CSMT Metro to Gaimukh in one loop. In second loop train will run from Bhakti Park (Wadala) to Kapurbawdi with an effective headway of 3.25 minutes.

a) CSMT Metro to Bhakti Park (Wadala) and Kapurbawdi to Gaimukh Section (Refer attachment –I/B)

- 6.50 minutes Effective Headway with 8-car train.
- Available Peak Hour Peak Direction Capacity of 21711@ 6 persons per square meter of standee area.
- Available Peak Hour Peak Direction Capacity of 27692@ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 25058 is in the Section between Manpada to Tikuji-Ni-Wadi and demand in the remaining sections is in the range of 5009 to 24771 only. The planned capacity is slightly less than the PHPDT Demand in four sections i.e Kapurbawdi to Manpada, Manpada to Tikuji-Ni-Wadi, Tikuji-Ni-Wadi to Dongari Pada, Dongari Pada to Vijay Garden, which can be fulfilled by accommodating 8 persons per square meter of standee area.

b) Bhakti Park (Wadala) to Kapurbawdi (Refer attachment –I/B)

- 3.25 minutes Effective Headway with 8-car train.
- Available Peak Hour Peak Direction Capacity of 43422@ 6 persons per square meter of standee area.

- Available Peak Hour Peak Direction Capacity of 55385@ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 36635 is in the Section between Bhandup Metro to Shangrila and demand in the remaining sections is in the range of 22013 to 35443 only. The planned capacity is more than the PHPDT Demand.

Traffic demand and train capacity for this Line in the year 2031 is tabulated and represented on chart enclosed as Attachment I/B.

The above Train Operation Plan is based on calculations on the basis of available traffic data. In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by adjusting the Headway.

The PHPDT capacity provided on the route in different years of operation is tabulated below:

TABLE -6.2: Capacity Provided for Line: CSMT Metro-Gaimukh

Sections	Year	Head-way (min)	Total No. of Rakes	Rake Consist	Total No. of Cars**	Provision for No. of cars in DPR of Sep'17	Additional No. of cars for Line- 11#	Max. PHPDT Demand	PHPDT Capacity Available
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2021	6.50	46	6-car	276	232	44	17460	16209 (20677*)
Bhakti Park to Kapurbawdi		3.25						32460	32418 (41354*)
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	2031	6.50	46	8-car	368	264	104	25058	21711 (27692*)
Bhakti Park to Kapurbawdi		3.25						36635	43422 (55385*)

* @ 8 persons per square meter of standee area

** Total No. of cars shown above are the total cars calculated as per PHPDT data.

Additional cars requirement for Line-11 has been calculated after subtracting provision for no. of cars in previous Line-4 (Bhakti Park - Gaimukh) DPR (Sep'17) from the total car requirements.

6.7 TRAIN FREQUENCY

TABLE -6.3: Train Frequency Line: CSMT Metro-Gaimukh

Section	2021		2031	
	Peak Hour Head-way	Lean Hour Head-way	Peak Hour Head-way	Lean Hour Head-way
CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh	6.50 min	10 to 24 min	6.50 min	10 to 24 min
Bhakti Park to Kapurbawdi	3.2 min	5 to 12 min	3.2 min	5 to 12 min

No services are proposed between 00:00 hrs to 5.00 hrs, which are reserved for maintenance of infrastructure and rolling stock.

6.7.1 Hourly Train Operation plan

The hourly distribution of daily transport capacity is presented in **Table 1.1 & 1.2** for ‘CSMT Metro to Gaimukh’ Section for the years 2021 and 2031 enclosed as **Attachment II.**

The directional split for Line: CSMT Metro to Gaimukh is presented in **Table 2** enclosed as **Attachment III**.

6.8 VEHICLE KILOMETER

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for Mumbai Metro Rail Network, Line: CSMT Metro-Gaimukh is given in **Table 3** enclosed as **Attachment IV**.

6.9 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.**

Requirements of coaches is calculated based on following assumptions-

Assumptions –

(i) Train Composition planned as under

6 car Train Composition (with 66.67% Powering)	:DMC +TC +MC+MC+TC+DMC
8 car Train Composition (in year 2031) with 62.5% Powering	:DMC +TC +MC+MC+TC+MC+TC+DMC

(ii) Coach requirement has been calculated based on headway during peak hours.

(iii) Traffic reserve is taken as one train to cater to failure of train on line and to make up for operational time list.

(iv) Repair and maintenance reserve has been estimated as 10 % of total requirement (Bare).

(v) The calculated number of rakes in fraction is rounded off to next higher number.

(vi) Schedule speed is taken as: 35kmph

(vii) Total Turn round time is taken as 6 min at terminal stations.

Option-II: Loop Train Operation

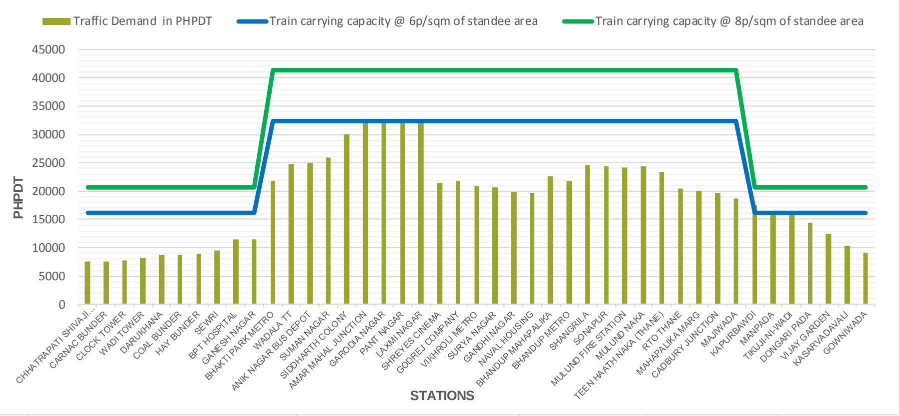
Attachment - I/A

PHPDT Demand and Capacity Chart

Mumbai Metro Line: (CSMT Metro to Gaimukh) 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:	**2240**	
Headway (min.)	**6.50**	**CSMT Metro-Bhakti Park and Kapurbawdi - Gaimukh**
Headway (min.)	**3.25**	**Bhakti Park-Kapubawdi**

S.No.	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	CHHATRAPATI SHIVAJI MAHARAJ TERMINUS	CARNAC BUNDER	7522	16,209	20,677
2	CARNAC BUNDER	CLOCK TOWER	7617	16,209	20,677
3	CLOCK TOWER	WADI TOWER	7843	16,209	20,677
4	WADI TOWER	DARUKHANA	8225	16,209	20,677
5	DARUKHANA	COAL BUNDER	8659	16,209	20,677
6	COAL BUNDER	HAY BUNDER	8749	16,209	20,677
7	HAY BUNDER	SEWRI	8995	16,209	20,677
8	SEWRI	BPT HOSPITAL	9498	16,209	20,677
9	BPT HOSPITAL	GANESH NAGAR	11538	16,209	20,677
10	GANESH NAGAR	BHAKTI PARK METRO	11539	16,209	20,677
11	BHAKTI PARK METRO	WADALA TT	21807	32,418	41,354
12	WADALA TT	ANIK NAGAR BUS DEPOT	24706	32,418	41,354
13	ANIK NAGAR BUS DEPOT	SUMAN NAGAR	24904	32,418	41,354
14	SUMAN NAGAR	SIDDHARTH COLONY	25838	32,418	41,354
15	SIDDHARTH COLONY	AMAR MAHAL JUNCTION	30049	32,418	41,354
16	AMAR MAHAL JUNCTION	GARODIA NAGAR	32336	32,418	41,354
17	GARODIA NAGAR	PANT NAGAR	**32460**	32,418	41,354
18	PANT NAGAR	LAXMI NAGAR	32321	32,418	41,354
19	LAXMI NAGAR	SHREYES CINEMA	32326	32,418	41,354
20	SHREYES CINEMA	GODREJ COMPANY	21519	32,418	41,354
21	GODREJ COMPANY	VIKHROLI METRO	21803	32,418	41,354
22	VIKHROLI METRO	SURYA NAGAR	20851	32,418	41,354
23	SURYA NAGAR	GANDHI NAGAR	20578	32,418	41,354
24	GANDHI NAGAR	NAVAL HOUSING	19868	32,418	41,354
25	NAVAL HOUSING	BHANDUP MAHAPALIKA	19699	32,418	41,354
26	BHANDUP MAHAPALIKA	BHANDUP METRO	22669	32,418	41,354
27	BHANDUP METRO	SHANGRILA	21860	32,418	41,354
28	SHANGRILA	SONAPUR	24629	32,418	41,354
29	SONAPUR	MULUND FIRE STATION	24301	32,418	41,354
30	MULUND FIRE STATION	MULUND NAKA	24099	32,418	41,354
31	MULUND NAKA	TEEN HAATH NAKA (THANE)	24372	32,418	41,354
32	TEEN HAATH NAKA (THANE)	RTO THANE	23355	32,418	41,354
33	RTO THANE	MAHAPALIKA MARG	20489	32,418	41,354
34	MAHAPALIKA MARG	CADBURY JUNCTION	20039	32,418	41,354
35	CADBURY JUNCTION	MAJIWADA	19640	32,418	41,354
36	MAJIWADA	KAPURBAWDI	18724	32,418	41,354
37	KAPURBAWDI	MANPADA	**17460**	16,209	20,677
38	MANPADA	TIKUJI-NI-WADI	16209	16,209	20,677
39	TIKUJI-NI-WADI	DONGARI PADA	16122	16,209	20,677
40	DONGARI PADA	VIJAY GARDEN	14413	16,209	20,677
41	VIJAY GARDEN	KASARVADAVALI	12530	16,209	20,677
42	KASARVADAVALI	GOWNIWADA	10380	16,209	20,677
43	GOWNIWADA	GAIMUKH	9115	16,209	20,677



Option-II: Loop Train Operation

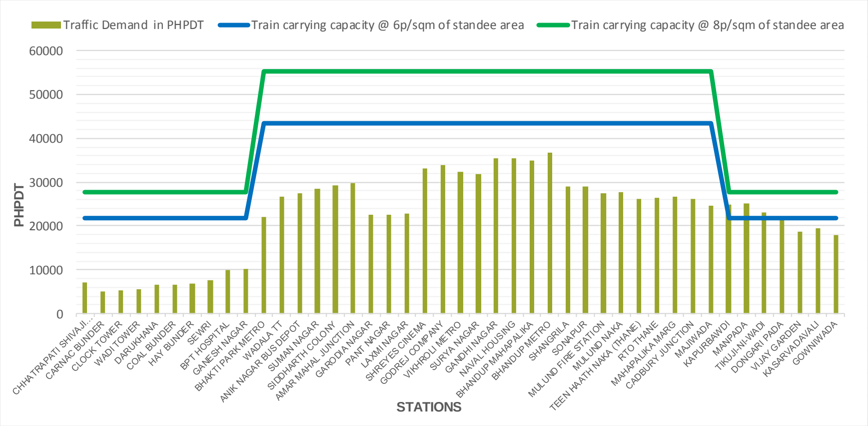
Attachment - I/B

PHPDT Demand and Capacity Chart

Mumbai Metro Line (CSMT Metro to Gaimukh) Corridor

Year: 2031
No. of cars per train 8
Passenger Capacity @ 6 persons/sqm of a 8-Car Train: 2352
Passenger Capacity @ 8 persons/sqm of a 8-Car Train: 3000
Headway (min.) 6.50 CSMT Metro-Bhakti Park and Kapurbawdi - Gaimukh
Headway (min.) 3.25 Bhakti Park-Kapubawdi

S.No.	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	CHHATRAPATI SHIVAJI MAHARAJ TERMINUS	CARNAC BUNDER	7211	21,711	27,692
2	CARNAC BUNDER	CLOCK TOWER	5009	21,711	27,692
3	CLOCK TOWER	WADI TOWER	5281	21,711	27,692
4	WADI TOWER	DARUKHANA	5678	21,711	27,692
5	DARUKHANA	COAL BUNDER	6525	21,711	27,692
6	COAL BUNDER	HAY BUNDER	6669	21,711	27,692
7	HAY BUNDER	SEWRI	6848	21,711	27,692
8	SEWRI	BPT HOSPITAL	7563	21,711	27,692
9	BPT HOSPITAL	GANESH NAGAR	9855	21,711	27,692
10	GANESH NAGAR	BHAKTI PARK METRO	10100	21,711	27,692
11	BHAKTI PARK METRO	WADALA TT	22013	43,422	55,385
12	WADALA TT	ANIK NAGAR BUS DEPOT	26732	43,422	55,385
13	ANIK NAGAR BUS DEPOT	SUMAN NAGAR	27358	43,422	55,385
14	SUMAN NAGAR	SIDDHARTH COLONY	28397	43,422	55,385
15	SIDDHARTH COLONY	AMAR MAHAL JUNCTION	29308	43,422	55,385
16	AMAR MAHAL JUNCTION	GARODIA NAGAR	29712	43,422	55,385
17	GARODIA NAGAR	PANT NAGAR	22472	43,422	55,385
18	PANT NAGAR	LAXMI NAGAR	22559	43,422	55,385
19	LAXMI NAGAR	SHREYES CINEMA	22859	43,422	55,385
20	SHREYES CINEMA	GODREJ COMPANY	33008	43,422	55,385
21	GODREJ COMPANY	VIKHROLI METRO	33840	43,422	55,385
22	VIKHROLI METRO	SURYA NAGAR	32324	43,422	55,385
23	SURYA NAGAR	GANDHI NAGAR	31751	43,422	55,385
24	GANDHI NAGAR	NAVAL HOUSING	35417	43,422	55,385
25	NAVAL HOUSING	BHANDUP MAHAPALIKA	35443	43,422	55,385
26	BHANDUP MAHAPALIKA	BHANDUP METRO	34828	43,422	55,385
27	BHANDUP METRO	SHANGRILA	**36635**	43,422	55,385
28	SHANGRILA	SONAPUR	28991	43,422	55,385
29	SONAPUR	MULUND FIRE STATION	29034	43,422	55,385
30	MULUND FIRE STATION	MULUND NAKA	27507	43,422	55,385
31	MULUND NAKA	TEEN HAATH NAKA (THANE)	27597	43,422	55,385
32	TEEN HAATH NAKA (THANE)	RTO THANE	26242	43,422	55,385
33	RTO THANE	MAHAPALIKA MARG	26425	43,422	55,385
34	MAHAPALIKA MARG	CADBURY JUNCTION	26725	43,422	55,385
35	CADBURY JUNCTION	MAJIWADA	26182	43,422	55,385
36	MAJIWADA	KAPURBAWDI	24719	43,422	55,385
37	KAPURBAWDI	MANPADA	24771	21,711	27,692
38	MANPADA	TIKUJI-NI-WADI	**25058**	21,711	27,692
39	TIKUJI-NI-WADI	DONGARI PADA	23201	21,711	27,692
40	DONGARI PADA	VIJAY GARDEN	21843	21,711	27,692
41	VIJAY GARDEN	KASARVADAVALI	18634	21,711	27,692
42	KASARVADAVALI	GOWNIWADA	19359	21,711	27,692
43	GOWNIWADA	GAIMUKH	17991	21,711	27,692



Option-II: Loop Train Operation

Attachment- II

TABLE 1.1A
Hourly Train Operation Plan
Mumbai Metro Line: (CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh)
Year- 2021

6.5 - Headway (min)

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	**6.50**	**10**	**9**
9 to 10	**6.50**	**10**	**9**
10 to 11	**6.50**	**10**	**9**
11 to12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	**6.50**	**9**	**10**
18 to 19	**6.50**	**9**	**10**
19 to 20	**6.50**	**9**	**10**
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	30	2	2
Total No. of train trips per direction per day		**105**	**105**

TABLE 1.1B
Hourly Train Operation Plan
Mumbai Metro Line: (Bhakti Park to Kapurbawdi)
Year- 2021

3.25 - Headway (min)

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	**3.25**	**19**	**18**
9 to 10	**3.25**	**19**	**18**
10 to 11	**3.25**	**19**	**18**
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	**3.25**	**18**	**19**
18 to 19	**3.25**	**18**	**19**
19 to 20	**3.25**	**18**	**19**
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		**207**	**207**

TABLE 1.2A

Hourly Train Operation Plan

Mumbai Metro Line: (CSMT Metro to Bhakti Park and Kapurbawdi to Gaimukh)

Year- 2031

6.5 - Headway (min)

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	**6.50**	**10**	**9**
9 to 10	**6.50**	**10**	**9**
10 to 11	**6.50**	**10**	**9**
11 to12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	**6.50**	**9**	**10**
18 to 19	**6.50**	**9**	**10**
19 to 20	**6.50**	**9**	**10**
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	30	2	2
Total No. of train trips per direction per day		**105**	**105**

TABLE 1.2B

Hourly Train Operation Plan
Mumbai Metro Line: (Bhakti Park to Kapurbawdi)
Year- 2031

3.25 - Headway (min)

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	**3.25**	**19**	**18**
9 to 10	**3.25**	**19**	**18**
10 to 11	**3.25**	**19**	**18**
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	**3.25**	**18**	**19**
18 to 19	**3.25**	**18**	**19**
19 to 20	**3.25**	**18**	**19**
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		**207**	**207**

Option-II: Loop Train Operation

Attachment III

TABLE 2

Mumbai Metro Line: (CSMT Metro to Gaimukh) Corridor

PHPDT for the year 2021

S.No	From Station	To Station	Peak hour Load	Directional Split to CSTM	Directional Split to Gaimukh
1	CHHATRAPATI SHIVAJI MAHARAJ TERMINUS	CARNAC BUNDER	7522	50%	50%
2	CARNAC BUNDER	CLOCK TOWER	7617	50%	50%
3	CLOCK TOWER	WADI TOWER	7843	50%	50%
4	WADI TOWER	DARUKHANA	8225	50%	50%
5	DARUKHANA	COAL BUNDER	8659	50%	50%
6	COAL BUNDER	HAY BUNDER	8749	50%	50%
7	HAY BUNDER	SEWRI	8995	50%	50%
8	SEWRI	BPT HOSPITAL	9498	50%	50%
9	BPT HOSPITAL	GANESH NAGAR	11538	50%	50%
10	GANESH NAGAR	BHAKTI PARK METRO	11539	50%	50%
11	BHAKTI PARK METRO	WADALA TT	21807	50%	50%
12	WADALA TT	ANIK NAGAR BUS DEPOT	24706	50%	50%
13	ANIK NAGAR BUS DEPOT	SUMAN NAGAR	24904	50%	50%
14	SUMAN NAGAR	SIDDHARTH COLONY	25838	50%	50%
15	SIDDHARTH COLONY	AMAR MAHAL JUNCTION	30049	50%	50%
16	AMAR MAHAL JUNCTION	GARODIA NAGAR	32336	50%	50%
17	GARODIA NAGAR	PANT NAGAR	**32460**	50%	50%
18	PANT NAGAR	LAXMI NAGAR	32321	50%	50%
19	LAXMI NAGAR	SHREYES CINEMA	32326	50%	50%
20	SHREYES CINEMA	GODREJ COMPANY	21519	50%	50%
21	GODREJ COMPANY	VIKHROLI METRO	21803	50%	50%
22	VIKHROLI METRO	SURYA NAGAR	20851	50%	50%
23	SURYA NAGAR	GANDHI NAGAR	20578	50%	50%
24	GANDHI NAGAR	NAVAL HOUSING	19868	50%	50%
25	NAVAL HOUSING	BHANDUP MAHAPALIKA	19699	50%	50%
26	BHANDUP MAHAPALIKA	BHANDUP METRO	22669	50%	50%
27	BHANDUP METRO	SHANGRILA	21860	50%	50%
28	SHANGRILA	SONAPUR	24629	50%	50%
29	SONAPUR	MULUND FIRE STATION	24301	50%	50%
30	MULUND FIRE STATION	MULUND NAKA	24099	50%	50%
31	MULUND NAKA	TEEN HAATH NAKA (THANE)	24372	50%	50%
32	TEEN HAATH NAKA (THANE)	RTO THANE	23355	50%	50%
33	RTO THANE	MAHAPALIKA MARG	20489	50%	50%
34	MAHAPALIKA MARG	CADBURY JUNCTION	20039	50%	50%
35	CADBURY JUNCTION	MAJIWADA	19640	50%	50%
36	MAJIWADA	KAPURBAWDI	18724	50%	50%
37	KAPURBAWDI	MANPADA	**17460**	50%	50%
38	MANPADA	TIKUJI-NI-WADI	16209	50%	50%
39	TIKUJI-NI-WADI	DONGARI PADA	16122	50%	50%
40	DONGARI PADA	VIJAY GARDEN	14413	50%	50%
41	VIJAY GARDEN	KASARVADAVALI	12530	50%	50%
42	KASARVADAVALI	GOWNIWADA	10380	50%	50%
43	GOWNIWADA	GAIMUKH	9115	50%	50%

Option-II: Loop Train Operation **Attachment IV**

TABLE 3
Mumbai Metro Line: (CSMT Metro to Gaimukh) Corridor
Vehicle Kilometer

Year	2021			2031		
	CSMT Metro to Bhakti Park	Bhakti Park to Kapurbawdi	Kapurbawdi to Gaimukh	CSMT Metro to Bhakti Park	Bhakti Park to Kapurbawdi	Kapurbawdi to Gaimukh
Section Length	12.69	26.33	7.76	12.69	26.33	7.76
No of cars per train	6	6	6	8	8	8
No of working Days in a year	340	340	340	340	340	340
Number of Trains per day each Way	105	207	105	105	207	105
Daily Train -KM	2665	10901	1630	2665	10901	1630
Annual Train - KM (10^5)	9.06	37.06	5.54	9.06	37.06	5.54
Annual Vehicle - KM (10^5)	54.37	222.38	33.25	72.49	296.51	44.34

Option-II: Loop Train Operation

Attachment-V

TABLE 4

Mumbai Metro Line: (CSMT Metro to Gaimukh) Corridor

RAKE REQUIREMENT

Year-2021

S. No.	Section		Length (km)	Gauge	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							
	From	To											Bare	Bare (round-up)	Traffic Reserve	R&M	Total No. Of Rakes (6-car configuration)*	Total no. of cars	Cars required as per previous DPR**	Additional cars required for Line-11
1	CSMT Metro	Gaimukh	46.78	SG	35	2021	6.50	80.19	3	0	6	166.38	25.60	26	1	4	**31**	**186**	**232**	**44**
2	Bhakti Park	Kapurbawdi	26.33	SG	35	2021	6.50	45.14	3	0	6	96.28	14.81	15	0	0	**15**	**90**		
																TOTAL	**46**	**276**	**232**	**44**

Note: Effective headway between Bhakti park and Kapurbawdi is 3.25 min.

Year-2031

S. No.	Section		Length (km)	Gauge	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							
	From	To											Bare	Bare (round-up)	Traffic Reserve	R&M	Total No. Of Rakes (8-car configuration)#	Total no. of cars	Cars required as per previous DPR**	Additional cars required for Line-11
1	CSMT Metro	Gaimukh	46.78	SG	35	2031	6.50	80.19	3	0	6	166.38	25.60	26	1	4	**31**	**248**	**264**	**104**
2	Bhakti Park	Kapurbawdi	26.33	SG	35	2031	6.50	45.14	3	0	6	96.28	14.81	15	0	0	**15**	**120**		
																TOTAL	**46**	**368**	**264**	**104**

Note: Effective headway between Bhakti park and Kapurbawdi is 3.25 min.

*	**Passenger capacity @ 6p/sqm for a train of 6 car configuration**	**1756**
#	**Passenger capacity @ 6p/sqm for a train of 8 car configuration**	**2352**

** **Previuos provision of car requiremnet has been taken from DPR of Line-4: Bhakti Park to Gaimukh corridor of Mumbai Metro dtd. Sep'17**

NOTE: Repair & Maintenance Reserve as a percentage of total requirement (Bare + Traffic Reserve) = **10%**

CHAPTER-7

MAINTENANCE DEPOT

7.1 **CORRIDOR:** CSMT Metro – Gaimukh corridor of Mumbai Metro Rail Network, comprises as below:

Corridor	**Route length(km)**
CSMT Metro to Gaimukh	46.78

7.2 DEPOT- CUM- WORKSHOP

7.2.1 It is proposed to establish one depot- cum- workshop near Gaimukh 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 train 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 (preferably as close to depot as possible) to cater to the required stability facilities.
(v) In case of space constraint for depot two storeyed Stabling lines can also be planned.

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.

7.3 MAINTENANCE PHILOSOPHY

- Monitoring of the performance of all key Rolling Stock equipment by suitable advanced condition monitoring techniques available. 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.
- Increase in the periodic maintenance intervals with predictive maintenance based on condition monitoring.
- Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.
- Periodic review of maintenance practices to update replacement cycle of critical components based on experience.
- 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. 331 kms running per train per day, taking in consideration the passenger load of 2021, 2031 respectively.

TABLE- 7.1

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

Type of Schedule	Interval	Work Content	Locations
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, wheelset/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:

TABLE- 7.2

S.N.	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 & intensive cleaning 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:

Traffic data are available up to year 2031 only; hence space to be earmarked for future expansion beyond 2031 year for stabling, inspection and workshop line.

(i) Planned rakes as per TOP:

TABLE- 7.3

Year	No. of Coaches	No. of Rakes	Total No. of coaches
2021	6-Coach	46	276
2031	8-Coach	46	368

(ii) Requirement of Stabling Lines (SBL), Inspection Lines (IBL) and Workshop Lines (WSL) in the Depot -cum -Workshop.

Stabling and Inspection Lines

TABLE- 7.4

Year	No. of Rakes	SBLs	IBLs
2021	46	42 lines x one train of 8-car	Two bays of 3 lines each with one train of 8-Car, required from year 2021 and will cater up to year 2031.
2031	46	42 lines x one train of 8-car	

Workshop Lines

TABLE- 7.5

Year	No. of Rakes	WSLs
2021	46	Three bays of 2 lines each with one train of 8-Car, required from year 2021 and will cater up to year 2031.
2031	46	

7.6 REQUIREMENT OF MAINTENANCE/INSPECTION LINES FOR DEPOT-CUM-WORKSHOP:

TABLE- 7.6

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
i) Year 2021 - Maximum no. of rake holding is (46 TS x 6 = 276 Cars)		
'A' Checks (5000 km) approx. 15 days	(46X6) Cars = 276 Cars	3 Line x one train of 8- Cars (with Sunken Floor)

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
'B' Checks (15000 km) approx. 45 days.	(46X6) Cars = 276 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	2 Line x one train of 8- Cars (with sunken Floor)
Requirement		2 bays of 3 lines each with one train of 8-Cars
ii) Year 2031 -Maximum no. of rake holding is (46 TS x 8 = 368 Cars)		
'A' Checks (5000 km) approx. 15 days	(46 X 8) Cars = 368 Cars	3 Line x one train of 8- Cars (with Sunken Floor)
'B' Checks (15000 km) approx. 45 days.	(46 X 8) Cars = 368 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	2 Line x one train of 8- Cars (with sunken Floor)
Requirement		No additional requirement. Available 2 bays of 3 lines each with one train of 8-Cars will cater 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 and other pneumatic systems.
- Bogie
- Traction Motor
- Vehicle doors, windows and internal fittings
- Power system including converter, circuit breaker etc.

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 mtrs. For the design of the stabling lines in the depot and terminal stations or elsewhere (as may be required), following approximate dimensions have been taken in consideration, however final dimensions shall be decided based on actual site conditions/ area available at the time of design finalization of depot:

(i) Length of one 8- Car rake= 184 m
(ii) Pathway in the entry side=10m
(iii) Free length at outer ends of two trains of 8- Car rakes (for cross pathway, Signal and Friction buffers) = 10m
(iv) Total length of Stabling lines = (ii) + (i) + (iii) = 10+184+10= 204 m (approx.)

Looking to the 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.

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) Embedded track in the entry side =10 m
(iii) Pit length of IBL = 188 m
(iv) Embedded track length at outer ends of IBL = 12 m
(v) Total length of Inspection lines = (ii) + (iii) + (iv) = 10+188+12= 210 m (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= 4.25 m
(iii) Width of a 3 line Inspection Bay= (ii)+(i)+(i)+(ii) = 4.25+6.25+6.25+4.25 = 21 m

a) There shall be two inspection bay of 210 m X 21 m size each with provision of accommodating three inspection lines each having sunken floor and overhead roof inspection platforms in two lines adjacent to I-Girder. 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 1:10 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. Both lines of inspection bay shall be provided with EOT crane of 1.5 T to facilitate lifting of equipment on retractable OHE.

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 the arrangement close by for cleaning of HVAC filter under high pressure water jet.

7.8.3 Workshop Shed at Depot:

Requirement of workshop lines is planned as under:

TABLE- 7.7

Year	IOH & POH	Major Overhauling	Unscheduled repairs /lifting	Total	Remarks
2021	1	4 line 8-Car train and free space of 8-car length for storage of other equipment.	1 line x1 train of 8-Car train length.	Three bays of 2 lines each with one train of 8- Cars is to be required for the year 2021 and catering up to year 2031.	The size of workshop shall be 210 m X 21 m for one working bay comprising of two lines capable of accommodating one 8-Car rake with Bogie turn table facility, one line of 8- Car rake length with free space of 8- Car rake length for storage of wheel/ bogie/ equipment etc.
2031					

(a) Each bay shall be comprising of two lines (as detailed in ‘Remarks’ above). Size of the workshop bay is proposed to be 210m x 21m. The unscheduled lifting and heavy repair line shall be fitted with jack system capable to lift the 8- Car unit simultaneously for quick change of bogie, thereby saving down time of Rolling Stock. 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 AW0 (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 210 m 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

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)

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 50m long. The unloading bay should be of 50 m X 30 m and the bearing capacity of the floor should be 15-20 MT/m^2.

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 and minimum turning radius for the trailer movement should be 20-23 m. in case of space limitation a point lifting jack system can be installed.

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 main line train operation 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 7.8.2 & 7.8.3 above.

II. Stabling Lines in Depot:

a) The requirement of lines shall be in accordance with the details indicated in para 7.8.1 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 Table 7.8.

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

A test track of 1000 mtrs. 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, Inspection and intensive cleaning sheds. Thus, the pneumatic pipeline shall run within the workshop, inspection and intensive cleaning 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 cum rail vehicle equipped with re-railing and rescue item:

   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 road cum rail vehicle equipped with re-railing and rescue item 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 7.12.1. 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) of 50 m X 16 m 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 rigid/ retractable OHE in such a way that, the cranes become operational only when the rigid/ retractable 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, workshop and inspection shed 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 AND LIST OF PLANTS &EQUIPMENTS AT DEPOT-CUM-WORKSHOP:

7.12.1 List of Buildings at Depot-cum-workshop:

TABLE- 7.8

S.No.	Name of Building	Size	Remarks
1.	Inspection Shed	210m x 21m for each bay.	Servicing of Cars for 15 days &45 days inspection.
	Workshop Shed	210 x 21m for each bay.	Major repair & overhaul of rolling stocks, diesel shunters, electric tractors, tower wagons. All heavy lifting jobs. Space for future provision to be kept beyond year 2031.
	Associated Sections	210m x 8m	Rooms for carrying out the inspection & workshop activity.
	Stabling line shed (Covered Stabling)	204m x54 m (for initial provision of 10 SBL lines)	Provision for total area (covered & uncovered SBL) as per requirement of stabling of 46 rakes of 8-car length during year 2021 is to be made which will cater to the requirement of year 2031 also.
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.

S.No.	Name of Building	Size	Remarks
			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.
	Auto coach washing platform	20m X 10m	
7.	Washing apron for Interior Cleaning	184m x 6.5m	Heavy wet washing of rakes from inside, under frame, roof at 30 days interval.
8.	Blowdown plant	30m X 5m (additional to intensive cleaning)	Heavy cleaning of under frame and roof through compressed air at 30 days interval.
9.	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.
10.	ETU Building	30m X 15m	For parking of CMV and OHE machinery.
11.	Security office & Time Office Garages (4 Nos.)	15m x 8m	For security personnel. For time punching For parking vehicle jeep, truck etc.
12.	Check Post (2 Nos.)	5m x 3m	For security check of incoming/outgoing staff material and coaches.
13.	Depot control centre & Crew booking centre	25mx20m (double storey)	To control movement of trains in and out of the depot and for crew booking.
14.	O.H raw water Tank	1,00,000 Ltrs. Capacity	For Storage of water.
15.	Pump house Bore well	7.3mx5.4m (200 mm bore)	Submersible type pump planned with 200 mm diameter bore well.
16.	Dangerous goods Store	15m x 10m	For Storage of paints, inflammables & Lubricants
17.	a) Traction 25kV/33kV/66kV sub station b) Feeding Post	a)120m x 80m b) 15m x30m	Traction Power Supply
18.	Waste Collection Bin	10m x 10m	Garbage dumping
19.	Repair shops for S & T	40m x 20m	For the AFC gates, Signaling and telecom equipment.
20.	Work shop Manager Office	30m x 20m	Office of Depot in charge

S.No.	Name of Building	Size	Remarks
21.	ATP & ATO Room	10m x 8m	To keep equipments of ATP/ATO
22.	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.
23.	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.
24.	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:

TABLE- 7.9

S. No.	Description	Approx. Unit Price (INR Lakh)	MML-4 Corridor Depot as per DPR (Sep'17)		Additional Requirement	
			IBL-4 Lines		IBL-2 lines	
			WSL-4 Lines		WSL-2 lines	
			Qty.(set)	Approx. Cost Provision (INR Lakh)	Qty.(set)	Approx. Cost Provision (INR Lakh)
1	Under floor Pit Wheel lathe	621.00	**1**	**621.00**	**0**	**0**
2	Syn. Pit Jacks-for **8 cars** unit	1700.00	**1**	**1700.00**	**0**	**0**
3	Automatic Train Washing Plant	268.00	**1**	**268.00**	**0**	**0**
4	Battery Shunting Loco	349.89	**1**	**349.89**	**0**	**0**
5	Electric Tractors (RRM)	199.00	**1**	**199.00**	**0**	**0**
6	Electric Tractors (RRM) for UFWL	184.00	**1**	**184.00**	**0**	**0**
7	Syn. Mobile Jacks for **4 cars** unit	136.40	**1**	**136.40**	**1**	**136.40**
8	Bogie Turn Table	27.86	**4**	**111.44**	**2**	**55.72**
9	Re-railing & Rescue equipment (set)	81.99	**1**	**81.99**	**0**	**0**
10	Rail cum Road Vehicle (RRV)	42.26	**1**	**42.26**	**0**	**0**
11	Blow Down Plant	196.00	**1**	**196.00**	**0**	**0**
12	Mobile jib Cranes (1T Manual)	1.53	**1**	**1.53**	**1**	**1.53**
13	Under track Mobile Lifting Table (1T for IBL)	2.75	**3**	**8.25**	**3**	**8.25**
14	CI/SIV Mobile Lifting Table (3T for WS)	3.62	**1**	**3.62**	**1**	**3.62**
15	Arial Work Lift Platform	19.61	**1**	**19.61**	**1**	**19.61**
16	High Pressure Wash Pumps	5.37	**2**	**10.74**	**0**	**0**

S. No.	Description	Approx. Unit Price (INR Lakh)	MML-4 Corridor Depot as per DPR (Sep'17)		Additional Requirement	
			IBL-4 Lines		IBL-2 lines	
			WSL-4 Lines		WSL-2 lines	
			Qty.(set)	Approx. Cost Provision (INR Lakh)	Qty.(set)	Approx. Cost Provision (INR Lakh)
17	AC Filter cleaning machine	23.50	1	23.50	0	0
18	Mobile compressor-10bar	4.20	1	4.20	1	4.20
19	HP compressor-17bar	3.36	1	3.36	0	0
20	EMU Battery Charger	5.56	2	11.12	2	11.12
21	Box Container for re-railing equipment	5.12	1	5.12	0	0
22	wooden blocks	0.77	1	0.77	0	0
23	Auxiliary truck	1.82	1	1.82	0	0
24	Road Truck	10.56	1	10.56	0	0
25	Battery operated Platform Truck for WS and DCOS	6.33	2	12.66	0	0
26	Welding & Cutting Equipments	2.24	1	2.24	0	0
27	Work Benches	0.54	10	5.40	4	2.16
28	Vertical Carousal storage system	35.00	1	35.00	0	0
29	Weighing scales	2.65	1	2.65	0	0
30	Storage Bins	7.59	1	7.59	0	0
31	Pallet Trucks	0.39	5	1.95	2	0.78
32	Fork Lift Truck-3T(Elect)	10.35	1	10.35	1	10.35
33	Stackers (1T for DCOS)	9.50	1	9.50	0	0
34	Mobile Safety Steps & Ladders	5.12	LS	5.12	0	0
35	Set of Pallets	15.00	LS	15.00	0	0
36	Storage racks for DCOS stores	62.50	LS	62.50	0	0
37	Storage racks for workshop, tool room	31.50	LS	31.50	0	0
38	Electric and Pneumatic Tools	33.50	LS	33.50	0	0
39	Measuring & calibration Instruments	62.51	LS	62.51	0	0
40	Special Jigs and Fixtures	60.29	LS	60.29	0	0
41	Industrial Furniture	90.00	LS	90.00	0	0
42	Miscellaneous/other machinery	93.71	LS	93.71	0	0
43	Display boards inside depot	7.50	LS	7.50	0	0
44	Industrial vacuum Cleaners (heavy duty + dry/wet)	4.83	1	4.83	0	0

S. No.	Description	Approx. Unit Price (INR Lakh)	MML-4 Corridor Depot as per DPR (Sep'17)		Additional Requirement	
			IBL-4 Lines		IBL-2 lines	
			WSL-4 Lines		WSL-2 lines	
			Qty.(set)	Approx. Cost Provision (INR Lakh)	Qty.(set)	Approx. Cost Provision (INR Lakh)
45	Small Part Cleaner	1.00	1	1.00	1	1.00
46	Polyester Web Sling+B51+B51:B70:BB51:B70	1.00	LS	1.00	0	0
47	25KV OHE Live Indicators	2.60	3	7.80	3	7.80
48	Wheel Gauges/Templates	3.80	LS	3.80	0	0
49	Ultrasonic Flaw Detector	2.18	1	2.18	0	0
50	Memory Recorder/Chart recorder etc.	10.00	1	10.00	0	0
51	Induction heater	8.40	1	8.40	0	0
52	Hyd. Axle Bearing puller	9.60	1	9.60	0	0
53	Training equipment/ diagnostic software/Camera, Projector, computer equipment/laptop etc.	16.79	LS	16.79	0	0
54	Industrial Videoscope	10.13	2	20.26	0	0
55	Lifting jacks for Aircon (two post lift)	4.37	1	4.37	0	0
56	Auto wheel profile meters and attachments for dia. and back to back measurement.	19.18	1	19.18	0	0
57	Coupler backlog Gauge	8.15	1	8.15	0	0
58	25 Ton Hydraulic C Frame Press	7.44	1	7.44	0	0
59	Hydraulic work bench for Gear Box	16.00	1	16.00	0	0
60	Hydraulic work bench for couplers	7.60	1	7.60	0	0
61	Special tools for coupler	17.50	LS	17.50	0	0
62	Other tools/equipment as per RS contractor	50.00	LS	50.00	0	0
63	Bogie Test Stand	388.00	1	388.00	0	0
64	Wheel Press (300T)	467.50	1	467.50	0	0
65	Vertical turret lathe	131.00	1	131.00	0	0
66	Damper testing machine	52.98	1	52.98	0	0
67	Spring testing machine	201.10	1	201.10	0	0
68	Rail fed Bogie wash plant	188.10	0	0.00	0	0
69	Heating oven for TM	5.88	1	5.88	0	0
70	High Voltage test set	2.00	1	2.00	0	0

S. No.	**Description**	**Approx. Unit Price (INR Lakh)**	**MML-4 Corridor Depot as per DPR (Sep'17)**		**Additional Requirement**	
			IBL-4 Lines		IBL-2 lines	
			WSL-4 Lines		WSL-2 lines	
			Qty.(set)	**Approx. Cost Provision (INR Lakh)**	**Qty.(set)**	**Approx. Cost Provision (INR Lakh)**
71	SS cage for HV Test Set	3.20	**1**	**3.20**	**0**	**0**
72	Impulse Tester for TMs	11.05	**1**	**11.05**	**0**	**0**
	OVER ALL TOTAL			**6,021.76**		**262.54**

7.13 UN-ATTENDED TRAIN OPERATION (UTO)

(i) Proper segregation for UTO and non-UTO zone shall be earmarked while finalizing of depot layout.

(ii) Train Operator (TO) platform of 10m X 12m (L X B) shall be provided in each overlap zone of UTO and non-UTO.

(iii) Bulb fencing of depot tracks shall be done up to 1.5 m height from T.O.R. (Top of the Rail) level.

(iv) Gates should be provided in some interval with locking facility.

(v) All crossing roads which crosses the track should have gates with locking facilities.

(vi) All stabling lines should have SPK (Staff Protection Key) to avoid unauthorized entry.

CHAPTER - 8

POWER SUPPLY ARRAGEMENTS

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, ventilation fan & air-conditioning etc) and workshops in depots & other maintenance infrastructure within premises of metro system. The power requirements of Wadala (Bhakti Park) to CSMT Metro 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 parameters: -

(i) Specific energy consumption of rolling stock at Pantograph/ Current Collector – 50 kWh/1000 GTKM for 25 kV ac system as per MOUD guideline.
(ii) Elevated/at –grade station load – initially 250 kW, which will increase to 300 kW in the year 2031.
(iii) Auxiliary load of Underground station is of the order of 2200 kW initially, which will increase to 2500 kW in the year 2031.
(iv) Depot auxiliary load - initially 2000 kW, which will increase to 2200 kW in the year 2031.

Keeping in view of the train operation plan and demand of traction and auxiliary 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
Line 11: Wadala (Bhakti Park) to CSMT Metro (8 Underground & 2 Elevated, 12.774 km)	Traction	4.96 MVA	6.62 MVA
	Auxiliary	22.67 MVA	25.82 MVA
	Total	**27.63 MVA**	**32.44 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 section of Mumbai metro system is extension of Line 4 which is being designed to handle about 36,635 passengers per direction during peak hours when trains are expected to run at **6.5** 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 there must be two sources of supply and both the sources of Supply & their 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 will be 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 this section.

The Mumbai Metro Corridors from Wadala (Bhakti Park) to CSMT Metro is 12.774 Km, which is Extension for Line 4 Corridor of Mumbai Metro Network from Gaimukh to Wadala (35 Km, 34 Elevated stations).

As per the Detailed Project Report for Line 4 Corridor from Gaimukh to Wadala (35 km, 34 Elevated stations), three RSS are planned at following locations:

a) At Gaimukh Depot,
b) Near RTO Thane Station and
c) Near Ghatkopar or Chembur Station.

In view of above planned Receiving Sub-Stations, one Receiving Sub-stations is proposed to cater to load of Wadala (Bhakti Park) to CSMT Metro Section. One RSS will be set up near Sewri Metro Station and the proposed RSS near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented for Emergency Supply in case of Failure of RSS near Sewri Metro Station.

This is an economical solution without compromising reliability. It is proposed to receive power supply for traction as well as auxiliary services from the following grid sub-stations of M/s TATA Power Ltd. at 110 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	Wadala (Bhakti Park) to CSMT Metro	220/110 kV Parel Grid Sub-station or 220/110 kV Proposed Wadala Grid Substation of M/s TATA	Near Sewri Metro Station	2 to 3 km

*Note: Proposed RSS of near Ghatkopar or Chembur Station of Gaimukh to Wadala Corridor (Line 4) will be augmented to meet the additional requirement of this Corridor.

DMRC has done a joint survey/ meeting with M/s MMRDA and M/s TATA Power Company Ltd on 04.06.18 & 05.06.18 for this section 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)
Wadala (Bhakti Park) to CSMT Metro	RSS Near Sewri Metro Station				
	Traction	4.96	6.62	9.21	11.39
	Auxiliary	22.67	25.82	25.04	29.22
	Sub-total (A)	27.63	32.44	34.25	40.61
	RSS Near Ghatkopar or Chembur				
	Traction	8.49	9.53	13.45	16.15
	Auxiliary	4.73	6.74	27.40	32.56
	Sub-total (B)	13.22	16.27	40.85	48.71

******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 located near Sewri Metro Station. 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 and tunnel walls.

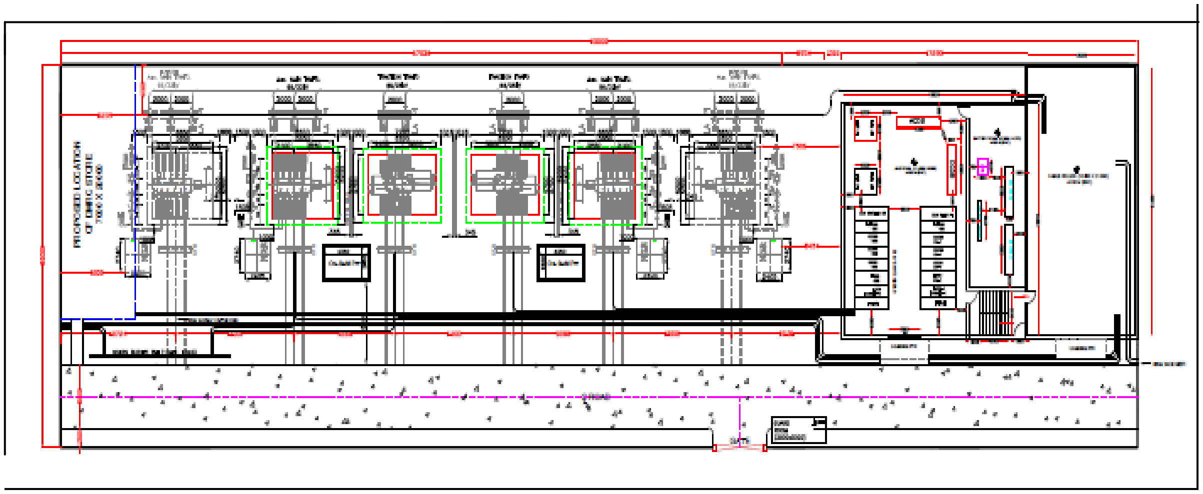
In case of tripping of this RSS of this section owing to fault or input supply failure, train services can be maintained from Ghatkopar or Chembur RSS of Line 4. However, in case of total grid failure, all trains may come to a halt but station lighting, fire and hydraulics & other essential services can be catered to by stand-by DG sets. However, no train services can be run with power supply received from these 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

Typical High Voltage Gas Insulated Sub-Station (GIS)

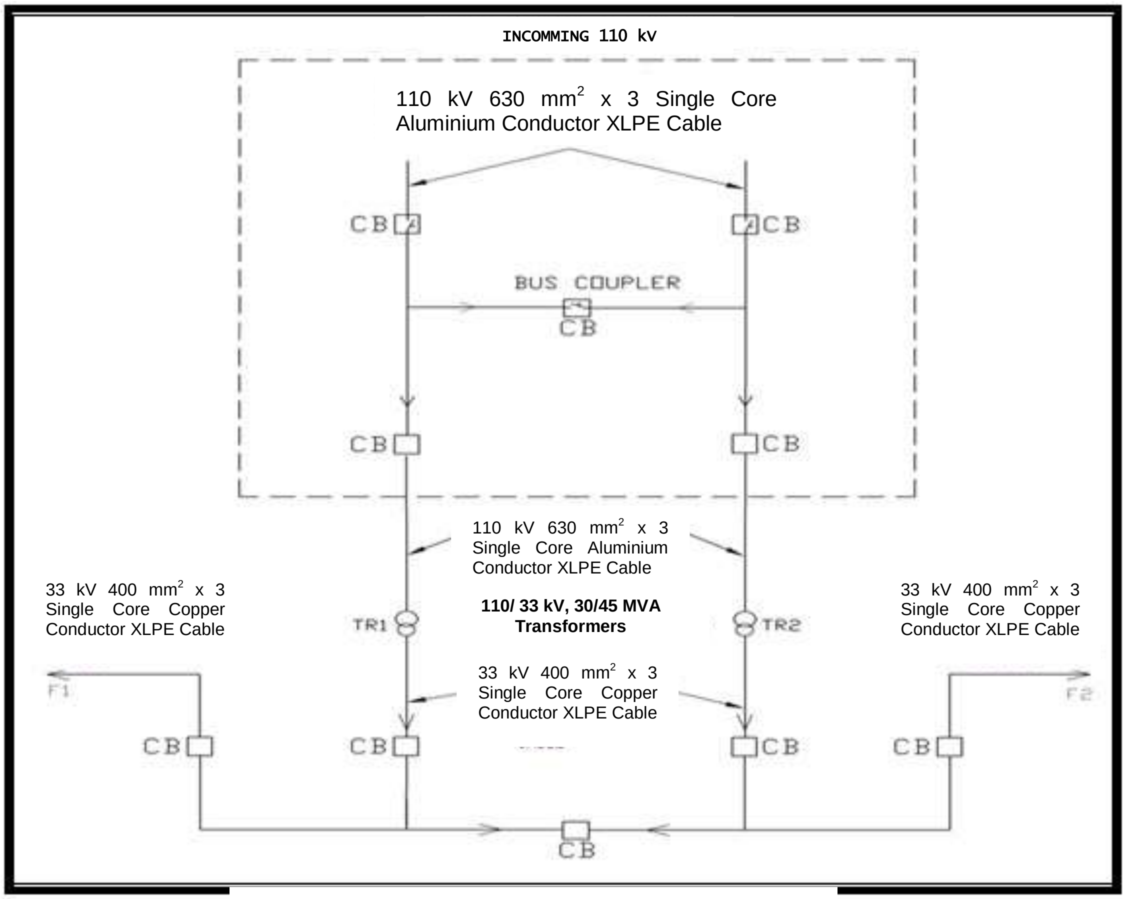
The 110 kV cables will be laid through public pathways from the Sub-stations of Supply Authority to RSS of Metro Authority. The RSS near Sewri Metro Station shall be provided with 2 Nos. (One as standby) 110/25 kV 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 110/33 kV 30/45 MVA (ONAN/ ONAF) three phase Transformers for feeding auxiliary loads.

The Auxiliary Main Transformer of RSS near Ghatkopar or Chembur will be augmented to 30/45 MVA (ONAN/ ONAF) three phase Transformers by enhancing the Capacity of Auxiliary Transformers. The capacity of transformers may be reviewed considering the load requirement/distribution of extension this section at the time of detailed design.



Typical Layout of GIS RSS

Gas Insulated Switchgear (GIS) type Switchgear is planned on account of less space availability in Mumbai and reduction in maintenance. 110 kV GIS substation land requirement will be approx. 60 X 50 m (3000 sq. m).



TYPICAL 110/33kV RSS LAYOUT

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** – In future, 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. In DC traction system it is mostly imported.

- Though in underground section higher side tunnel diameter is required.

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-** The regeneration is 18%, because 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.

- **Higher Consumption of Specific Energy:** As per MOUD guideline specific energy consumption in 750 V dc system is 60 kWh/GTKM and in 25 KV ac system is 50 kWh/GTKM. The specific energy consumption in 750 V dc system is higher as compared to 25 kV ac system. Hence operating cost will increase in 750 V dc system (copy enclosed).

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.

d) 2x25 kV ac single phase Traction System

The following are the benefit of 2x25 kV ac traction system used for Chhatrapati Shivaji Maharaj Terminus (CSMT) to Gaimukh (47 kms) corridor are:

- The electromagnetic interference in of 2x25 kV systems is very less and hence no BT/RC system is required which has its own maintenance and reliability issues. However, additional space for autotransformer shall be required.

- The line loss in of 2x25 kV system is almost half as compared to 25 kV conventional system.

- In the event of 2 x 25 kV traction systems being adopted no of neutral section shall reduce.

- Load balancing will be better on all the three phase using Scott connected transformer.

- Since the OHE current is much lower in the of 2x25 kV systems; hence the OHE voltage profile will be better than conventional system. In fact the voltage drop at the terminal end for the similar load will be aimost half in of 2x25 kV system.

- Harmonics: since the fault currents are much higher in of 2x25 kV & 220/132 kV side, there are less harmonics on the system. Fifth harmonics on the system are in the range of 1% of less as compared to around 3% or higher, in case of conventional system. Due to fewer harmonic, the reliability of the Traction installation equipment and of electric rolling stock in expected to be better.

- Substation spacing: The inter-spacing between sub-station is almost double in of 2x25 kV system as compared to conventional system. Therefore the number of substation almost reduces to half in the 2x25 kV AT system (with proper planning) as compared to the conventional system. This brings in substantial saving of costly space of around 2000 sq. m. in Mumbai metro area, besides saving due to use of lesser high voltage cable.

- 2x25 kV system is highly suitable for high dense load, as the voltage fed to the system at 25 kV as system due to better voltages and thus improved efficiency of the rolling stock.

- Arcing problems are encountered at BT overlap in 25 kV system and there have been melting cases of contact wire at the BT overlap location when bridging by stationary pantograph. No such problem will be encountered in 2x25 kV system.

- With the use of 2x25 kV system return conductor shall be replaced be feeder wire and the design shall be finalized accordingly.

In view of above techno-economic considerations, 25 kV AC traction system is suggested for Chhatrapati Shivaji Maharaj Terminus (CSMT) to Wadala (Bhakti Park) (12.774 km) corridor.

8.5 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

25 kV AC traction current produces 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. In underground section, two earth conductors OPC and tunnel earth wire (TEW) are proposed to be laid down inside tunnel and all the metallic reinforcement steel bars of cut & cover tunnel, track bed, system services like walkway, hydrant pipes etc are connected to maintain continuity.

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

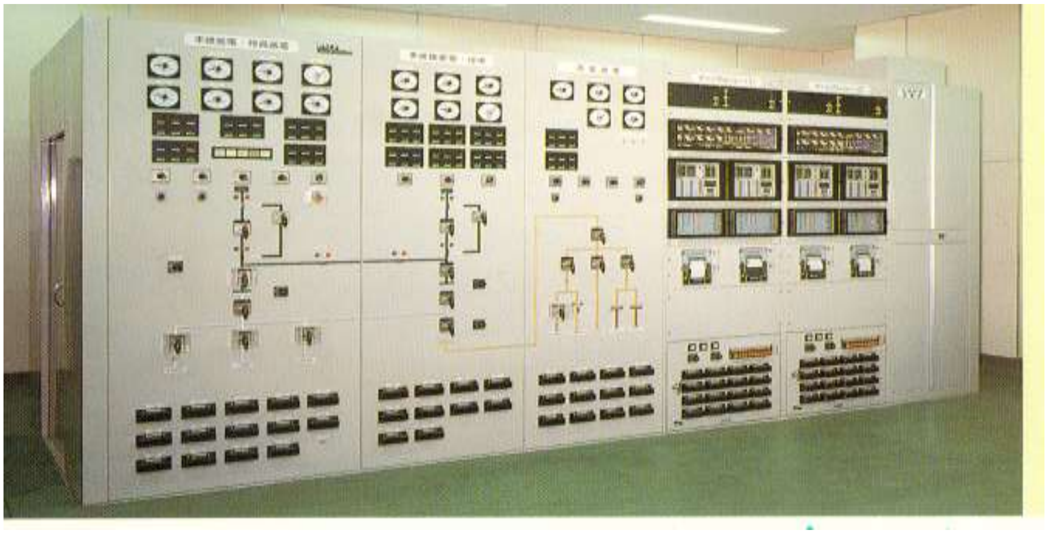
Auxiliary sub-stations (ASS) are envisaged to be provided at each station. The ASS will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 300 kW for elevated/at-grade & 2500 kW for underground stations. Accordingly, two dry type cast resin transformers (33/0.415 kV) of 315 kVA capacity are proposed to be installed at the elevated/ at grade stations (one transformer as standby). Underground station will have two ASS's equipped with one dry type cast resin transformers (33/0.415 kV) of 3150 kVA capacity.

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 be provided with 33kV/415V, 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 150 sq.mm silver copper contact wire and 65 sq.mm Magnesium Copper catenary wires. Because of the advancements in telecom technology, booster transformer has not been in the scope & Return conductor (RC) shall be Aluminium Conductor Steel Reinforced (ACSR) 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. Final sizing of Catenary may be decided at the time of Detailed Design Stage as per Simulation Study.

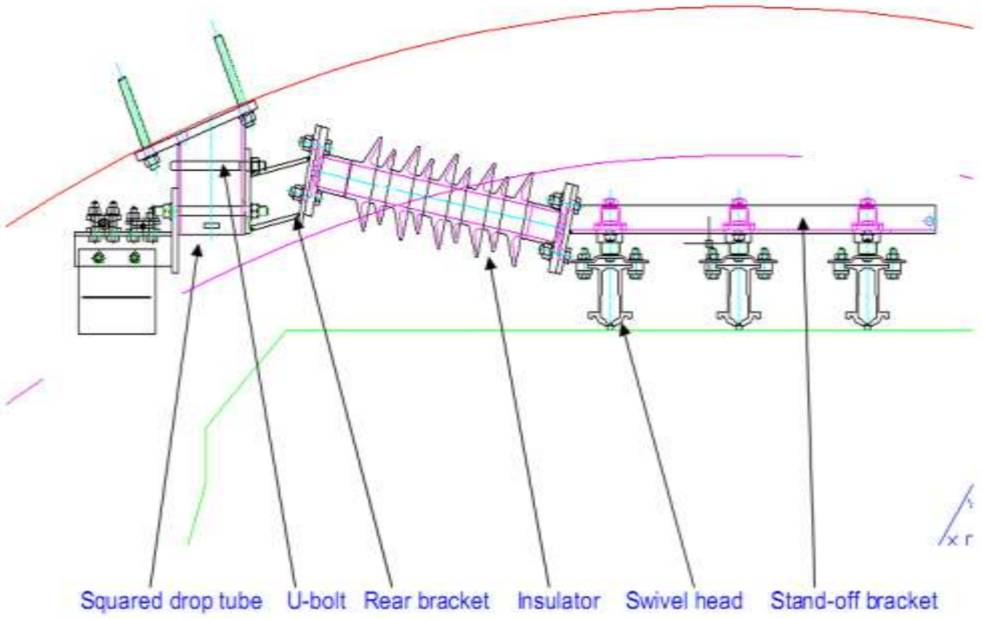
8.8.1 25 kV Rigid Overhead Equipment system (ROCS)

25kV Rigid ROCS system comprises a hollow Aluminum Conductor Rail of adequate cross section with 150 sq.mm copper contact wire held with elastic pinch. The Al conductor rail is supported by an insulator & cantilever arrangement attached to drop-down supports fixed to tunnel roof. The supports are located at every 10 to 12m (approx.) and there is no tension in the conductors and hence, no tensioning equipment in tunnel. The design of 25kV rigid OCS system shall be in accordance to electrical clearances & contact wire height as per IEC 60913, which is summarized below:

a) Contact wire height ……………………………...4318mm

b) Structure to Live parts clearances…………...270/170/150mm (Static/ Dynamic/ Absolute min dynamic)

c) Vehicle to Live parts clearances……………..…290/190/150mm (Static/ Dynamic/ Absolute min dynamic)



25 V ROCS Support

8.9 RATING OF MAJOR EQUIPMENT

Based on emergency demand expected at the RSSs of this section as shown in Table 8.3, shall be provided with 2 Nos. (One as standby) 110/25 kV 21.6/30 MVA (ONAN/ ONAF) Traction Transformers for feeding Traction load and 2 Nos. (one as standby) 220/33 kV 30/45 MVA (ONAN/ONAF) three phase Transformers for feeding auxiliary loads. The incoming cable shall be 3-phase single core XLPE insulated with 630 mm^2 Aluminum conductors to meet the normal & emergency loading requirements and fault level of the 110 kV supply, respectively.

33 kV and 25 kV switchgear shall be rated for 1250 A and 2000 A respectively 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 400 mm^2 FRLSH Copper 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 feeding Post. 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 160 kVA capacity at the elevated & 2X900 kVA capacity for underground stations respectively. The requirement of 900/1000 kVA DG set at underground station is dispensable if two 33/0.415 kV Auxiliary Sub-Stations are fed from two different Receiving Sub-Stations which are taking supply from different Grid Sub-Stations. This arrangement will comply with the requirements of NFPA 130, 70 and 110. In view of this, 380 kVA DG Set capacity at each underground station is sufficient for firefighting system and Emergency Lighting and Fire detection & Alarm System.

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

UPS Supply to also be considered for following emergency services:

- Emergency Lighting
- Fire Detection & Fire Alarm system.
- Station Control Room
- Control Supply

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 21 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. Some of the regenerated energy rolling stock is consumed by auxiliary application itself and remaining energy is fed back to 25kV ac OHE to be consumed by nearby trains

(iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100%) 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 re-generative braking 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 resulting saving of electrical energy.

(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 MAJOR EHV LINE CROSSING THE ALIGNMENT

Tentatively at Seven locations 220/110 kV HT Multi-circuit lines are crossing the corridor between Wadala (Bhakti Park) and Sewri Metro Elevated Section. Detailed survey / estimation etc will be done after finalisation and approval of DPR

8.17 ELECTRIC POWER TARIFF

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 30-38% 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 72.08 million units in initial years 2021, which will be about 85.74 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 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 for FY 2017 – 18 demand charges Rs 240/ kVA per month and energy charges Rs 7.13/ kWh for TATA company Ltd. 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.

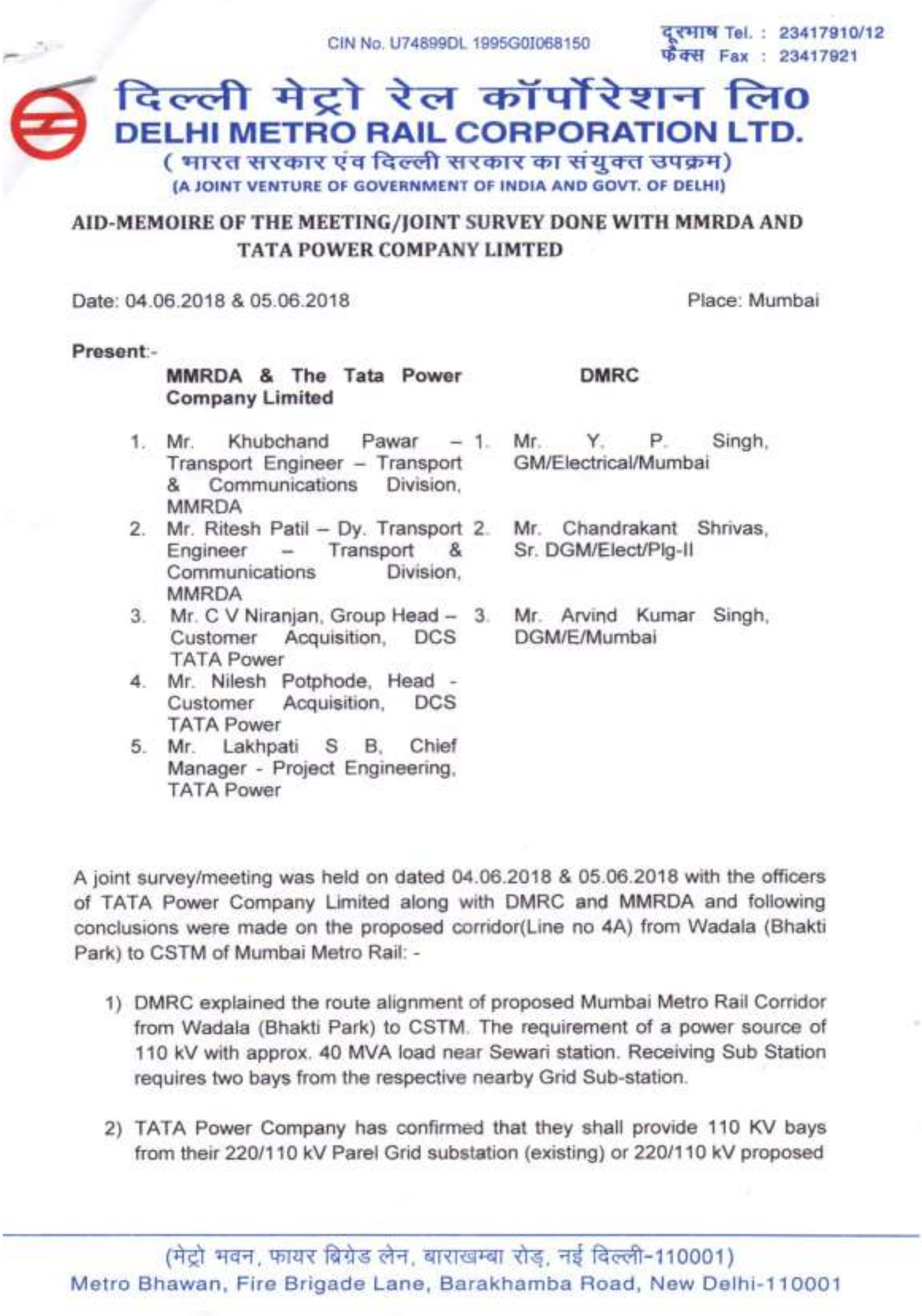
MUMBAI METRO			**Annexure 8.1**	
Line-11: Power Calculation from Wadala(Bhakti Park) to CSMT				
POWER (Traction & Auxiliary)				
S.No.	**Particulars**	**Unit**	**2021**	**2031**
A	**Traction Power Requirement**	1	2	3
1	No. of cars	(2DMC+2TC+2MC) (2DMC+2TC+4MC)	6	8
2	Passenger Weight	T	114.1	152.9
3	Train Tare Weight	T	254.0	338.0
4	Total Train Weight	T	368.1	490.9
5	Section Length	km	13.21	13.21
6	Headway	mts	6.50	6.50
7	SEC at Pantograph/ current Collector (As per MOUD guideline)	KWhr/ 1000 GTKM	50	50
8	No. of Trains/hr in both directions	Nos.	18	18
9	Peak Traction Power Requirement	MW	4.49	5.99
11	Depot Power Requirements	MW	1.00	1.30
12	No. of Depot	No	0	0
13	Total Traction Power Requirement	MW	4.49	5.99
	Total Traction Power Requirement (MVA) assuming 5% energy losses and 0.95 pf	**MVA**	**4.96**	**6.62**
B	**Aux. Power Requirement**			
1	Elevated/at-grade Station Power Consumption	MW	0.25	0.30
2	Underground station Power Consumption	MW	2.20	2.50
3	Mid Shaft	MW	0.30	0.30
4	No. of Elevated/at-grade Stations	Nos.	3	3
5	No. of Underground stations	Nos.	8	8
6	No. of Mid Shaft	Nos.	0	0
7	Total Station Aux Power Requirement	MW	18.4	20.9
8	Depot Aux Power Requirement	MW	2.0	2.2
9	No. of Depot	No.	0	0
10	Total Aux Power Requirement	MW	18.35	20.90
	Total Aux. Power Requirement (MVA) assuming 5% energy losses and 0.85 pf for aux loads	**MVA**	**22.67**	**25.82**
C (A+B)	**Total Traction & Aux. Power Requirement (MVA)**	**MVA**	**27.63**	**32.44**

Note:
1. The Depot Power requirement has already been considered in DPR for Line - 4 (Bhakti Park to Kasarvadavali). Hence Depot power not considered in above calculation.
2. The requirement of PD load is not considered in Power calculation.

MUMBAI METRO			**Annexure 8.1**	
Line-11: Energy Calculation from Wadala(Bhakti Park) to CSMT				
ENERGY CONSUMPTION				
S.No.	**Particulars**	**Unit**	**2021**	**2031**
A	**Traction Energy**	1	2	3
1	Section Length	KM	13.21	13.21
2	No. of Trains per direction in a day	Nos.	105	105
3	Weight of Train & Passenger	T	368.1	490.9
4	SEC at Pantograph/ current Collector (As per MOUD guideline)	KWH/ 1000 GTKM	50	50
	Yearly Traction Energy consumption with 365 days working	**million units**	**18.64**	**24.86**
B	**Auxiliary Energy**			
1	Elevated/at-grade Station	MW	0.25	0.30
2	Underground Station	MW	2.20	2.50
3	Mid Shaft	MW	0.30	0.30
4	No. of Elevated/at-grade Stations	Nos.	3	3
5	No. of Underground Stations	Nos.	8	8
6	No. of Mid Shaft	Nos.	0	0
7	Total Station Aux. Power Requirement	MW	18.35	20.90
8	Depot Aux power requirement	MW	2.00	2.20
9	No. of Depot	No	0	0
10	Total Aux. Power Requirement	MW	18.35	20.90
11	Total Aux. Power Requirement (MVA) assuming 5% energy losses and 0.85 pf for Aux. loads	**MVA**	**22.67**	**25.82**
12	Diversity Factor of Aux. loads		0.40	0.40
	Yearly Aux. Energy Consumption 19 hrs/day and 365 days working (million units)	**million units**	**53.45**	**60.88**
C (A+B)	**Net Annual Energy Consumption (Traction & Aux.)**	**million units**	**72.09**	**85.74**

Note:
1. The Depot Power requirement has already been considered in DPR for Line - 4 (Bhakti Park to Kasarvadavali). Hence Depot power not considered in above calculation.
2. The requirement of PD load is not considered in energy calculation.

Annexure – 8.2



CIN No. U74899DL 1995GOI068150
दूरभाष Tel. : 23417910/12
फैक्स Fax : 23417921

दिल्ली मेट्रो रेल कॉर्पोरेशन लिο
DELHI METRO RAIL CORPORATION LTD.
(भारत सरकार एंव दिल्ली सरकार का संयुक्त उपक्रम)
(A JOINT VENTURE OF GOVERNMENT OF INDIA AND GOVT. OF DELHI)

AID-MEMOIRE OF THE MEETING/JOINT SURVEY DONE WITH MMRDA AND TATA POWER COMPANY LIMTED

Date: 04.06.2018 & 05.06.2018 Place: Mumbai

Present:-

	MMRDA & The Tata Power Company Limited		**DMRC**
1.	Mr. Khubchand Pawar – Transport Engineer – Transport & Communications Division, MMRDA	1.	Mr. Y. P. Singh, GM/Electrical/Mumbai
2.	Mr. Ritesh Patil – Dy. Transport Engineer – Transport & Communications Division, MMRDA	2.	Mr. Chandrakant Shrivas, Sr. DGM/Elect/Plg-II
3.	Mr. C V Niranjan, Group Head – Customer Acquisition, DCS TATA Power	3.	Mr. Arvind Kumar Singh, DGM/E/Mumbai
4.	Mr. Nilesh Potphode, Head - Customer Acquisition, DCS TATA Power		
5.	Mr. Lakhpati S B, Chief Manager - Project Engineering, TATA Power		

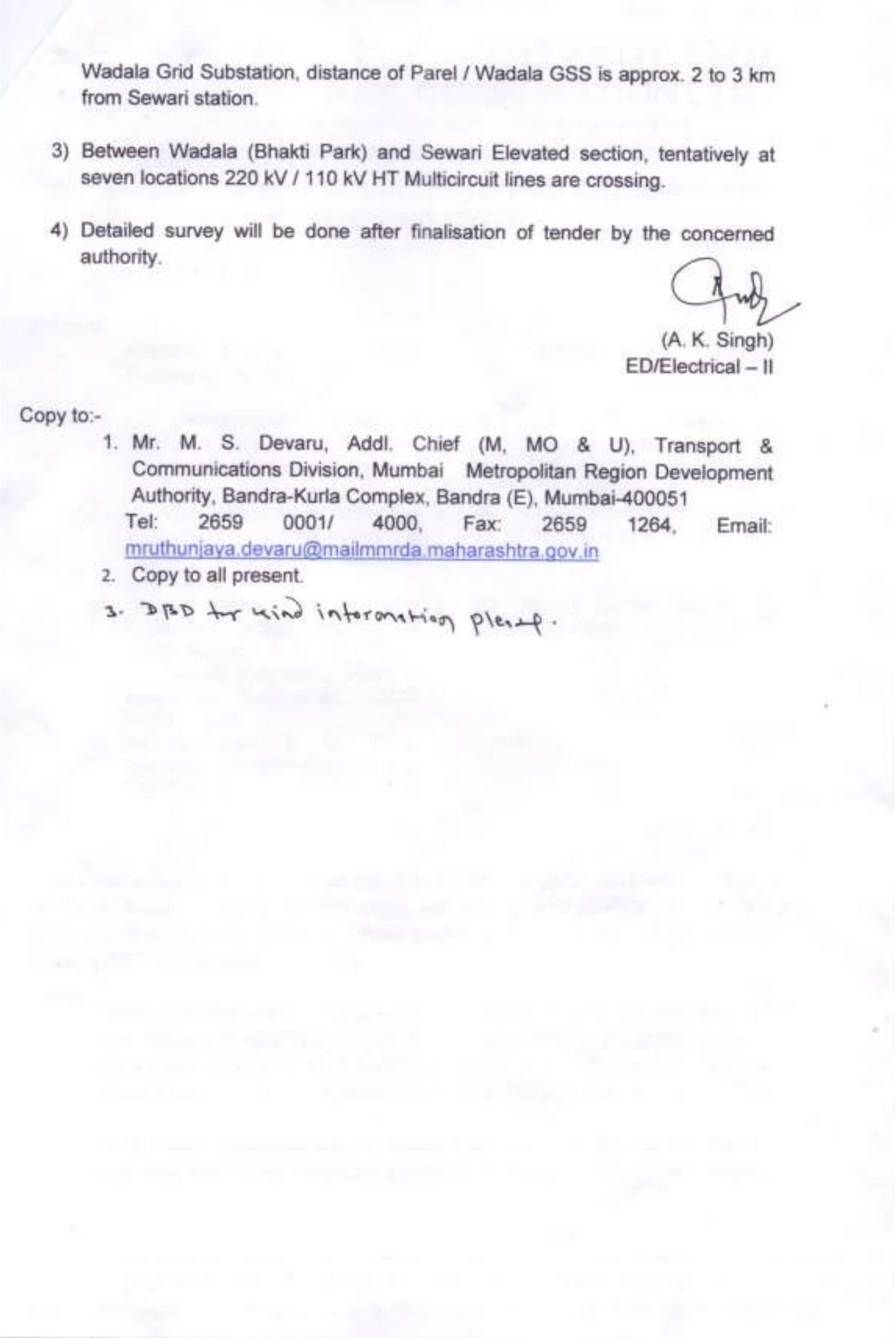
A joint survey/meeting was held on dated 04.06.2018 & 05.06.2018 with the officers of TATA Power Company Limited along with DMRC and MMRDA and following conclusions were made on the proposed corridor(Line no 4A) from Wadala (Bhakti Park) to CSTM of Mumbai Metro Rail: -

1) DMRC explained the route alignment of proposed Mumbai Metro Rail Corridor from Wadala (Bhakti Park) to CSTM. The requirement of a power source of 110 kV with approx. 40 MVA load near Sewari station. Receiving Sub Station requires two bays from the respective nearby Grid Sub-station.

2) TATA Power Company has confirmed that they shall provide 110 KV bays from their 220/110 kV Parel Grid substation (existing) or 220/110 kV proposed

(मेट्रो भवन, फायर ब्रिग्रेड लेन, बाराखम्बा रोड, नई दिल्ली-110001)
Metro Bhawan, Fire Brigade Lane, Barakhamba Road, New Delhi-110001

Annexure – 8.2



Wadala Grid Substation, distance of Parel / Wadala GSS is approx. 2 to 3 km from Sewari station.

3) Between Wadala (Bhakti Park) and Sewari Elevated section, tentatively at seven locations 220 kV / 110 kV HT Multicircuit lines are crossing.

4) Detailed survey will be done after finalisation of tender by the concerned authority.

(A. K. Singh)
ED/Electrical – II

Copy to:-

1. Mr. M. S. Devaru, Addl. Chief (M, MO & U), Transport & Communications Division, Mumbai Metropolitan Region Development Authority, Bandra-Kurla Complex, Bandra (E), Mumbai-400051
   Tel: 2659 0001/ 4000, Fax: 2659 1264, Email: mruthunjaya.devaru@mailmmrda.maharashtra.gov.in
2. Copy to all present.
3. DBD for kind information please.

CHAPTER - 9

VENTILATION AND AIR-CONDITIONING SYSTEM

9.0 INTRODUCTION

This chapter covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed corridor from CSMT Metro to Wadala (Bhakti Park). VAC System includes the following:

- Station Air-conditioning System
- Smoke Management System
- Tunnel Ventilation System
- Control and Monitoring facilities

9.1 ALIGNMENT

This extension of Line-4 from CSMT to Wadala (Bhakti Park) (Line-11) has length of the order of 12.774 km, 10 stations, out of which 8 are underground, 2 are elevated. The underground section begins from CSMT Metro and continues upto Sewri Metro Station. The inter-station distances between two underground stations varies from 851.11m to 1584.60m.

9.2 REQUIREMENT FOR VENTILATION AND AIR-CONDITIONING

The underground stations are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide ventilation and air-conditioning in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the official;
- Removing body heat, obnoxious odors and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the tunnel;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, transformer, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Elevators, Escalators, Automatic Fare Collection Gates etc. working in the stations;
- Removing heat from air conditioning plant and Station sub-station and other equipments.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered to be appropriate. In winter season it may not be necessary to warm the ventilating air as the heat generated by the equipments within the station premises would be sufficient to maintain the comfort requirement.

9.3 EXTERNAL ENVIRONMENT CONDITIONS AND WEATHER DATA

The analysis of Mumbai weather suggests that the dry bulb temperature varies between 20 deg C to 35 deg C, with its peak is in month of May. Mumbai receives its heavy rainfall between the month of May and October.

Air-Quality (Environmental control) in public places like MRT stations is required to be maintained for city like Mumbai. Therefore, it requires consideration of appropriate measures for air-pollution control in Metro stations, while designing the VAC system. The design weather data from the ISHRAE handbooks have been used to arrive at the design criteria. For VAC system, it is suggested that 1% criteria would be acceptable on techno economic reasons.

9.4 SUB SOIL TEMPERATURE

The temperature conditions of sub-soil play a vital role in the system design of the underground stations and important for facilitating adequate heat exchange between the tunnel structures and soil. It is proposed that water table surrounding the underground alignment shall be reviewed. The sub soil temperature of Mumbai is estimated to be 25 °C (approx.). It is to be obtained or to be measured at site.

9.5 INTERNAL DESIGN CONDITIONS IN UNDERGROUND STATIONS

With tropical humid ambient conditions of Mumbai, it is essential to maintain appropriate conditions in the underground stations in order to provide a comfort and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the “Designed inside Conditions”.

The patrons will stay for much shorter durations in underground stations, the comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated is given out by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The ‘Effective Temperature’ criterion was used in selecting the comfort condition in earlier corriodor of Mumbai and other Metro, in this criteria comfort is defined as the function of temperature and the air velocity experienced by a person. An index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient condition of the metabolic rate and is evaluated based on the changes to the surrounding ambient of a person in a short period of about 10 to 12 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a underground section where the train headway is expected to be six minutes or less, then RWI is the preferred criterion.

9.6 DESIGN PARAMETERS FOR VAC SYSTEM

Based on the above discussion, the following VAC system design parameters are assumed in the present report.

(1) Outside ambient conditions

Based upon ISHRAE-2017 recommended design conditions for 1% criteria is as under

Summer :	34.9 DB, 23.1 WB
Monsoon:	30.9 DB, 27.4 WB

For Mumbai Metro Underground Corridor it is suggested to use 1% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 1% of the total time.

1. Inside design conditions

a. Platform and Concourse areas:	27^{o}C at 55% RH

2. Tunnel design conditions

a. Normal conditions	Max. average temperature DB 40^{o}C
b. Congested conditions	Max. stratified temperature DB 50^{o}C

3. Minimum fresh air

a. 10% or 18 cmh/person	(In station public areas)

9.7 DESIGN CONCEPTS FOR VAC SYSTEM

There are various VAC design concepts technically feasible for underground section that can provide and maintain acceptable environment conditions under different requirement and constraints. These are: Open type, Closed type and Platform Screen Doors (PSDs). Similar to other corridor of Mumbai Metro, PSD Design has been considered for CSMT Metro to Wadala (Bhakti Park) U/G station and tunnel.

9.8 STATION AIR-CONDITIONING

The platform and concourse areas will be air-conditioned using supply of cooled air from 'Air Handling Units' located in Environmental Control System (ECS) plant rooms. Each Platform and Concourse will be served by at least two air handling units (AHU's) with the distribution systems combined along to ensure coverage of all areas in the event of single equipment failure. Based on the initial estimation about 4 units having capacity of the order of 20 m^3/s each would be sufficient for the station.

Air Handling Unit

These air-conditioning systems mix return air with a desired quantity of fresh air. The outside (fresh) air requirement is based on occupancy, with a minimum of 5 liters per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimize the enthalpy reduction needed to be achieved by the cooling coil. This mixture of fresh and return air is then filtered by means of suitable filters and then cooled by a cooling coil of AHUs before being distributed as supply air via high level insulated ductwork to diffusers & grills, discharging the air into the serviced space in a controlled way to minimize draughts. Return air from the platform as well as concourse areas is extracted via the separate Return Air Fans (RAFs) which either returned the air to the AHUs or exhausted to the atmosphere as per requirement.

UVC Emitters is installed in the AHUs for the reduction of molds and fungus growth on their coils and keeps the surface clean, eliminating need for coil cleaning programme and improve the overall coil efficiency of AHUs.

Based on the initial concept design, the estimated capacity for the station would be around 600 TR and hence 3 units of 200TR or 2 units of 300TR may be installed for full system capacity (i.e. design PHPDT traffic requirement). Water-cooled chiller units having screw compressors, which are energy efficient on part load are recommended to be provided at each station. These units are installed in a chiller plant room at ground level. During the detail design stage this estimated capacity might get marginally changed depending on the calculated heat loads.

9.9 VENTILATION AND AIR-CONDITIONING OF ANCILLARY SPACES

Ancillary spaces such as Staff Room, Equipment Room, will be mechanically ventilated or air conditioned in accordance with the desired air change rate, temperatures and humidity.

All ancillary areas that require 24-hour air-conditioning will be provided with Fan Coil Units (FCUs). These FCUs are supplied chilled water from main Chilled Water plant during the revenue hours and from Air Cooled Chillers during the non-revenue hours. Return air will be circulated through washable air filters.

Air Cooled Chiller

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filters, common to a group of ancillary areas.

9.10 STATION SMOKE MANAGEMENT SYSTEM

The Return Air Fans (RAFs) provided for the re-circulation of the air to the Air Handling Units will be used for the smoke extract purposes from the public areas

(Concourse and Platform) and will operate in various modes depending on the location of the fire. The control of this system in fire mode will be fail-safe. These Return Air Fans will be provided with “essential” power supplies, with automatic changeover on loss of normal supply. During smoke extraction, RAFs extract the smoke to the atmosphere through exhaust shaft and fresh air feeds from entrance. AHUs will remain OFF during smoke extraction.

Smoke down stand will be provided underneath the ceiling around floor openings for stairs and escalators, so that a smoke reservoir is formed on the ceiling. The smoke will be contained in this reservoir at ceiling level and exhausted to atmosphere. By controlling smoke in this manner, it is possible to maintain a relatively smoke clear layer above human head height and to protect the escape route, giving sufficient time for evacuation. The stations will be designed to accommodate the full smoke exhaust volumes and thus prevent the reservoir from completely filling with smoke. To provide an additional barrier against smoke migration, the overall smoke management system would be designed to provide a draught of fresh air through entrances and escape routes, to assist in protecting those routes from smoke.

9.11 SPACE REQUIREMENT FOR VAC SYSTEM

The station air conditioning equipment plant rooms are normally located at each end of the concourse for the two level stations. The approximate area for air handling equipment room would be 500-600 m^2 at each end of the station. There shall be supply shafts and exhaust shafts of about 10 m^2 each at each end of the stations.

9.12 DESIGN CONCEPTS FOR TVS SYSTEM

There are various TVS design concepts technically feasible for underground section that can provide and maintain acceptable environment conditions inside the tunnel under different requirement and constraints. These are: Open type; Closed type; Use of jet fans; use of mid-shafts; etc.

Under the normal train running the train heat generated inside the tunnel sections would be removed by the train piston action. It is envisaged that for the design outside conditions, it may not be necessary to provide forced ventilation using Tunnel Ventilations Fans for normal operating conditions. Two tunnel ventilation shafts would be provided at each end of the station. All these shafts are connected to the tunnels through dampers.

Generally each tunnel ventilation shaft is connected to a fan room in which there are two reversible tunnel ventilation fans (TVF) are installed with isolation dampers. These dampers are closed when the fan is not in operation. Dampers are also used to close the connections to tunnels and nozzles under different operating conditions. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated in a more accurate manner with the help of Computer Simulations during the detailed design stage.

Tunnel Ventilation Dampers

9.13 TUNNEL VENTILATION SYSTEMS (TVS)

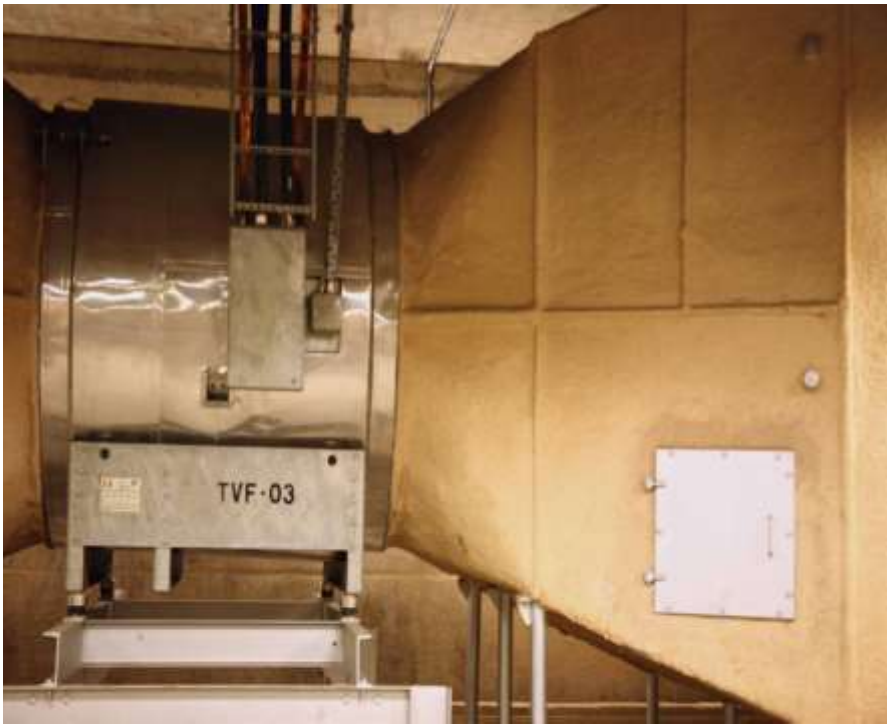
The TVS is provided for underground section essentially to carry out the following functions:

(a) Provide a tenable environment along the path of egress from a fire incident in enclosed stations and enclosed train ways.

(b) Produce airflow rates sufficient to prevent back layering of smoke in the path of egress within enclosed trainways.

(c) Be capable of reaching full operational mode within 180 seconds.

(d) Accommodate the maximum number of trains that could be between ventilation shafts during an emergency.



Tunnel Ventilation Fan

Tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room at each end of the station. The fan capacity may vary from 75 m^3/s to 100 m^3/s. It is expected that nozzles may not be required as the full height PSD will be provided at the station. The booster fans (jet fans) will be required to be installed to direct the flow in the desired direction at crossover or portal locations.

Tunnel Booster Fan

The Trackway Exhaust System (part of Tunnel Ventilation System) will be provided to extract the heat generated by the train Air-Conditioning and braking system from the station trackway. Two fans of each approx. 30 m^3/sec at each end of the station will be required for the trackway exhaust system. For the makeup air in the station trackway, trackway supply air fans will also be required to be provided.

There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:

9.14 NORMAL CONDITIONS

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the track way exhaust system.

9.15 CONGESTED CONDITIONS

Congested conditions occur when delays cause disruption to the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures beyond 50 ^{o}C will result in reducing performance of coach air conditioners that lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature (depending on the rolling stock design) in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a 'push-pull' effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust mode. Booster (jet) fans will be used to direct air into the desired tunnel, if required.

9.16 EMERGENCY CONDITIONS

Emergency conditions are when smoke is generated in the tunnel or station track way. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the fire fighting purposes. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction depending upon the location of Fire on the train.

9.17 PRESSURE TRANSIENTS

The movement of trains within the underground system induces unsteady air motion in the tunnels and stations. Together with changes in cross section, this motion of air results in changes in air pressure within trains and for wayside locations. These changes in pressure or 'pressure transients' can be a source of passenger discomfort and can also be harmful to the wayside equipment and structures. Two types of transient phenomenon are generally to be examined:

a) Portal Entry and Exit Pressure Transients – As a train enters a portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train. There is one portal location between Sewri and BPT Hospital station.

b) Wayside Pressure Transients – As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains. Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

9.18 SPACE REQUIREMENT FOR TUNNEL VENTILATION SYSTEM

The tunnel ventilation equipment plant rooms are normally located at each end of the concourse (or platform level) of the stations. The approximate area for tunnel ventilation fan room would be 300-400 sq. m. respectively at each end of the station. Two tunnel vent shafts of approximately 15 sq. m. area will be constructed at each end of the stations.

.

9.19 CONTROL AND MONITORING FACILITIES

For the underground stations the control and monitoring of station services and systems such as station air-conditioning, ventilation to plant rooms, lighting, pumping systems, lifts & Escalators, etc shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel Ventilation as well as Smoke Management system will normally be done through OCC. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network (such as FOTS).

There shall be an Auxiliary Power Controller at OCC who will be monitoring these services and systems. The command will be initiated at OCC and relayed up to the relevant equipment for operation. The feedback signal is received through SCADA whether the command is implemented or not. The control from OCC is generally performed using ‘Mode Tables’ for each system. This table defines the sequence of the desired equipment that needs to be operated based on the event. The abnormal conditions such as train congestion, emergency, fire inside tunnel and station would be detected by various components and the emergency response thereto will be activated based on the mode tables. In the event that remote control is not possible due to any reason, the local control via SCR would be performed. In case the control at work station in SCR is also not available, the manual overriding provisions shall be provided through Ventilation Control Panel (VCP) place in the SCR.
The OCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

9.20 CODES AND STANDARDS

The concept design is guided by the following codes and standards:

(a) SEDH – Subway Environment Design Handbook

(b) ASHRAE – Handbook, current series

(c) NFPA 130 - Standard for Fixed Guideway Transit and Passenger Rail Systems

(d) ISHRAE - Indian Weather Data 2017

CHAPTER – 10

ENVIRONMENT AND SOCIAL IMPACT ASSESSMENT

10.1 LEGAL, POLICY AND INSTITUTIONAL FRAME WORK

The need for a well-developed legal mechanism to conserve resources, protect the environment and ensures the health and well being of the people in India is more than ever before. Keeping pace with international laws, the Ministry of Environment and Forest enacted Environmental Protection Act in 1986. Over the years, the Government of India has framed several policies and promulgated number of Acts, Rules and Notifications aimed at management and protection of the environment. 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
- CRZ Regulations

10.1.1 Water and Water Pollution

The use of water resources and also the discharge of polluted water (sewerage) are primarily regulated by the Water (Prevention and Control of Pollution) Act, 1974 amended in 1988. The Water Cess Act, 1977 amended in 1992 and 2003, including Rules 1978 and 1991 provides for levy and collection of Cess on water consumed with a view to generate resources for prevention and control of water pollution. The Act assigns functions and powers to the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCBs) for prevention and control of water pollution.

The Environment (Protection) Act 1986 amended in 1991 and Rules also lays down specific standards. Municipal Corporation of Greater Mumbai (MCGM) also has a role in supply of water, disposal of domestic waste water, solid waste disposal and regulation of rainwater harvesting etc.

10.1.2 Air Quality

The Air (Prevention and Control of Pollution) Act, 1981 and amended in 1987 including Rules 1982 and 1983 was enacted to prevent, control and reduce air pollution. According to Section 21 of the Act, no person shall establish or operate any activity, which can cause air pollution without obtaining Consent to Establish (CTE) and Consent to Operate (CTO) as per the Air Act from Maharashtra Pollution Control Board. The Act also lays down national ambient air quality standards for pollutants like PM_{10}, $PM_{2.5}$, Sulphur dioxide, Oxides of Nitrogen, Carbon monoxide etc with the intent of managing air quality for different category of areas (residential, industrial and sensitive). Ambient Air Quality Standards have been notified by the CPCB vide Gazette Notification dated 16th November 2009.

10.1.3 Noise Levels

With the objective of regulating ambient noise quality in the environment, the Union Government has notified the Noise Pollution (Regulation and Control) Rules, 2000 amended in 2002 and 2006 under the EPA. The noise standards for different category of areas are based on the weighted equivalent noise level (Leq). The EPA also lays down equipment noise standards for DG sets, Air conditioners and Construction Equipment, which would be in use for the project. Ambient Noise level standards have been notified by the MoEF vide Gazette Notification dated 26th December 1989 and also in the Schedule III of the Environmental (Protection) Rules 1986. It is based on the ‘A’ weighted equivalent noise level (L_{eq}).

10.1.4 Solid Waste and Construction & Demolition Waste Management

Project construction and operation generates solid waste at site. The MMRDA would be responsible to ensure SHE manual guidelines implementation by contractors for collection and handling of solid waste as per the provisions of the Municipal Solid Waste Rules, 2000. The Hazardous Waste (Management and Handling) Rules, 2000 require facilities to classify wastes into categories, manage them as per the prescribed guidelines and obtain prior authorization from the SPCB for handling, treatment, storage and disposal of Hazardous Wastes. The application form for authorization for Hazardous waste management is available from the office of Maharashta Pollution Control Board. Similarly, Construction and. Demolition waste would have to be disposed off properly during construction phase.

10.2 INSTITUTIONAL FRAMEWORK

The Ministry of Environment and Forests (MoEF) is the nodal agency in the administrative structure of the central government for planning, promotions, co-ordination and overseeing the implementation of India’s environmental and forestry policies and programs. The major responsibilities of MoEF include:

- Environmental resource conservation and protection, including environmental impact assessment, clearance of developmental projects;

- Co-ordination with the other ministries and agencies, voluntary organizations and professional bodies for environmental action plans;
- Promotion of research and development, manpower planning and training and creation of environmental awareness;
- Liaison and coordination with international agencies involved in environmental matters.
- Forest clearance

10.2.1 Central and State Pollution Control Boards

The Central Pollution Control Board is responsible for pollution control throughout the country. In addition to the control of air, noise and water pollution it is also responsible to ensure effective control of disposal of hazardous wastes and storage and handling of hazardous chemicals and substances. With the enactment of air and water pollution laws, states have set-up their own State Pollution Control Boards (SPCBs) to monitor industrial emissions and effluents and to approve the operation of new industries after careful scrutiny. The functions of the SPCBs include:

- The planning of comprehensive state programs for the prevention and control of air and water pollution and to ensure the implementation thereof;
- Inspection of pollution control equipment/ plants for monitoring of their efficiency.

The SPCB in consultation with the Central Pollution Control Board may establish norms for air quality, gaseous emission and noise level etc.

10.3 CLEARANCES

For the proposed project, required clearances/permissions related to environment have been summarized below:

Table 10.1: 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.	District Forest Office/State Forest Department/ District Collector	MMRDA
2	CRZ Clearance	The Ministry of Environment and Forests had issued the Coastal Regulation Zone (**CRZ**) Notification on 19.2.1991 under the Environment (Protection) Act, 1986, with the aim to provide comprehensive measures for the protection and conservation of our coastal environment.	MCZMA	MMRDA

S.No.	Permissions/ Clearances	Acts / Rules / Notifications / Guidelines	Concerned Agency	Responsibility
		B. Implementation Stage		
3	Consent to operate hot mix plant, crushers, batching plant	Air (Prevention and Control of Pollution) Act 1981	Maharashtra State Pollution Control Board	Contractor
4	Permission for withdrawal of groundwater	Environment (Protection) Act, 1986	Central Ground Water Authority	Contractor
5	Permission for sand mining from river bed	Environment (Protection) Act, 1986	Mining Department/ MoEF	Contractor
6	Authorization for Disposal of Hazardous Waste	Hazardous Waste (Management and Handling) Rules 1989	Maharashtra State Pollution Control Board	Contractor
7	Disposal of bituminous and other wastes	Hazardous Waste (Management and Handling) Rules 1989	Local civic body to use local solid waste disposal site	Contractor
8	Consent for disposal of sewage from labour camps.	Water (Prevention and Control of Pollution) Act 1974	Maharashtra State Pollution Control Board	Contractor
9	Pollution Under Control Certificate	Central Motor and Vehicle Act 1988	Department of Transport, Govt. of Maharashtra authorised testing centres	Contractor
10	Roof Top Rain Water Harvesting (RWH)	Central Groundwater Authority (CGWA) Guidelines	Central Ground Water Authority	Contractor
11	Permission for groundwater extraction for drinking purpoes	Environment (Protection) Act, 1986	CGWA	Contractor
12	Employing Labour/ workers	The Building and Other Construction Workers (Regulation of Employmentv and Conditions of Service) Act, 1996	District Labour Commissioner	Contractor

10.4 OBJECTIVE AND SCOPE OF THE STUDY

The objective of the 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 fundinng agencies. The scope of EIA includes the impacts resulting from pre-construction, during construction and operation phases of CSMT- Wadala (Bhakti Park) 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. The MoEF, Government of India, Notification of 14th September 2006 and its amendment dated 1st December 2009 enlist projects in Schedule that require environmental clearance. However, as per the said notification Railway/ Metro projects do not require environmental clearance from MoEF.

10.5 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, minimum 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 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.

The standard methodology for the data collection, impact assessment and formulation of management plans is adopted. The national acts, legislation and laws along with guidelines were consulted with a view to ensuring compliance with various requirements. Environmental baseline data for environmental attributes from primary and secondary sources were collected and compiled. The primary sources include site visits, visual inspection, field studies, monitoring and analysis.

10.5.1 Data Collection

The existing land-use pattern of the area has been identified mainly as urban human settlements, roads, Trees and water bodies.

Water Resources in the project were considered in terms of precipitation, surface run off; quantity and quality of water.

Air and Noise quality is an important consideration during construction and operation phases. Ambient air quality and noise levels were monitored in project area to develop present baseline levels in the area. Terrestrial **Ecology** was also studied.

10.5.2 Environmental Impact Assessment

The objective of the study is to assess the impacts as a result of construction of the proposed metro corridor. The changes likely to occur in different components of the environment were studied and analyzed. Based on project particulars and the existing environmental conditions, potential impacts were identified that are expected to be affected as a result of the proposed project and wherever possible, these are quantified. Both positive and negative impacts are evaluated to get an idea about resultant impacts. The environmental impact of the project includes changes in land use, soil, erosion, water quality, air quality and noise levels etc. The impact on soil due to disposal of waste water and erosion during construction were predicted. On the other hand, the project will provide higher living standard, better quality of life, less travel time, better connectivity and transport facilities.

10.5.3 Environmental Management Plan

The management plans are essential to ensure that stress/ loads on the systems are within carrying capacity. The management plan aims at maintaining the environmental quality of project area with respect to pre-project stage. An environmental management strategy/ plan is developed to mitigate the adverse impacts. Efforts are made to enhance the quality of environmental attributes.

10.5.4 Environmental Monitoring

Monitoring would indicate any environmental problem, which has come up due to an ongoing activity. This will facilitate to assess the effectiveness of management / mitigation measures.

10.6 PROJECT DESCRIPTION

10.6.1 Transport Situation in Mumbai

Public transport systems in Mumbai include the Mumbai Suburban railway, Monorail, Metro, Brihanmumbai Electric Supply and Transport (BEST) buses, black-and-yellow meter taxis, auto rickshaws and ferries. Suburban railway and BEST bus services together accounted for about 88% of the passenger traffic in 2008. Auto rickshaws are allowed to operate only in the suburban areas of Mumbai, while taxis are allowed to operate throughout Mumbai.

Rail

The Mumbai Suburban Railway, popularly referred to as Locals forms the backbone of the city's transport system. It is operated by the Central Railway and Western Railway zones of the Indian Railways. Mumbai's suburban rail systems carried a total of 6.3 million passengers every day in 2007, which is more than half of the Indian Railways daily carrying capacity. The Mumbai Monorail and Mumbai Metro have been built and are being extended in phases to relieve overcrowding on the existing network. The Monorail opened in early February 2014. The first line of the Mumbai Metro opened in early June 2014.

Bus

Mumbai's bus services carried over 5.5 million passengers per day in 2008. Public buses run by BEST cover almost all parts of the metropolis, as well as parts of Navi Mumbai, Mira-Bhayandar and Thane. The BEST operates a total of 4,608 buses with CCTV cameras installed, ferrying 4.5 million passengers daily over 390 routes. Its fleet consists of single-decker, double-decker, vestibule, low-floor, disabled-friendly, air-conditioned and Euro III compliant diesel and compressed natural gas powered buses. BEST introduced air-conditioned buses in 1998.

Water

Water transport in Mumbai consists of ferries, hovercrafts and catamarans. Services are provided by both government agencies as well as private partners Hovercraft services plied briefly in the late 1990s between the Gateway of India and CBD Belapur in Navi Mumbai. They were subsequently scrapped due to lack of adequate infrastructure.

Road

Mumbai is served by National Highway 3, National Highway 4, National Highway 8, National Highway 17 and National Highway 222 of India's National Highways system. The Mumbai-Pune Expressway was the first expressway built in India. The Eastern Freeway was opened in 2013. The Mumbai Nashik Expressway, Mumbai-Vadodara Expressway, are under construction.

Air

The Chhatrapati Shivaji International Airport (formerly Sahar International Airport) is the main aviation hub in the city and the second busiest airport in India in terms of passenger traffic. It handled 36.6 million passengers and 694,300 tonnes of cargo during FY 2014–2015. An upgrade plan was initiated in 2006, targeted at increasing the capacity of the airport to handle up to 40 million passengers annually and the new terminal T2 was opened in February 2014.

Sea

Mumbai is served by two major ports, Mumbai Port Trust and Jawaharlal Nehru Port Trust, which lies just across the creek in Navi Mumbai. Mumbai Port has one of the best natural harbours in the world, and has extensive wet and dry dock accommodation facilities. Jawaharlal Nehru Port, commissioned on 26 May 1989, is the busiest and most modern major port in India. It handles 55–60% of the country's total containerised cargo. Ferries from Ferry Wharf in Mazagaon allow access to islands near the city. The city is also the headquarters of the Western Naval Command, and also an important base for the Indian Navy.

10.6.2 Project Area

The metro project in Mumbai is proposed between CSMT- Bhakti Park (Wadala) (12.774 Km). The proposed alignment would serve the city by ultimately providing connectivity between CSMT and Bhakti Park. This line already extends upto Kasarwadavalli via Ghatkopar and Thane.

10.6.3 Proposed Metro Corridor

One metro corridor is proposed in Mumbai to cater the requirement of the city along western express highway for a length of about 12.774 km. The corridor will be underground between CSMT- Sewri Metro and after chainage 8022.5 m the corridor will be elevated. The Metro corridor will have standard Guage alignment.

10.6.4 Route Alignment

The proposed route alignment of metro corridor between CSMT and Bhakti Park runs along the harbour road in Mumbai city. The alignment has 10 stations.

10.6.5 Route Length and Stations

An underground corridor is planned between CSMT Metro to chainage 8022.5m after Sewri Metro station. Thereafter, elevated option has been adopted upto the end of the proposed corridor between CSMT Metro to Bhakti Park to minimize the adverse effects on the existing properties and the road network. At places, the alignment steers off the road. The details of stations have been elaborated in the **Table 10.2.**

Table 10.2 Stations of CSMT-Bhakti Park Metro Corridor

Station No	Stations Names	Centre line Chainage (m)	Type of Station
1	Dead End	(-) 530.0	
2	CSMT Metro	0.0	Underground
3	Carnac Bunder	1584.6	Underground
4	Clock Tower	2474.0	Underground
5	Wadi Bunder	3620.5	Underground
6	Darukhana	4598.0	Underground
7	Coal Bunder	5780.6	Underground
8	Hay Bunder	6805.0	Underground
9	Sewri Metro	7656.1	Underground
10	Bpt Hospital	9754.2	Elevated
11	Ganesh Nagar	10722.1	Elevated
12	Bhakti Park	12694.1	Elevated
13	Dead End	12800.0	

Source: DPR and Alignment Drawing

Eight stations will be underground and the three stations will be two level stations with the concourse and station facilities on the lower level and platforms on the higher level.

10.6.6 Boarding and Alighting

Trafic projection for different horizon years have been worked out in the DPR. However, the projections for the year 2021 have been summarized in Table 10.3.

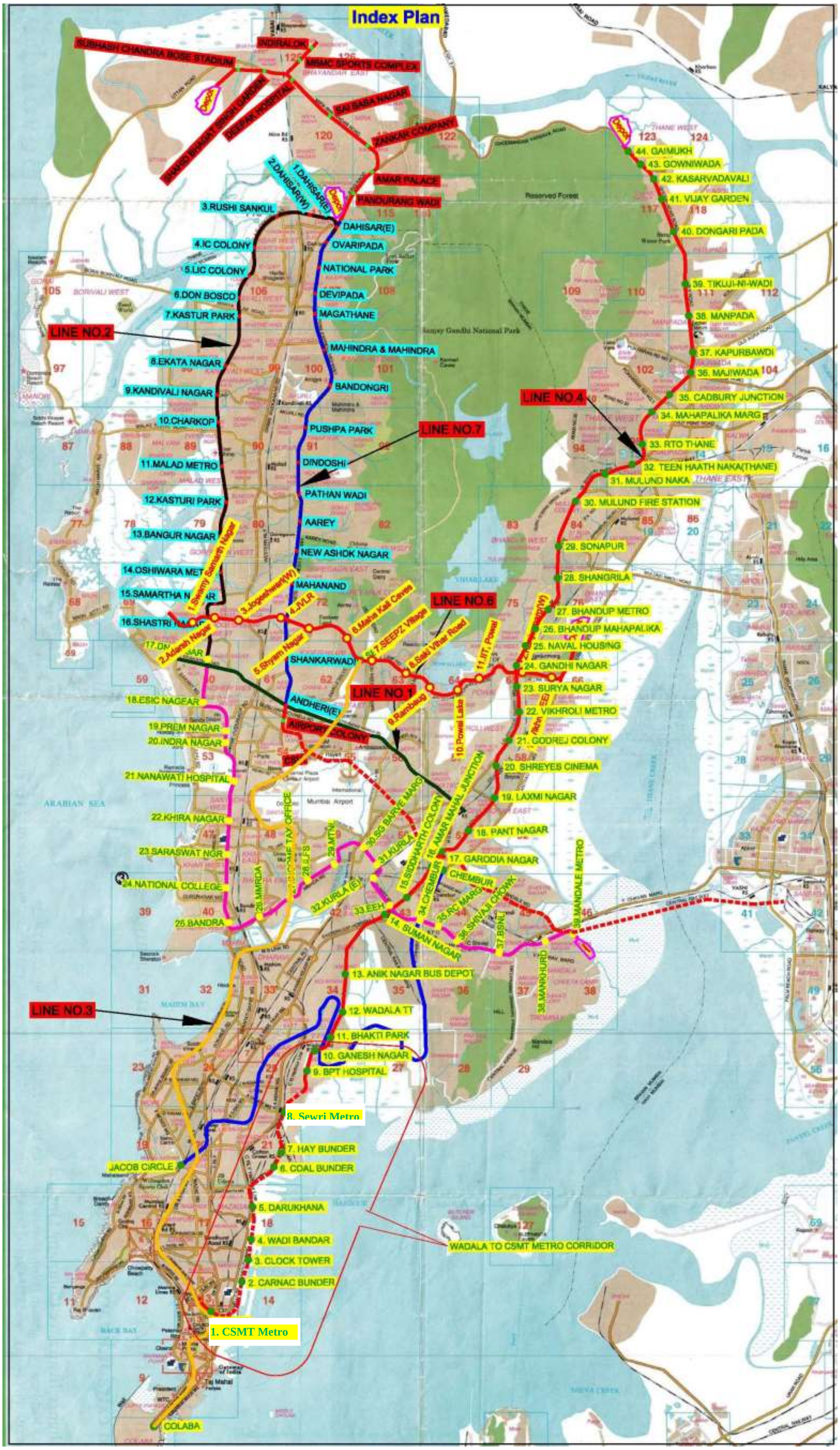


Fig. 10.1 Index Plan

Table 10.3: Direction wise Volume and Boarding Alighting (2021)

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2004	0	2004	**CSMT Metro**	0	0	7522
42	1	2045	**Carnac Bunder**	7522	8	104
293	46	2292	**Clock Tower**	7617	143	368
849	55	3086	**Wadi Bunder**	7843	320	703
695	72	3710	**Darukhana**	8225	238	671
171	8	3873	**Coal Bunder**	8659	56	147
894	72	4695	**Hay Bunder**	8749	158	404
258	112	4841	**Sewri Metro**	8995	101	604
3970	761	8050	**BPT Hospital**	9498	1713	3753
1456	233	9273	**Ganesh Nagar**	11538	776	777
1845	1593	9525	**Wadala RTO (Bhatkti Park Metro)**	11539	363	10631
2872	1914	10483	**Wadala TT**	21807	2426	5325
670	429	10724	**Anik Nagar (Anik Nagar Bus Dept)**	24706	813	1011
1638	300	12062	**Suman Nagar**	24904	867	1801
3165	791	14435	**Siddharth Colony**	25838	1208	5419
2561	180	16816	**Pestom Sagar (Amar Mahal Junction)**	30049	418	2705
479	173	17122	**Garodia Nagar**	32336	372	497
74	96	17099	**Pant Nagar**	32460	233	93
519	531	17087	**Laxmi Nagar**	32321	446	452
2894	5839	14141	**Amrut Nagar (Shreyas Cinema)**	32326	14471	3663
957	329	14770	**Ambewadi (Godrej Company)**	21519	879	1164
496	1394	13872	**Vikhroli Metro**	21803	1776	823
144	245	13771	**Surya nagar**	20851	629	356
1504	2207	13068	**Gandhi nagar**	20578	2370	1661
0	41	13027	**Naval Kousing**	19868	170	0
2439	48	15417	**Bhandup mahapalika**	19699	14	2984
380	449	15348	**Bhandup Metro**	22669	1027	219
2423	948	16823	**Nahur Metro (Shagrila)**	21860	2026	4794
548	675	16696	**Sonapur**	24629	907	579
132	53	16775	**Mulund Fire Station**	24301	243	41
515	851	16440	**Mulund naka**	24099	694	967
719	1163	15995	**Teen Hath naka**	24372	1658	641
1116	3208	13903	**RTO Thane**	23355	4175	1310

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
1072	1037	13938	**Thane Mahapalika Marg**	20489	1370	920
31	721	13248	**Siddheshwar Lake (Cadbury Junction)**	20039	515	116
899	1155	12992	**Majiwada**	19640	2056	1140
574	2081	11485	**KapurBawdi**	18724	1940	677
545	1099	10931	**Manpada**	17460	1862	610
1783	620	12094	**Patli Pada (Tikuji Ni wadi)**	16209	2404	2317
599	2429	10264	**Dongari pada**	16122	2793	1084
648	1499	9413	**Kavesar Gaon (Vijay Garden)**	14413	2757	873
424	1808	8029	**kasarvadavali**	12530	2690	540
426	1557	6898	**Gowniwada**	10380	1906	641
0	6898	0	**Gaimukh**	9115	9115	0
45721	45722	**17122**	**PHPDT/Ridership**	**32460**	71101	71102
			1168242			

Table 10.4: Direction wise Volume and Boarding Alighting (2031)

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
2366	0	2366	**CSMT Metro**	0	0	7211
473	165	2674	**Carnac Bunder**	7211	2347	145
205	186	2693	**Clock Tower**	5009	120	392
655	294	3054	**Wadi Bunder**	5281	304	701
820	266	3608	**Darukhana**	5678	379	1226
95	4	3699	**Coal Bunder**	6525	7	151
546	19	4225	**Hay Bunder**	6669	42	221
257	403	4080	**Sewri Metro**	6848	427	1141
4683	755	8008	**BPT Hospital**	7563	1879	4172
1804	184	9627	**Ganesh Nagar**	9855	649	894
2336	1317	10646	**Wadala RTO (Bhatkti Park Metro)**	10100	320	12234
2990	1002	12633	**Wadala TT**	22013	1330	6048
617	340	12910	**Anik Nagar (Anik Nagar Bus Dept)**	26732	438	1064
1724	582	14052	**Suman Nagar**	27358	1433	2472
6210	2166	18096	**Siddharth Colony**	28397	5496	6137
1191	335	18952	**Pestom Sagar (Amar Mahal Junction)**	29038	496	1170
254	2909	16297	**Garodia Nagar**	29712	7438	198
316	351	16261	**Pant Nagar**	22472	325	412
720	957	16023	**Laxmi Nagar**	22559	632	931
8156	1828	22351	**Amrut Nagar**	22859	4667	14815

Boarding	Alighting	Vol (CSMT-Gaimukh)	Stations	Vol (Gaimukh-CSMT)	Boarding	Alighting
			(Shreyas Cinema)			
1078	2404	21024	**Ambewadi (Godrej Company)**	33008	1300	2133
915	2030	19910	**Vikhroli Metro**	33840	2513	996
594	1322	19181	**Surya nagar**	32324	1182	609
4043	1829	21395	**gandhi nagar**	31751	1689	5355
892	215	22072	**Naval Kousing**	35417	979	1006
235	472	21835	**Bhandup mahapalika**	35443	951	335
1654	937	22552	**Bhandup Metro**	34828	1211	3017
1224	2436	21341	**Nahur Metro (Shagrila)**	36635	8191	547
260	303	21297	**Sonapur**	28991	223	266
574	1038	20833	**Mulund Fire Station**	29034	1950	423
268	353	20749	**Mulund naka**	27507	437	527
1245	2145	19849	**Teen Hath naka**	27597	2580	1225
1073	1796	19126	**RTO Thane**	26242	1811	1994
1112	1784	18454	**Thane Mahapalika Marg**	26425	1589	1889
1713	2096	18071	**Siddheshwar Lake (Cadbury Junction)**	26725	2726	2183
1069	2245	16895	**Majiwada**	26182	2728	1265
2508	1073	18331	**KapurBawdi**	24719	819	872
8046	4682	21695	**Manpada**	24771	8219	8506
1130	3545	19280	**Patli Pada (Tikuji Ni wadi)**	25058	3963	2106
1118	2976	17421	**Dongari pada**	23201	3028	1669
0	2074	15348	**Kavesar Gaon (Vijay Garden)**	21843	3209	0
600	0	15948	**kasarvadavali**	18634	13	738
1156	1495	15609	**Gowniwada**	19359	2621	1253
0	15609	0	**Gaimukh**	17991	17991	0
68921	68921	22552	**PHPDT/Ridership**	**36635**	100649	100648
			1695705			

Source: DPR

10.7 SYSTEM REQUIREMENT

The corridor will be elevated as well as underground. The issue of Broad Gauge vs. Standard Gauge for Metro in India has been debated for quite some time and the decision is in favour of Standard Gauge. On the viaducts, it is proposed to adopt plinth type ballastless track structure with RCC derailment guards integrated with the plinths.

10.8 CONSTRUCTION METHODOLOGY

The segmental construction has been proposed. The superstructure of a large part of the viaduct comprises of simply supported spans. It is proposed to provide Double U girders as superstructure for the viaduct.

10.9 MAINTENANCE DEPOT

The line will be part of Line 4 upto Gaimukh. Thus, separate maintenance Depot has not been proposed for this corridor.

10.10 POWER REQUIREMENT

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting & air-conditioning 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:

- Specific energy consumption of rolling stock at Pantograph/ Current Collector – 50 kWh/1000 GTKM for 25 kV ac system as per MOUD guideline.
- Elevated/at –grade station load – initially 250 kW, which will increase to 300 kW in the year 2031.
- Auxiliary load of Underground station is of the order of 2200 kW initially, which will increase to 2500 kW in the year 2031.
- Depot auxiliary load - initially 2000 kW, which will increase to 2200 kW in the year 2031.

Keeping in view of the train operation plan and demand of traction and power, power requirements projected for the year 2021 and 2031 are summarized in table 10.4 below:

Table 10.4 Power Demand Estimation (MVA)

Corridor	Load	Year	
		2021	2031
Line-11: Wadala (Bhakti Park) to CSMT Metro (8 Underground and 2 Elevated Stations, 12.774 km)	Traction	5.49 MVA	5.84 MVA
	Auxiliary	22.67 MVA	25.82 MVA
	Total	**28.16 MVA**	**31.66 MVA**

10.11 ENVIRONMENTAL BASELINE DATA

10.11.1 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 and monitoring during March 2018. Climatological data was collected from Indian 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 10.5**.

Table 10.5 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
AIR, NOISE AND METEOROLOGY				
4	Ambient Air Quality	PM_{10},$PM_{2.5}$, SO_2, NO_x	Three	Sampling/ Monitoring locations
5	Noise	Noise levels in dB (A) Leq, Lmax, Lmin, L_{10}, L_{50}, L_{90}	Three	Sampling/ Monitoring locations
6	Soil Quality	Physico-chemical parameters	One	Sampling/ Monitoring locations
SOCIO-ECONOMIC				
7	Socio-economic aspects	Socio-economic profile	Once	Field Studies, Literature review.
ECOLOGY				
8	Trees	Number	Once	Filed Studies

The sampling/ monitoring sites have been depicted in **Fig. 10.2**.

Fig. 10.2 Sampling/ Monitoring locations

10.12 LAND ENVIRONMENT

The Project area is situated in Mumbai. The elevation of the project area is ranging between 2m to 16 m above the mean sea level (a-MSL). Parameters involved in land environment are, physiography, geology and soils, and seismicity. These are discussed in the following paragraphs.

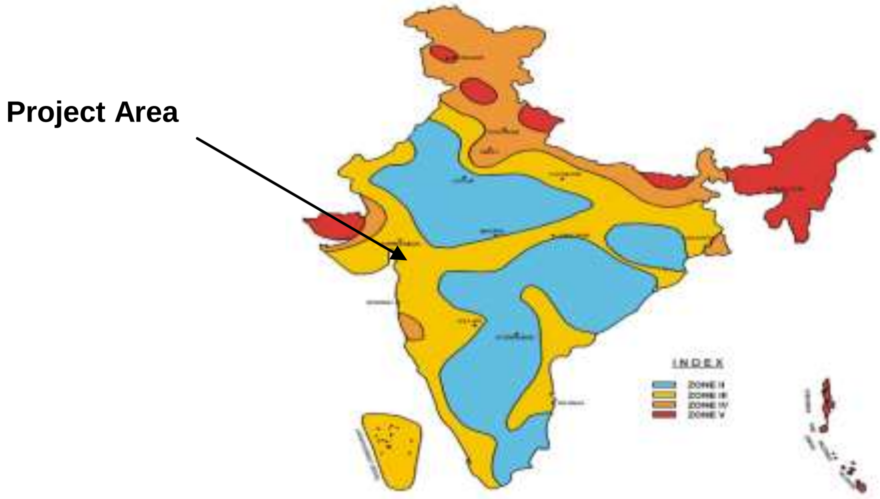
10.12.1 Geography, Geology and Soil

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 10 m 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. 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 Cretaceousand early Eocene eras.

10.12.2 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 10.3).**



10.13 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.

10.13.1 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. 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.

10.13.2 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. The data of Central Ground Water Board (CGWB) from the year 1998 to 2007 shows decline in ground water levels in major parts of Mumbai.

10.13.3 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.10.2.** Ground and surface water samples were collected in July 2017**.** Water quality has been given in **Table 10.6.**

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 10.6 Ground Water Quality at Project Site

S. No.	PARAMETER	Near CSMT	Near BPT Hospital	UNIT	IS : 10500:2012 (Limits)	
					Acceptable	Permissible
Sampling Date: 03.03.2018						
1	Colour	< 5.0	< 5.0	Hazen	5	15
2	pH	6.90	7.16	–	6.5-8.5	No relaxation
3	Total Hardness (as $CaCO_3$)	296.0	318.0	–	200	600
4	Calcium Hardness (as $CaCO_3$)	192.0	165.0	NTU	75	200
5	Iron (as Fe)	< 0.1	< 0.1	–	0.3	No relaxation
6	Chloride (as Cl)	99.8	56.4	mg/L	250	1000
7	Residual Free Chlorine	< 0.2	< 0.2	mg/L	0.2	1
8	Fluoride (as F)	< 1.0	< 1.0	mg/L	1	1.5
9	Total Dissolved Solids	650.0	668.0	mg/L	500	2000
10	Magnesium Hardness (as $CaCO_3$)	82.0	144.0	mg/L	30	100
11	Copper (as Cu)	< 0.01	< 0.01	mg/L	0.05	1.5
12	Manganese (as Mn)	< 0.1	< 0.1	mg/L	0.1	0.3
13	Sulphate (as SO_4)	40.6	49.2	mg/L	200	400
14	Nitrate (as NO_3)	1.16	1.06	mg/L	45	No relaxation
15	Phenolic Compounds	< 0.001	< 0.001	mg/L	0.001	0.002
16	Mercury (as Hg)	< 0.001	< 0.001	mg/L	0.001	No

S. No.	PARAMETER	Near CSMT	Near BPT Hospital	UNIT	IS : 10500:2012 (Limits)	
					Acceptable	Permissible
						relaxation
17	Selenium (as Se)	< 0.005	< 0.005	mg/L	0.01	No relaxation
18	Arsenic (as As)	< 0.005	< 0.005	mg/L	0.01	0.05
19	Cyanide (as CN)	Absent	Absent	mg/L	0.05	No relaxation
20	Lead (as Pb)	< 0.005	< 0.005	mg/L	0.01	No relaxation
21	Zinc (as Zn)	< 0.05	< 0.05	mg/L	5	15
22	Total Chromium (as Cr)	< 0.01	< 0.01	mg/L	0.05	No relaxation
23	Nickel (as Ni)	< 0.01	< 0.01	mg/L	0.02	No relaxation
24	Aluminium (as Al)	< 0.01	< 0.01	mg/L	0.03	0.2
25	Boron (as B)	< 0.25	< 0.25	mg/L	0.5	1
26	Cadmium (as Cd)	< 0.001	< 0.001	mg/L	0.003	No relaxation
27	Total Suspended Solids	< 5.0	< 5.0	mg/L	-	-
28	Biological oxygen demand	< 2.0	< 2.0	mg/L	-	–
29	Chemical oxygen demand	< 4.0	< 4.0	mg/L	-	–
30	Oil & Grease	ND	ND	mg/L	-	-
31	Pesticides	ND	ND	mg/L	0.1	No relaxation
32	Total Phosphate	< 0.3	< 0.3	mg/L	-	-
33	Total Kjheldal Nitrogen	< 1.0	< 1.0	mg/L	100	-
34	Dissolved Oxygen	4.1	5.6	mg/L	-	-
35	Poly Aromatic Hydrocarbon	ND	ND	mg/L	0.0001	No relaxation
36	Total Coliform	Absent	Absent	MPN/100 ml	Shall not be detectable in 100ml sample	-

ND-Not Detected

Table 10.7 Surface Water Quality at Project Site

S. No.	PARAMETER Sampling Date: 03-03-2018	Near Coal Bunder	Ganesh Nagar	UNIT
1	Colour	30	25	Hazen
2	pH	7.12	7.26	–
3	Total Hardness (as $CaCO_3$)	64.0	82	mg/L
4	Calcium Hardness (as $CaCO_3$)	37.0	48	mg/L

S. No.	PARAMETER Sampling Date: 03-03-2018	Near Coal Bunder	Ganesh Nagar	UNIT
5	Iron (as Fe)	< 0.1	< 0.1	mg/L
6	Chloride (as Cl)	32.9	39.9	mg/L
7	Residual Free Chlorine	< 0.2	< 0.2	mg/L
8	Fluoride (as F)	< 1.0	< 1.0	mg/L
9	Total Dissolved Solids	207.0	272.0	mg/L
10	Magnesium Hardness (as $CaCO_3$)	39.0	36.0	mg/L
11	Copper (as Cu)	< 0.01	< 0.01	mg/L
12	Manganese (as Mn)	< 0.1	< 0.1	mg/L
13	Sulphate (as SO_4)	29.3	24.8	mg/L
14	Nitrate (as NO_3)	9.18	11.18	mg/L
15	Phenolic Compounds	< 0.001	< 0.001	mg/L
16	Mercury (as Hg)	< 0.001	< 0.001	mg/L
17	Selenium (as Se)	< 0.005	< 0.005	mg/L
18	Arsenic (as As)	< 0.005	< 0.005	mg/L
19	Cyanide (as CN)	Absent	Absent	mg/L
20	Lead (as Pb)	< 0.005	< 0.005	mg/L
21	Zinc (as Zn)	0.16	0.21	mg/L
22	Total Chromium (as Cr)	< 0.01	< 0.01	mg/L
23	Nickel (as Ni)	<0.01	<0.01	mg/L
24	Aluminium (as Al)	< 0.01	< 0.01	mg/L
25	Boron (as B)	< 0.25	< 0.25	mg/L
26	Cadmium (as Cd)	< 0.001	< 0.001	mg/L
27	Total Suspended Solids	157.0	187.0	mg/L
28	Biological oxygen demand	9.9	13.9	mg/L
29	Chemical oxygen demand	41.6	47.6	mg/L
30	Oil & Grease	ND	ND	mg/L
31	Pesticides	ND	ND	mg/L
32	Total Phosphate	< 0.3	< 0.3	mg/L
33	Total Kjheldal Nitrogen	1.58	1.58	mg/L
34	Dissolved Oxygen	5.9	5.2	mg/L
35	Poly Aromatic Hydrocarbon	ND	ND	mg/L
36	Total Coliform	Absent	Absent	MPN/100 ml
ND - Not Detected				

10.14 METEOROLOGY

10.14.1 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.

10.14.2 Temperature

The temperature data for Mumbai has been taken. The month-wise minimum & maximum temperatures have been given in **Table 10.8.**

Table 10.8 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.

10.14.3 Rainfall

The detail of rainfall at the Mumbai (Santacruz) is given in **Table 10.9.**

Table 10.9 Monthwise 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	

S. No.	Month	Rainfall	Peak Rainfall
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.

10.15 AIR ENVIRONMENT

The atmospheric concentrations of air pollutants were monitored at 2 locations near the proposed alignment during the month of July 2017. Locations of air monitoring station are shown in **Figure 10.2.** Air Monitoring was carried out for PM$_{10}$, NOx, SO$_2$ and CO . Results of the air quality monitoring are presented in **Table 10.10.**

Table 10.10 Ambient Air Quality Results

S.No.	**PARAMETER**	**Particulate Matter (PM$_{10}$)**	**Particulate Matter (PM$_{2.5}$)**	**Sulphur dioxide (as SO$_2$)**	**Nitrogen dioxide (as NO$_2$)**	**Carbon monoxide (as CO)**
	UNIT	**$\mu g/m^3$**	**$\mu g/m^3$**	**$\mu g/m^3$**	**$\mu g/m^3$**	**mg/m^3**
	03/04-03-2018					
1	CSMT	213.6	66.3	8.98	23.1	< 1.15
2	Coal Bunder	217.6	87.5	8.91	24.9	< 1.15
3	Ganesh Nagar	196.2	75.5	8.61	21.6	< 1.15
	04/05-03-2018					
1	CSMT	239.7	73.3	7.99	21.8	< 1.15
2	Coal Bunder	227.3	8.97	8.86	22.4	< 1.15
3	Ganesh Nagar	185.2	73.4	8.09	21.5	< 1.15
	Limits as per EPA Act	**100.0**	**60.0**	**80.0**	**80.0**	**4.0**

The results show that the concentration of all parameters is within permissible limits except suspended particulates PM$_{10}$ as well as PM$_{2.5}$.

10.16 NOISE ENVIRONMENT

Noise is responsible for adverse impact 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 nine locations on 03-05 March 2018 for 24 hours. The locations of Noise level monitoring has been shown in **Fig.10.2**. The noise levels so obtained are summarized in **Table 10.11.**

Table 10.11 Noise Levels [Values in dB(A)]

S.No.	Location\ Parameter	Day/Night	Leq	Lmax	Lmin	L90	L50	L10
	03/04-03-2018							
1	CSMT	**L Day**	64.4	73.6	46.2	61.4	64.4	67.7
		L Night	51.6	68.5	41.2	47.5	51.3	54.3
2	Coal Bunder	**L Day**	63.5	74.7	52.6	48.8	68.7	69.7
		L Night	53.6	64.8	44.8	46.6	54.5	59.4
3	Ganesh Nagar	**L Day**	63.1	74.4	47.8	58.7	63.7	65.5
		L Night	54.8	68.3	44.6	47.6	48.6	54.6
	04/05-03-2018							
1	CSMT	L Day	63.5	72.6	62.3	54.1	65.2	69.5
		L Night	57.8	64.8	48.1	46.5	57.2	59.8
2	Coal Bunder	L Day	64.4	75.5	47.3	60.5	63.9	66.4
		L Night	52.3	70.0	44.5	48.3	52.8	53.4
3	Ganesh Nagar	L Day	63.2	76.3	62.5	55.1	66.6	70.6
		L Night	58.6	59.4	47.8	45.4	54.2	58.6

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 permissibble limits which may be due to heavy traffic movement on the western express highway.

10.17 SOIL QUALITY

Soil quality in project area has been worked out by sampling at one location and the test results are given in **Table 10.12**

Table 10.12 Soil Sample Analysis Sampling Date:- 11.07.2017

S. No.	PARAMETER	Bhakti Park	UNIT
1	pH	7.02	-
2	Conductivity	594	µs/cm
3	Calcium as Ca	1228.4	mg/kg
4	Sodium as Na	137.5	mg/kg
5	Potassium as K	129.7	mg/kg

S. No.	PARAMETER	Bhakti Park	UNIT
6	Organic Matter	0.82	mg/kg
7	Magnesium as Mg	328.8	% by mass
8	Texture	Sandy Clay	mg/kg
9	Sand	56.9	% by mass
10	Slit	15.7	% by mass
11	Clay	27.4	% by mass
12	Nitrogen Available	657.3	mg/kg
13	Phosphorus	65.9	mg/kg

10.18 TREES

Tree survey has been carried out along the proposed alignment. Tree with Girth at Breast Height (GBH) is 30 cm have been counted. The alignment does not pass through any forest area. About 53 trees are likely to be felled due to the project allignment between Bhakti Park and Chainage 8022 including station areas. No rare or endangered species of trees have been noticed during field survey.

10.19 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 theMCGM, 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. 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.

10.20 SOCIO-ECONOMIC SURVEY

A socio-economic survey was undertaken in March 2018 for the proposed corridors to assess the socio-economic conditions of project-affected families/people and to examine the impacts of the proposed metro alignment on their conditions. The survey has been undertaken on the corridor using structured questinnaire. It was found that there are about 116 Shops, 62 houses, 2 sheds, part of 2 factories and some area of Bharat Petroleum are likely to be affected due to the project.

10.21 ARCHAEOLOGICAL SITES

There are many heritage sites in Mumbai which are very much far off from the corridor alignment.

10.22 ENVIRONMENTAL IMPACTS ASSESSMENT

10.22.1 General

The primary function of an environmental impact assessment study is to predict and quantify the magnitude of impacts, evaluate and assess the importance of the identified changes and formulate plans to monitor and mitigate the actual changes. Environmental impacts could be positive or negative, direct or indirect, local, regional or global, reversible or irreversible. The main aim of the project is to decongest the road traffic. The project is designed keeping in view population growth, future traffic demands and environmental protection aspects.

Negative impacts likely to result from the proposed development have been listed under the following headings:

- Impacts due to Project Location;
- Impacts due to Project Design;
- Impacts due to Construction; and
- Impacts due to Project Operation.

For each of these headings, potential impacts have been considered.

10.22.2 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.

A. 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;

- **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.

- **Change of Land Use**

The details of land required (permenant and temporary) and change in land use are presented in **Table 10.13.** The required land (permenant & temporary) for the construction of the proposed alignment is both government as well as private land which shall be allotted by Mumbai Metropolital 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 10.13 Change in Land Use (m^2)

S.No.	Permanent Land Requirement	Govt.	Private	Total
1.	Station & facilities	12448	1590	14038
2.	Running Section	20584	6977	27561
3.	Ramp	3957	0	3957
4.	Receiving Sub Station	5600	0	5600
5.	Ventillation Shaft	800	0	800
6.	Ancillary Structures	3150	450	3600
	Total	**51541**	**8983**	**60524**
	Temporary Land Requirement			
1.	Office/ Site Office	4000	0	4000
2.	Segment Casting Yards	40000	0	40000
	Construction of UG stations by cut and cover method	0	7674	7674
3.	Portion of alignment before start of Ramp by Cut and Cover method	4772	0	4772
	Total	**48772**	**7674**	**56446**

Source: DPR

- **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 53 trees which are likely to be felled during construction. These include trees in alignment, station area and Depot area. Trees are assets in purification of urban air, which by utilizing CO_2 from atmosphere, release oxygen into the air. 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.

- **Utility/ Drainage Problems**

  Metro lines are mostly planned to run through the urban area. The alignment will cross many properties, canals/ 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.

- **Socio-Economic Impact on PAPs**

  As such 116 shops, 62 houses 2 sheds and part of 2 factories have been found to be affected due to land acquisition for the proposed Mumbai metro project. Almost all the establishments are being affected due to ROW of the alignment and Station areas. It is also found that 156 employees are also working in the affected commercial establishments mostly shops. These are also getting affected and shall be compensataed as per Act 30 of 2013 and for resettlement and rehabilitation policy for Mumbai Urban Transport Project (MUTP). There would be an effort to restore their socio-economic status by resettling and rehabilitating the affected owners of commercial properties and their employees.

- **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.

B. Impacts Due to Project Design

Considered impacts, due to project designs are:

- Lighting,
- Risk Due to Earthquake.

- **Lighting**

  The platforms, concourse, staircase and escalator areas both for 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 which could attract birds during night. Maximum illumination level proposed is 200Lux which provides normal lighting.

- **Risk Due to Earthquake**

  The project area lies in Zone III of Bureau of Indian Standards (BIS) Seismic Zoning Map (**Fig. 10.3**). 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.

C. 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

- **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.

- **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 part of western express highway and service road. 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 significant cover above the roof of metro corridor in underground section and safe distance between buildings and proposed corridor in elevated section of the corridor except at a few shops the alignment is passing over the shops. Here special care has to be taken for safety of the structures during construction when they will be shifted.

- **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.

- **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. However, this activity will be only short-term. Protective measures shall be undertaken during construction phase. Movement of trucks and other heavy equipments at construction site would generate dust during construction phase.

- **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 suggestedto 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 project whose water demand is, in any case, met by Municipal Corporation of Greater Mumbai supplied water.

- **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. The construction material shall be sourced only from legalized and approved quarries.

- **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).

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.

- **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. 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.

- **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.

- **Loss of Historical and Cultural Monuments**

No historical/ cultural monuments will be lost as a result of the proposed development.

D. 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

- **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). The noise level reduces with distance logarithmically.

- **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 norms in working metros is about 23 kld for each elevated station and about 100 kld for an underground station. 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.

There would be total water requirement of 869 KLD in 8 underground stations@ 100kld and 2 elevated stations @ 23 KLD for each station. However, arrangement of water will have to be made at each station separately.

- **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, the solid waste generation is about 0.8 – 1.2 cum/day at elevated stations. Thus, about 9 to 13 cum of solid waste will be generated from nine stations of this corridor of Mumbai metro. The maintenance of adequate sanitary facilities for temporarily storing refuse on the premises is the responsibility of the project authorities. The storage containers for this purpose need to be designed. To avoid odour and the accumulation of fly-supporting materials, garbage containers should be washed at frequent intervals

- **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.

E. 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 chapter deals with the positive impacts of the project. The introduction of the corridor will also yield benefits from non-tangible parameters such as saving 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 1000 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. 405 persons) may 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 CSMT- Bhakti Park (Wadala) 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 urban area and will be a boom to rural economy.

- **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 n reduced accidents on roads.

- **Traffic Congestion Reduction**

  To meet the forecast transport demand in the year 2026, 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.

- **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.

- **Carbon Credits**

  Due to savings in fuel and reduction in airpollution 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.

- **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.

F. 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 10.14**.

Table 10.14 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	*		

S. No.	Parameter	Negative Impact	No Impact	Positive Impact
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			*

10.23 ANALYSIS OF ALTERNATIVES AND PUBLIC CONSULTATION AND INFORMATION DISCLOSURE

10.23.1 Analysis of Alternatives

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) is incorporated and implementation of Line -3 between Colaba- BKC-Aarey is being 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 have been submitted to MMRDA.An SPV named as Mumbai Metro rail Corporation Ltd. (MMRC) is incorporated and implementation of Line -3 between Colaba- BKC-Aarey is being done by the SPV. MMRDA now intends to implement 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.

10.23.2 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

Consultations were conducted at the early stage of EIA preparation, mostly involving local communities and organizations. Successive consultations shall be conducted by the MMRDA after the initial drafting 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 requirements of funding agencies. All the five principles of information dissemination, information solicitation, integration, co ordination and engagement into dialogue will be incorporated in the consultation process.

10.24 ENVIRONMENTAL MANAGEMENT PLAN

10.24.1 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. 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.

10.24.2 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
- Training and Extension

a) 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 53 trees are likely to be lost due to the project. Three saplings are to be planted for felling a single tree. Hence 159 trees need to be planted. Plantation program will be finalized in consultation with Forest Department and project proponent would provide the funds for compensatory afforestation as per government policy.

b) 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. 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.

c) 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. 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. Sewerage drains 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.

d) 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. 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.

e) 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 State 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. The contractor shall approach only Authorized Recyclers for disposal of Hazardous Waste, under intimation to the MMRDA.

f) 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.

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.

g) 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. already exist 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. 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.

h) 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 insignificant 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.

i) 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.

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.

j) 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 level 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. 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. 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.

k) 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 both corridors. 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, acquisition of service lanes, 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 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.

l) 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 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.

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.

m) 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 sewerage disposal systems 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. At underground stations the water requirement will be app. 100Kld. The water shall be provided from 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.

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 artifical recharge. The total length of the proposed elevated alignment is about 4.5 km and there would be 3 stations. Additionally, there are 8 underground stations. The estimated cost of rain water harvesting for elevated corridor is about 15 lakhs per km and 5.0 lakhs per station. The total cost of rainwater harvesting would be Rs. 82.5 Lakh for elevated section of the corridor.

Tree Protection

There is requirement of felling 53 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. Moreover MMRDA would chalk out the plantation program in close coordination with DFO Mumbai or will get plantation done through Forest Department by making the payment for plantation work including after care for three years. An attempt should 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 DFO. The cost of compensatory afforestation would be Rs.3.18 Lakh @ Rs 2000/- per tree for 159 trees.

n) 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.

10.24.3 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 set of preliminary EMP is presented in **Table 10.15,** 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 established 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 10.15 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 areas sensitive environmentally.	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 effluent from treatment plant	Options for final disposal shall be studied and the suitable disposal route shall be decided carefully to minimize the impact on receiving bodies. As far as possible zero discharge rules may be adopted.	During design stage / and pre construction of treatment plant	Contractor	MMRDA/EMP implementing 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 MSPCB 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

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
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 water	Measures shall be taken to avoid misuse of water. Construction agency shall be instructed accordingly to follow strict procedures while using the water for construction and drinking purpose.	Beginning with and continuing throughout construction	Contractor	MMRDA/EMP 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.	Through out 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	Forest Department	Forest Department
SOCIAL				
Loss of Access	Temporary access should be built at the	During	Contractor	MMRDA/ Traffic

Environmental Impact	Mitigation Measures Taken or To Be Taken	Time Frame	Implementing Organization	Responsible Organization
	interchange and other roads.	construction		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. • 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	During construction	Contractor	MMRDA/ Traffic department
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

10.25 ENVIRONMENTAL MONITORING PLAN

10.25.1 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. 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.

10.25.2 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 10.16.** 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 as reported in Chapter 3. 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 10.16**

TABLE 10.16 CONSTRUCTION STAGE MONITORING SCHEDULE

Item	Parameter	Frequency and Duration	Locations
Air	PM_{10}	2×24hours 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	13 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

10.25.3 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 10.17**. 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 10.17 OPERATION STAGE MONITORING SCHEDULE

Item	Parameter	Frequency and Duration	Locations
Air	PM_{10}	2×24hours Once a monthFor 3years	4 location
Water	Surface,Groundwater quality (IS 10500:1991)	Once a year For 3years	2+1 location
Noise	Noise Level (Leq)	24hours Once a year For 3years	4 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.

10.25.4 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.

10.26 COST ESTIMATES

10.26.1 Summary of Costs

All costs involved in Environmental mitigation and management and monitoring to be put on the account of Mumbai Metro Project corridors**.** A summary of these is presented in **Table 10.18.**

Table 10.18 Environmental Costs

S. No.	ITEM	COST Rs. lakh
1.	Rain Water Harvesting at stations and along alignment	82.50
2.	Air, Noise, vibration, Water, Waste Water, Solid waste, during construction and operation	12.50
3.	Ecological monitoring	5.00
4.	Tree Plantation 159 trees @ Rs.2000/- per tree	3.18
	Total	**103.18**

The social costs have been summarized in Table 10.19.

Table 10.19 Details of Cost of Resettlement and Rehabilitation (Rs. Lakh)

S. No.	Description	Entitlement	Unit	Quantity	Rate	Amount Rs. Lakh
1	Acquisition of Permanent land Private Land	Total Replacement Cost of land *	m^2			
2	Solatium	100% as per Act 30 of 2013.	m^2			
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(FA) Fully Affected	Area equivalent to affected area 20.91 m2 free of cost	Per unit	62		**
4.2	Commercial(FA)	Area equivalent to affected area 20.91 m2 free of cost	Per unit	116		**
5.	Subsistence Allowance a. to all	For a period of one year @Rs.3000/ month	Family	178	0.36	64.08
	b.vulnerable families (SC)	Additional 50000/- each family	Family	54	0.50	27.00
6.	Shifting Allowance	A lump sum shifting allowance of Rs.50,000/-	No.	178	0.50	89.00
7.	One time resettlement allowance	For All the affected families including employees in shops	Per Family	178	0.50	89.00

S. No.	Description	Entitlement	Unit	Quantity	Rate	Amount Rs. Lakh
8	Employees Transportation cost	12 Quarterly passes for differential distance	LS	156		5.00
9.	Independent Evaluation		LS		5.00	5.00
10.	Miscellaneous		LS		5.00	5.00
	Cost of R & R					**373.08**

* Cost of land taken as project cost

**refers the accommodation is available with MMRDA so additional cost is not given.

The compensation for loss of land, fire control, information systems and contractor's obligations have 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.

10.27 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. 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 - 11

MULTI MODAL TRAFFIC INTEGRATION AT METRO STATIONS

11.1 INTRODUCTION

This is extension of Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) at Wadala(Bhakti Park) end. It is being extended from Wadala to CSMT and length of this extension is 12.774 km and is named as Mumbai Metro Line-11. It is partly underground and partly elevated. Total Ten stations have been provided out of which eight are underground and two are elevated.

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.

11.2 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.

11.3 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.

11.4 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.

11.5 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. 2.65 crores 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 -12

FRIENDLY FEATURES FOR DIFFERENTLY ABLED

12.1 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) "Harmonised Guidelines and Space Standards for Barrier Free Built Environment for Persons with Disabled and Elderly Persons", 2016 (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.

12.2 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

12.3 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.

12.4 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.

12.5 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 (Fig. 12.4);
   - 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. 12.1 - Way finding signage

Fig. 12.2 - 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.

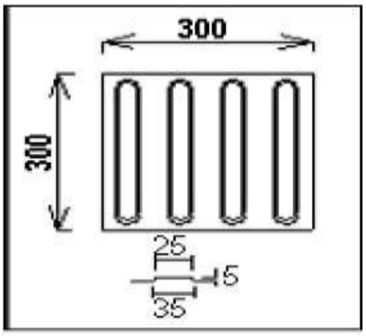


Fig. 12.3 - Guiding paver

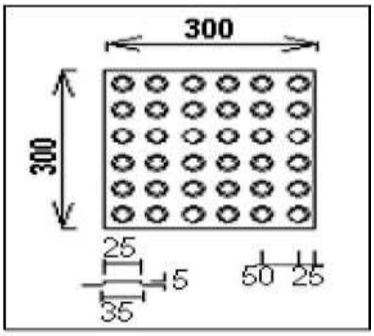


Fig. 12.4 - Warning paver

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 12.1).

Table 12.1 - 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.

12.6 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.

12.7 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. 12.5 - 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.

12.8 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.

12.9 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.

12.10 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.

12.11 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.)

12.12 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.

12.13 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.

12.14 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.

12.15 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.

12.16 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.

12.17 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.

12.18 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.

12.19 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.

12.19.1 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 detectable.
- 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.

12.19.2 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-13

SECURITY MEASURES FOR A METRO RAIL SYSTEM

13.1 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.

13.2 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.

13.3 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.

13.4 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.

13.5 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.

13.6 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 -14

DISASTER MANAGEMENT MEASURE

14.1 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.

14.2 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.

14.3 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.

14.4 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

14.5 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.

14.6 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.

14.7 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.

14.8 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 – 15

COST ESTIMATES

15.1 INTRODUCTION

Project Cost estimates for Mumbai Metro Line No. 11 from Wadala (Bhakti Park) to CSMT Metro has been prepared covering civil, electrical, signaling and telecommunication works, rolling stock, environmental protection, rehabilitation, considering 25 kV AC traction etc. at March 2018 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, whether in underground or elevated or at-grade construction, permanent way, OHE, signaling and telecommunication, have been estimated on rate per route km basis. Cost for underground alignment construction, excludes station length. Station length (260m) has to be done by cut and cover in general and by tunneling under compelling exceptional circumstances. The rates adopted for underground stations include cost of civil structures and architectural finishes. Similarly 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 except for Underground Civil works. A suitable escalation factor has been applied to bring these costs to March 2018 price level. In addition the rates of Civil works of elevated portion have been escalated by 10% to compensate the higher costs in Mumbai compared to Delhi. Rates of Civil works of underground portion are based on recently awarded works for Mumbai Metro Line-3, suitably escalated to March 2018 price level. Taxes & Duties such as Customs Duty, CGST, SGST and IGST wherever applicable, have been worked out on the basis of prevailing rates and included in the cost estimates separately.

The overall Capital Cost of Mumbai Metro Line-11 from Wadala (Bhakti Park) to CSMT Metro at March 2018 price level works out to **Rs. 6135 Crores** excluding applicable Taxes & Duties of **Rs. 950 crores** as tabulated hereunder.

Table 15.1 – Details of Capital Cost

Sr. No.	Name of the section	Capital Cost (Rs. Crore)	Taxes & Duties (Rs. Crore)	Total (Rs. Crore)
1.	Wadala(Bhakti Park) to CSMT Metro	6135	950	7085

Details and methodology of arriving at these costs are discussed in paras hereinafter.

15.2 CIVIL ENGINEERING WORKS

15.2.1 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. For underground and elevated alignment, no land is proposed to be acquired permanently, except small areas for locating entry/ exit structures, traffic integration etc. 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 (Govt. as well as Pvt.) are proposed to be taken over temporarily for construction depots, site office and for cut & cover method of underground station construction. 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 the cost estimate.

15.2.2 Formation and Alignment

Underground section: In the underground section work is proposed to be done by Tunnel Boring Machines, or Cut and Cover method, depending upon the site conditions. Rates adopted for cut and cover section, as well as for work to be done by T.B.M. are based on recently awarded works of Mumbai Metro Line-3, duly updated to March 2018 price level. Cost of mid-section ventilation shaft wherever needed, has also been included.

Elevated section: For elevated viaduct, the rates adopted are based on the completion cost for these works of Phase-II and ongoing Phase-III works, duly updated to March 2018 price level and enhanced by 10% for the higher cost at Mumbai as compared to Delhi.

15.2.3 Stations

Underground Stations: In the underground alignment, station lengths have to be done by cut and cover. Rate proposed for stations (length 260 m) includes Cost of station structures, platforms, architectural finishes, etc, and provisions for electrical and mechanical works, V.A.C., Lifts and Escalators etc., have been made separately. Provisions for O.H.E., P.way, Signaling and Telecommunication, Automatic fare collection installations, etc, have also been summed up in the cost estimates. Rates are based on recently awarded works of Mumbai Metro Line-3, duly updated to March 2018 price level.

Full Height Platform Screen Doors (PSD) are considered for underground stations and its cost is taken as 1.75 times of half height Platform Screen Doors (PSD).

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 been arrived based on Delhi metro Phase-III accepted rates added by 10% more for higher cost at Mumbai compared to Delhi

15.2.4 Permanent way

For underground and 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 March 2018 price level.

15.3 DEPOT

No additional depot has been proposed for this extension. Same depot of Gaimukh to Wadala (Bhakti Park) metro corridor, either at Owale or Gaimukh shall be used for this extension also after due augmentation.

15.4 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.

15.5 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.

15.6 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 underground alignment, elevated and at-grade section (Depot Augmentation) as the requirements are different and costs are more for underground section.

Provisions towards cost of lifts, escalators for underground and elevated stations have been made in the cost estimates. Rates provided are based on cost of similar ongoing Phase-III works duly updated to March 2018 price level.

15.7 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.

15.8 AUTOMATIC FARE COLLECTION

Adopted rates are based on accepted rates for similar work of Phase-II and ongoing Phase-III works duly updated to March 2018 price level.

15.9 ROLLING STOCK

Adopted rates are based on awarded rates of similar works of Mumbai Metro Line-3 duly updated to March 2018 price level.

15.10 SECURITY

A lump sum provision for providing security infrastructure in the station premises has been made on running kilometer basis. Adopted rates are as taken in phase III DPR suitably escalated to current price level.

15.11 MULTIMODAL TRAFFIC INTEGRATION

A lump sum provision of Rs. 2.65 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.

15.12 GENERAL CHARGES AND CONTINGENCES

Provision @ 5% 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.

15.13 CAPITAL COST ESTIMATES

15.13.1 Wadala (Bhakti Park) to CSMT Metro extension of Mumbai Metro Line-4

The overall Capital Cost for Wadala (Bhakti Park) to CSMT Metro (Mumbai Metro Line-11) at March 2018 price level works out to **Rs. 6135 Crores** excluding applicable Taxes & Duties of **Rs. 950 crores** as tabulated hereunder.

Table 15.2 - Capital Cost Estimate

Total length = 12.774 km

Ramp = 0.427 km; UG C&C = 0.236 km; UG TBM = 8.316 km; Elevated = 3.795 km

Total Station =10, Elevated = 2 & UG = 8

March 2018 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	5.154	103.08
b	Private	ha	100.00	0.898	89.80
1.2	Temporary Land (@5% pa for 4 years)	Ha.			
a	Government		4.00	4.877	19.51
b	Private		20.00	0.767	15.34
1.3	**R & R incl. Hutments etc.**	R. Km.	4.12	12.774	52.63
	Subtotal (1)				**280.36**
2.0	**Alignment and Formation**				
2.1	Underground section by T.B.M excluding station length (260m each)	R. Km.	185.95	6.236	1159.58
2.2	Underground section by Cut & Cover excluding station length (260m each)	R. Km.	123.97	0.450	55.79
2.3	Elevated section including station length (Including Cost of Rain Water Harvesting)	R. Km.	44.99	4.009	180.36
2.4	Special Span for crossing Eastern Freeway	LS			10.00
	Subtotal (2)				**1405.74**
3.0	**Station Buildings**				
3.1	Underground Station(260 m length) incl. EM works, lifts, escalators, VAC etc.	Each			
a	Underground Station- Civil works	Each	264.87	8	2118.96
b	Underground Station- EM works etc.	Each	72.68	8	581.44
3.2	Elevated stations(including finishes)	Each			
a	Type (A) way side- civil works	Each	35.44	2	70.88
b	Type (A) way side- EM works including lifts and escalators	Each	9.05	2	18.10
3.3	Providing Platform Screen Doors (PSD)				
a	Half height Platform Screen Doors (PSD) at all Elevated Stations	Each	2.79	4	11.16
b	Full height Platform Screen Doors (PSD) at all Underground Stations	Each	4.88	16	78.08
3.4	OCC bldg.				
a	Civil works	LS			0.00
b	EM works etc	LS			0.00
	Subtotal (3)				**2878.62**
4.0	**Depot Augmentation**	LS			
4.1	Depot				
a	Civil works	LS			7.85
b	EM works	LS			7.00
c	M&P for Rolling stock	LS			2.78
d	Depot 25 kV AC Traction (OHE)	LS			2.00
	Subtotal (4)				**19.63**
5.0	**P-Way**				
5.1	Ballast less track for Elevated and UG section	R. Km.	9.79	12.774	125.06

S. No.	Item	Unit	Rate	Qty.	Amount (Rs. in Cr.)
				Without taxes	
5.2	Ballasted track for Depot	R. Km.	5.38	3.00	16.14
	Subtotal (5)				**141.20**
6.0	**Traction & power supply incl. OHE , ASS etc. Excl. lifts & Escalators**				
6.1	Elevated Section 25 kV AC Traction (OHE) with ASS & Cabling	R.Km.	7.19	4.009	28.82
6.2	Underground Section 25 kV AC Traction (ROCS) with ASS, Cabling	R.Km.	11.15	8.765	97.73
6.3	RSS (GIS)	Each	61.27	1.00	61.27
	Subtotal (6)				**187.82**
7.0	**Signalling and Telecom.**				
7.1	Sig. & Telecom.	R. Km.	12.50	12.774	159.68
7.2	Automatic fare collection	Stn.			
	a) Underground stations	Each	5.36	8	42.88
	b) Elevated stations	Each	6.28	2	12.56
	Subtotal (7)				**215.12**
8.0	**Misc. Utilities, roadworks, other civil works such as median stn. signages Environmental protection**	R. Km.			
a	Civil works	R. Km.	5.14	12.774	65.66
b	EM works**	LS			30.00
	Subtotal (8)				**95.66**
9.0	**Rolling Stock (3.2 m wide Coaches)**	Each	9.00	44	396.00
	Subtotal (9)				**396.00**
10.0	**Capital expenditure on security**				
a	Civil works	R.Km.	0.08	12.774	1.02
b	EM works etc	R.Km.	0.33	12.774	4.22
	Subtotal (10)				**5.24**
11.0	**Staff quarter for O & M**				
a	Civil works	R.Km.	1.99	12.774	25.42
b	EM works etc	R.Km.	0.50	12.774	6.39
	Sub Total (11)				**31.81**
12.0	**Capital expenditure on Multimodal Traffic Integration**				
a	Capital expenditure on Multimodal Integration	Each	2.65	10	26.50
	Sub Total (12)				**26.50**
13.0	**Total of all items except Land**				**5455.96**
14.0	**General Charges incl. Design charges @ 5 % on all items except land#**				**272.80**
15.0	**Total of all items including G. Charges except land**				**5728.76**
16.0	**Contingencies @ 3 %**				**171.86**
17.0	**Gross Total**				**5900.62**
	Cost without land			**=**	**5901**
	Cost with land including contingencies on land			**=**	**6135**

**** For Elevated Portion only**

#In accordance with MoUD's letter F.No.K-14011/58/2013-MRTS-I(Vol.I)

Table 15.3 - Details of Taxes and Duties

Basic Customs duty = 5.1500
CGST Customs Duty = 9.4635
SGST Customs Duty = 9.4635
Total Customs Duty = 24.0770
General IGST = 12
General CGST = 6
General SGST = 6

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties		Total Taxes & Duties (Cr.)
			Total Customs Duty (Cr.)	Total GST (CGST & SGST) (Cr.)	
1	**Alignment & Formation**				
	Underground	1215.37	87.79	102.09	**189.88**
	Elevated	190.36		22.84	**22.84**
2	**Station Buildings**				
	a) Underground station-civil works	2118.96	153.05	177.99	**331.05**
	b) Underground station-EM works	581.44	70.00	34.89	**104.88**
	Elevated station - civil works	70.88		8.51	**8.51**
	Elevated station-EM works	18.10	0.87	1.74	**2.61**
3	**Depot**				
	Civil works	7.85	0.57	0.66	**1.23**
	EM and M&P works	11.78	0.57	1.70	**2.26**
4	**P-Way**	141.20	27.20	5.08	**32.28**
5	**Traction & power supply**				
	Traction and power supply	187.82	18.09	20.29	**38.37**
6	**S and T Works**				
	S & T	159.68	30.76	5.75	**36.50**
	AFC	55.44	10.01	2.49	**12.51**
	PSD	89.24	17.19	3.21	**20.40**
7	**R & R hutments**	52.63		6.32	**6.32**
8	**Misc.**				
	Civil works	111.98	0.00	13.44	**13.44**
	EM works	47.23	0.00	8.50	**8.50**
9	**Rolling stock**	396.00	57.47	5.86	**63.33**
10	**Rent on Temporary Land**	34.85		6.27	**6.27**
11	**General Charges**	272.80		49.10	**49.10**
	Total	**5763.61**	**473.56**	**476.73**	**950.29**
	Total taxes & Duties				**950**
Rate of Taxes & Duties on Total cost without taxes & duties					**16.49%**
Total Central GST & Basic Customs duty					525.79
Total State GST					424.50
Total Taxes & Duties					**950.29**

CHAPTER - 16

FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

16.1 INTRODUCTION

The Mumbai Metro Line-11 Project (Wadala i.e. Bhakti Park to CSMT Metro) is proposed to be constructed at an estimated cost of Rs.7085.00 Crore with all taxes and land cost. The route length of the proposed metro rail system and estimated cost at March 2018 price level without and with all taxes are placed in table 16.1 as under:

Table 16.1 Cost Details

Name of Corridor	Distance (KMs)	Estimated cost without taxes (Rs/Crore)	Estimated cost with all taxes & land cost (Rs/Crore)
Wadala (Bhakti Park) to CSMT Metro	12.774	6135.00	7085.00

The estimated cost at March 2018 price level includes an amount of Rs.5.24 Crore as one-time charges of security personal towards cost of weapons, barricades, and handheld 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.

16.2 COSTS

16.2.1 Investment Cost

16.2.1.1 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 @5% per annum. The taxes and duties consist of Custom Duty (CD), Central Goods and Service Tax (CGST), State Goods and Service Tax (SGST), Integrated Goods and Service Tax (IGST). 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 24.077% {Basic CD @ 5%, IGST (CGST & SGST) @ 18%} on the imported portions, Post-GST on construction of original works of metro project CGST and SGST has been taken @ 6% each while on supply of indigenously manufactured items and services GST has been taken @ 18%. have been considered for working out the estimated taxes and duties. It has been assumed that Maharashtra State Government will provide the land worth

Rs.319 crore on completion cost basis either 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.

It is assumed that the construction work will start on 01.04.2019 and is expected to be completed on 31.03.2024 with Revenue Opening Date (ROD) as 01.04.2024 for the corridors. The total completion costs duly escalated and shown in the table 16.2 have been taken as the initial investment. The cash flow of investments separately is placed in Table –16.2 as below.

Table 16.2 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 March 2018 Price Level	Completion Cost including cost of land cost and all taxes & duties
2019-20	436.00	458.00
2020-21	776.00	856.00
2021-22	1116.00	1292.00
2022-23	1699.00	2065.00
2023-24	1699.00	2168.00
2024-25	1019.00	1366.00
2025-26	340.00	478.00
Total	**7085.00**	**8683.00**

16.2.1.2 Although the construction is expected to get over by 31stMarch 2024, the cash flow spill over up to March 2026 on account of payment normally required to be made to the various contractors up to that period necessitated by contractual clauses.

16.2.1.3 The cost of Land of Rs. 319 crore included in the above completion cost will be provided free of cost by the Maharashtra Government.

16.2.3 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, and
(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 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. 6 per unit which has been used for all calculations. The O&M cost (excluding staff cost) has been obtained by providing an escalation of 5.00% per annum. The O&M costs have been tabulated in Table 16.3 as below:

Table 16.3 Operation and Maintenance Costs

Rs. In Crore

YEAR			Staff	Maintenance etc	Energy	Total
2024	-	2025	34.00	28.87	60.84	123.71
2025	-	2026	37.06	30.31	63.89	131.26
2026	-	2027	40.40	31.82	67.08	139.30
2027	-	2028	44.03	33.42	70.43	147.88
2028	-	2029	47.99	35.09	73.96	157.04
2029	-	2030	52.31	36.84	77.65	166.81
2030	-	2031	57.02	38.68	81.54	177.24
2031	-	2032	62.15	40.62	101.82	204.59
2032	-	2033	67.75	42.65	106.92	217.31
2033	-	2034	73.84	44.78	112.26	230.89
2034	-	2035	80.49	47.02	117.87	245.38
2035	-	2036	87.73	49.37	123.77	260.87
2036	-	2037	95.63	51.84	129.96	277.43
2037	-	2038	104.24	54.43	136.45	295.12
2038	-	2039	113.62	57.15	143.28	314.05
2039	-	2040	123.84	60.01	150.44	334.30
2040	-	2041	134.99	63.01	157.96	355.96
2041	-	2042	147.14	66.16	165.86	379.16
2042	-	2043	160.38	69.47	174.15	404.01
2043	-	2044	174.82	72.94	182.86	430.62
2044	-	2045	190.55	76.59	192.00	459.14
2045	-	2046	207.70	80.42	201.60	489.72
2046	-	2047	226.39	84.44	211.69	522.52
2047	-	2048	246.77	88.66	222.27	557.70
2048	-	2049	268.98	93.10	233.38	595.46
Grand Total			**2879.82**	**1377.69**	**3359.93**	**7617.47**

16.2.4 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.

16.2.5 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.

16.3 REVENUES

The Revenue of Mumbai Metro mainly consists of fare box collection and other incomes from property development, advertisement, parking etc.

16.3.1 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.

16.3.2 Traffic

16.3.2.1 (a) The projected ridership figures years as provided by MMRDA are as indicated in table 16.4 below: -

Table 16.4 Projected Ridership

Financial Year	Trips per day (lakhs)
2024-25	1.65
2031-32	3.51

(b) The growth rate for traffic is assumed @11.35% Per Annum till 2030-31 and @ 2.00% per annum thereafter.

16.3.2.2 Trip Distribution

The trip distribution data provided by MMRDA based on the traffic study conducted by them for the year 2021 for CSMT Metro to Gaimukh including Wadala to CSMT Metro is shown in Table 16.5 below: -

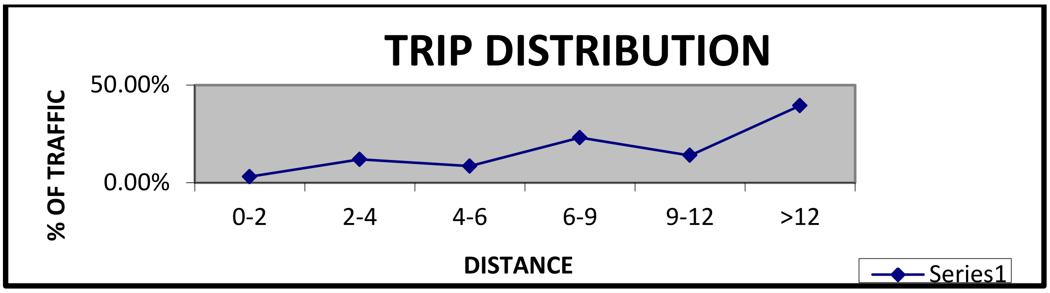
Table 16.5 Trip Distribution

Distance in km	Percent distribution
0-2	3.12%
2-4	11.96%
4-6	8.47%
6-9	23.07%
9-12	13.94%
>12	39.44%
Total	**100.00%**

The above trip distribution has been considered for FIRR calculation for the extension corridor of Wadala to CSMT Metro.

The graphic presentation of the same is placed below in Figure-16.1.

Figure 16.1 –Trip Distribution



16.3.2.3 Fare Structure

The fare structure for the FY 2024-25 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 @14.00% once in every two years. The fare structure for the FY 2024-25 as per the proposed fare slabs is shown in the table 16.6 below:

Table 16.6 Fare Structure in 2024-25

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 2024-25	
SLAB	FARE (Rs)
0-3 Kms	10.00
3-12 Kms	20.00
12-18 Kms	30.00
18Kms and More	40.00

16.3.2.3 Non Fare Box Revenues

Property Business and Advertisement:-Other revenues from Property Business 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.

Additional Property Development Income: - SPV/BOT operator will engage a developer/Concessionaire for generating rental income. It is assumed that about 10 Hectare. i.e., 30,00,000 square feet area will be available for property development with a FAR of 3. The developer will bring equity to the extent of Rs. 165.00 crore and the balance amount towards construction shall be raised by SPV as 12% Market Debt. The current rental revenue in Mumbai City is Rs. 40 per Sq. ft. The estimated development cost will be Rs.663.00 crore. It is assumed that the rental revenue will accrue to the developer from the FY 2025-26 which has been escalated @5% every year. Out of the estimated rental income, apart from meeting maintenance expenditure, the developer will repay the loan and interest. After meeting these obligations and retaining 14% return on his equity with an escalation @5% every year, the residual rental earnings will accrue to SPV, which has been taken into account in the FIRR calculations. The details of PD income accrue to SPV is tabulated as under; -

Table 16.7 Estimated generation of Rental Income from PD

Rs. in Crore

Year			Construction cost	Rental Income	Maintenance Expenditure	Loan	IDC	Loan repayment	Bal Loan Amount	Interest on Loan @12 %	Return @14% to the developer	Residual rental income to SPV
2020	-	2021	120			87	5		92		-33	
2021	-	2022	126			93	11		196		-33	
2022	-	2023	132			99	13		308		-33	
2023	-	2024	139			106	15		429		-33	
2024	-	2025	146			113	17		559		-33	
2025	-	2026		37	4			56	503	67	23	-113
2026	-	2027		51	5			56	447	60	24	-94
2027	-	2028		71	7			56	391	54	25	-71
2028	-	2029		112	11			56	335	47	26	-28
2029	-	2030		188	19			56	279	40	27	46
2030	-	2031		197	20			56	223	33	28	60
2031	-	2032		207	21			56	167	27	29	74
2032	-	2033		217	22			56	111	20	30	89
2033	-	2034		228	23			56	55	13	32	104
2034	-	2035		239	24			55	0	7	34	119
2035	-	2036		251	25						36	190
2036	-	2037		264	26						38	200
2037	-	2038		277	28						40	209
2038	-	2039		291	29						42	220
2039	-	2040		306	31						44	231
2040	-	2041		321	32						46	243
2041	-	2042		337	34						48	255
2042	-	2043		354	35						50	269
2043	-	2044		372	37						53	282
2044	-	2045		390	39						56	295
2045	-	2046		410	41						59	310
2046	-	2047		430	43						62	325
2047	-	2048		452	45						65	342
2048	-	2049		474	47						68	359
Total			**663**	**6476**	**648**	**498**	**61**	**559**		**368**	**820**	**3916**

16.4 FINANCIAL INTERNAL RATE OF RETURN (FIRR)

16.4.1 The Financial Internal Rate of Return (FIRR) without additional property development (PD) and with property development obtained for 30 years business model including construction period is (-) 0.27% and 1.68%.The FIRR with all taxes& duties including land cost without PD and with PD is produced in Table 16.8 and 16.9:-

Table 16.8 –FIRR without additional Property Development

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
2019	-	2020	458				458			0	-458
2020	-	2021	856				856			0	-856
2021	-	2022	1292				1292			0	-1292
2022	-	2023	2065				2065			0	-2065
2023	-	2024	2168				2168			0	-2168
2024	-	2025	1366	0	124		1490	107	11	118	-1372
2025	-	2026	478	0	131		609	119	12	131	-478
2026	-	2027	0	0	139		139	150	15	165	26
2027	-	2028	0	0	148		148	167	17	184	36
2028	-	2029	0	0	157		157	213	21	234	77
2029	-	2030	0	0	167		167	237	47	284	117
2030	-	2031	0	0	177		177	304	61	365	188
2031	-	2032	0	1125	205		1330	339	68	407	-923
2032	-	2033	0	0	217		217	392	78	470	253
2033	-	2034	0	0	231		231	401	80	481	250
2034	-	2035	0	0	245		245	463	93	556	311
2035	-	2036	0	0	261		261	472	94	566	305
2036	-	2037	0	0	277		277	551	110	661	384
2037	-	2038	0	0	295		295	562	112	674	379
2038	-	2039	0	0	314		314	651	130	781	467
2039	-	2040	0	0	334		334	664	133	797	463
2040	-	2041	0	0	356		356	770	154	924	568
2041	-	2042	0	0	379		379	786	157	943	564
2042	-	2043	0	0	404		404	916	183	1099	695
2043	-	2044	0	0	431		431	935	187	1122	691
2044	-	2045	0	0	459	778	1237	1086	217	1303	66
2045	-	2046	0	0	490	817	1307	1108	222	1330	23
2046	-	2047	0	0	523	0	523	1288	258	1546	1023
2047	-	2048	0	0	558	0	558	1314	263	1577	1019
2048	-	2049	0	0	595	0	595	1530	306	1836	1241
Total			**8683**	**1125**	**7617**	**1595**	**19020**	**15525**	**3029**	**18554**	**(-)0.27%**

Table 16.9 –FIRR with additional Property Development

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**
2019	-	2020	458				458			0	-458
2020	-	2021	856				856			0	-856
2021	-	2022	1292				1292			0	-1292
2022	-	2023	2065				2065			0	-2065
2023	-	2024	2168				2168			0	-2168
2024	-	2025	1366	0	124		1490	107	11	118	-1372
2025	-	2026	478	0	131		609	119	-101	18	-591
2026	-	2027	0	0	139		139	150	-79	71	-68
2027	-	2028	0	0	148		148	167	-54	113	-35
2028	-	2029	0	0	157		157	213	-7	206	49
2029	-	2030	0	0	167		167	237	93	330	163
2030	-	2031	0	0	177		177	304	121	425	248
2031	-	2032	0	1125	205		1330	339	142	481	-849
2032	-	2033	0	0	217		217	392	167	559	342
2033	-	2034	0	0	231		231	401	184	585	354
2034	-	2035	0	0	245		245	463	212	675	430
2035	-	2036	0	0	261		261	472	284	756	495
2036	-	2037	0	0	277		277	551	310	861	584
2037	-	2038	0	0	295		295	562	321	883	588
2038	-	2039	0	0	314		314	651	350	1001	687
2039	-	2040	0	0	334		334	664	364	1028	694
2040	-	2041	0	0	356		356	770	397	1167	811
2041	-	2042	0	0	379		379	786	412	1198	819
2042	-	2043	0	0	404		404	916	452	1368	964
2043	-	2044	0	0	431		431	935	469	1404	973
2044	-	2045	0	0	459	778	1237	1086	512	1598	361
2045	-	2046	0	0	490	817	1307	1108	532	1640	333
2046	-	2047	0	0	523	0	523	1288	583	1871	1348
2047	-	2048	0	0	558	0	558	1314	605	1919	1361
2048	-	2049	0	0	595	0	595	1530	665	2195	1600
Total			**8683**	**1125**	**7617**	**1595**	**19020**	**15525**	**6945**	**22470**	**1.68%**

The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in Table 16.10 below : -

Table 16.10 –FIRR with Additional PD Income (Sensitivity Analysis)

Capital Cost with Central Taxes but without land cost			
20% increase in capital cost	**10% increase in capital cost**	**10% decrease in capital cost**	**20% decrease in capital cost**
0.76%	1.20%	2.23%	2.84%
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**
-0.14%	0.83%	2.45%	3.15%
O&M COSTS			
10% increase in O&M cost		**10% decrease in O&M cost**	
1.34%		2.02%	

These sensitivities have been carried out independently for each factor.

16.5 FINANCING OPTIONS

Objectives of Funding: - The objective of funding metro rail systems is not only the availability of funds for construction but coupled with this objective of providing initial finances 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.

16.5.1 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 Central and State Government Control Delhi Metro Rail Corporation (DMRC) /Bangalore Metro Rail Corporation (BMRC)/Chennai Metro Rail Corporation (CMRL) etc.
(ii) Design, Built, Fund, Operate & Transfer (DBFOT), and
(iii) Public Private Partnership

SPV (DMRC/CMRL/BMRC) Model: -The State Government has already formed a fully owned SPV in the name of Mumbai Metro Rail Corporation (MMRC), which is responsible for the implementation of all the metro rail corridors under the Mumbai Metro rail project.

ODA/Multilateral funding Loan: -Overseas Development assistance from Japan International Cooperation Agency (JICA), AFD, KFW, EIB, etc. may be availed of for the Mumbai metro rail projects with interest @ 1.40% to 2.00% 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 Government of Maharashtra. 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. The loan can also be availed from other lending agencies like AFD, KFW, EIB etc whose interest rate is linked with six monthly LIOBOR.

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 0.20% per annum. The tenure of the loan is 40 years with 12 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.4631 crore shall be funded by JICA. In that case there will be no need to borrow from Market Borrowing.

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.

MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2. The funding pattern under this model (SPV) with sharing of overall taxes and duties, post GST in the ratio of 1:2 is placed in table 16.11 as under: -

Table 16.11 Funding pattern under SPV model (with all taxes and land)

(Rs./Crore)

Particulars	**With Taxes & Duties**	
	Amount	**% of contribution**
Equity By GOI	1282.00	15.33%
Equity By GOM	1282.00	15.33%
SD for Overall Taxes by GOM (2/3)	778.00	9.30%
SD for Overall Taxes by GOI (1/3)	391.00	4.67%
1.40% Loan from Multilateral/Overseas Development Agencies or 12% Domestic Market Borrowings	4631.00	55.37%
Total	**8364.00**	**100.00%**
SD for Land by GOM	319.00	
Total	**8683.00**	
PTA for Interest During Construction @1.40% (*) by GOM	56.00	
Grand Total	**8739.00**	

(*) In the case of loan @12% from domestic borrowings, the IDC works out to Rs.416 crore.

Private Participation under SPV: The private participation either for complete provisioning of metro rail or for some unbundled components will form an essential requirement for all metro rail project proposals seeking central financial assistance as per new Metro Policy 2017 issued by Ministry of Housing and Urban Affairs (MH&UA). Hence, it is advisable to include lifts and escalator and AFC system for private participation under the model of Kochi Metro, Nagpur Metro, Noida Metro.

Design, Built, Fund, Operate & Transfer (DBFOT) 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 Equity internal rate of return (EIRR) 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 without additional PD Income and with additional PD Income is placed in table 16.12 and 16.13 tabulated as under: -

**Table 16.12 Funding pattern under DBFOT – (16% EIRR)
(Without additional PD Income)**

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% Of contribution
VGF by GOI	1673.00	20.00%
VGF by GOM	6179.00	73.88%
Equity by Concessionaire	171.00	2.04%
Concessionaire's debt @12% PA	341.00	4.08%
Sub-Total	**8364.00**	**100.00%**
Land Free by GOM	319.00	
Sub-Total	**8683.00**	
IDC	112.00	
Grand Total	**8795.00**	

**Table 16.13 Funding pattern under DBFOT – (16% EIRR)
(With additional PD Income)**

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% Of contribution
VGF by GOI	1673.00	20.00%
VGF by GOM	5966.00	71.33%
Equity by Concessionaire	171.00	2.04%
Concessionaire's debt @12% PA	554.00	6.63%
Sub-Total	**8364.00**	**100.00%**
Land Free by GOM	319.00	
Sub-Total	**8683.00**	
IDC	135.00	
Grand Total	**8818.00**	

Public Private Partnership (PPP) Model: - Under this option, Government funds the fixed infrastructure such as land and basic civil structures, and the private investor funds all the systems such as rolling stock, signalling, power supply, traction, track, fare collection, E&M works etc including station architectural finishes. An example of this is Delhi Metro Airport line. Under this arrangement the government's investment will be about 57% of the cost of the Project and the PPP operator funds the remaining 43%. Under this model the concessionaire, operates and maintains the system to the required and agreed service and safety levels. All the revenues will accrue to the Operator and at the end of the concession period the project is handed over to the owner. Ridership risks are taken by the operator or shared by the operator and owner. The PPP operator pays a specified amount every year to the Govt. out of his revenues. It could be that he may even need a viability gap funding (VGF). The VGF (positive or negative) will be known only after competitive bidding. Based on the experience gained in Delhi Metro Airport line, DMRC does not recommend the proposal on PPP mode.

16.6 RECOMMENDATIONS

The FIRR for the corridors with all taxes and without additional PD income and with additional PD income works out to (-) 0.27% and 1.68%%. However, FIRR is not the only criteria to take up the metro project.

As per Metro Rail Policy 2017, issued by the Ministry of Housing and Urban Affairs, (MOH&UA), GOI, apart from financial viability, the economic and social viability of the project is also required to be assessed. The Economic Internal Rate of Return (EIRR) for any metro rail project proposal should be 14% and above for consideration of its approval. Accordingly, the metro corridors as discussed above are recommended for implementation provided the required EIRR works out to 14% or above.

The total fund contribution of GOI & GOM under various alternatives is tabulated in table 16.14 as under;

Table 16.14

Rs. In crore

Particulars	**SPV Model**	**DBFOT Model without additional PD Income**	**DBFOT Model with additional PD Income**
GOI	1673.00	1673.00	1673.00
GOM	2379.00	6498.00	6285.00
Total	**4052.00**	**8171.00**	**7958.00**

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 16.11. However, the state government may also explore the other sources of revenue from Transit Oriented Development and Value Capture Financing, which will be made available to metro authorities to meet out the O&M Expenses and servicing the debt properly.

The detailed cash flow statements under various alternatives are enclosed as per detail given below:-

Option	Table No.
SPV Model with Multilateral/Bilateral Loan	16.15
SPV Model with Multilateral/Bilateral Loan with Additional PD Income	16.16
SPV Model with Market Borrowings	16.17
SPV Model with Market Borrowings with Additional PD Income	16.18
DBFOT Model	16.19
DBFOT Model with Additional PD Income	16.20

The funding pattern assumed under SPV model with Multilateral / Bilateral Loan / Market Borrowing and DBFOT model with additional PD income is depicted in the pie chart i.e., Figure 16.2.1 &16.2.2 as under: -

Figure 16.2.1 - Funding pattern under SPV Model

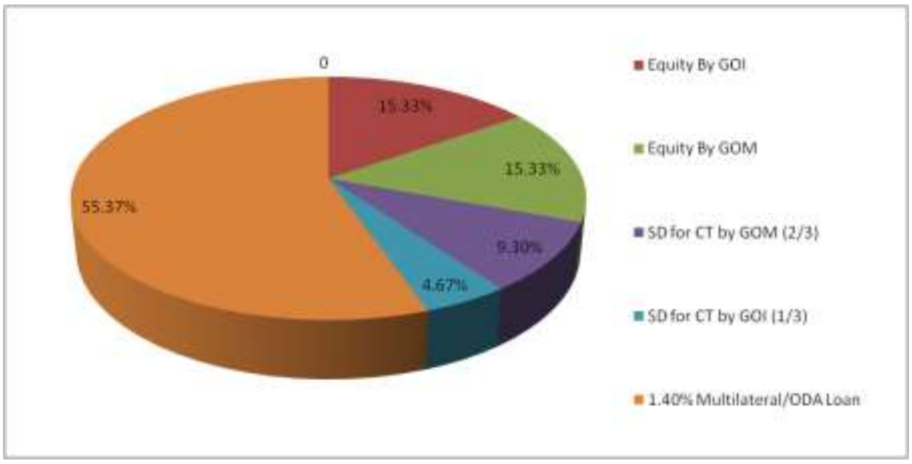


Figure 16.2.2- Funding pattern under DBFOT Model with additional PD income

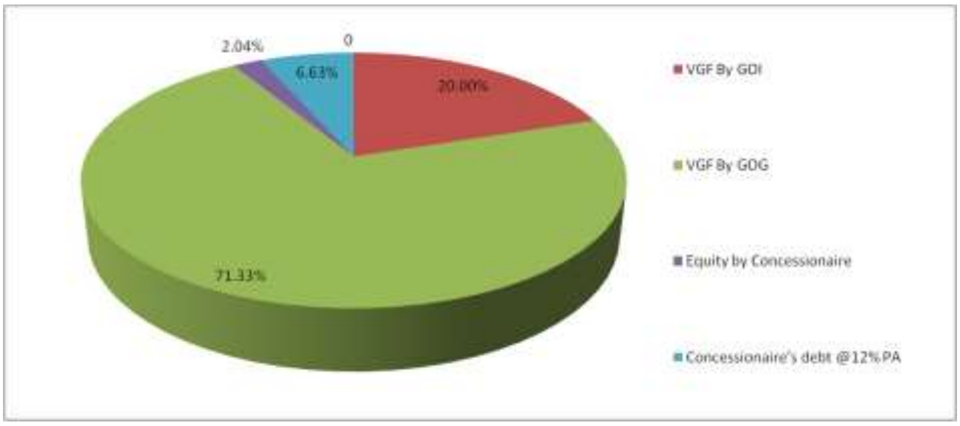


Table 16.15

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085
CAPITAL COST - CURRENT 8683
DOMESTIC FUNDING - BASE CASE

Multilateral Loan 1.40% 100.00% 1.40%
Front end Fee (one time) 0.20% 1.40%

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
2019 - 2020	458					458			0	-458	614	156	156	0	0	0	0	0				
2020 - 2021	856					856			0	-856	853	-3	153	0	0	0	0	0				
2021 - 2022	1292					1292			0	-1292	859	-433	-280	280	280	0	11	291				
2022 - 2023	2065					2065			0	-2065	747	-1318	-1598	1598	1318	0	13	1622				
2023 - 2024	2168					2168			0	-2168	746	-1422	-3020	3020	1422	0	32	3076				
2024 - 2025	1366	0	124	262		1490	107	11	118	-1372	233	-1133	-4153	4153	1133	0		4209	51	-319	-57	-57
2025 - 2026	478	0	131	262		609	119	12	131	-478		-478	-4631	4631	478	0		4687	62	-325	-63	-119
2026 - 2027	0	0	139	262		139	150	15	165	26		0	-4631	4631	0	0		4687	66	-302	-40	-159
2027 - 2028	0	0	148	262		148	167	17	184	36		0	0	0	0	0		4687	66	-291	-29	-189
2028 - 2029	0	0	157	262		157	213	21	234	77		0	0	0	0	0		4687	66	-251	11	-177
2029 - 2030	0	0	167	262		167	237	47	284	117		0	0	0	0	156		4531	66	-210	-105	-282
2030 - 2031	0	0	177	262		177	304	61	365	188		0	0	0	0	156		4375	63	-138	-32	-314
2031 - 2032	0	1125	205	296		1330	339	68	407	-923		0	0	0	0	156		4218	61	-155	-1140	-1454
2032 - 2033	0	0	217	296		217	392	78	470	253		0	0	0	0	156		4062	59	-102	37	-1417
2033 - 2034	0	0	231	296		231	401	80	481	250		0	0	0	0	156		3906	57	-103	37	-1380
2034 - 2035	0	0	245	296		245	463	93	556	311		0	0	0	0	156		3750	55	-40	100	-1280
2035 - 2036	0	0	261	296		261	472	94	566	305		0	0	0	0	156		3593	52	-43	96	-1183
2036 - 2037	0	0	277	296		277	551	110	661	384		0	0	0	0	156		3437	50	37	177	-1006
2037 - 2038	0	0	295	296		295	562	112	674	379		0	0	0	0	156		3281	48	35	175	-832
2038 - 2039	0	0	314	296		314	651	130	781	467		0	0	0	0	156		3125	46	125	265	-567
2039 - 2040	0	0	334	296		334	664	133	797	463		0	0	0	0	156		2968	44	123	263	-304
2040 - 2041	0	0	356	296		356	770	154	924	568		0	0	0	0	156		2812	42	230	370	66
2041 - 2042	0	0	379	296		379	786	157	943	564		0	0	0	0	156		2656	39	228	368	434
2042 - 2043	0	0	404	296		404	916	183	1099	695		0	0	0	0	156		2500	37	362	502	936
2043 - 2044	0	0	431	296		431	935	187	1122	691		0	0	0	0	156		2344	35	360	500	1436
2044 - 2045	0	0	459	319	778	1237	1086	217	1303	66		0	0	0	0	156		2187	33	492	-123	1313
2045 - 2046	0	0	490	344	817	1307	1108	222	1330	23		0	0	0	0	156		2031	31	466	-164	1149
2046 - 2047	0	0	523	344	0	523	1288	258	1546	1023		0	0	0	0	156		1875	28	651	839	1988
2047 - 2048	0	0	558	344	0	558	1314	263	1577	1019		0	0	0	0	156		1719	26	649	837	2825
2048 - 2049	0	0	595	344	0	595	1530	306	1836	1241		0	0	0	0	156		1562	24	872	1060	3885
	8683	**1125**	**7617**	**7377**	**1595**	**19020**	**15525**	**3029**	**18554**	**-0.27%**	**4052**				**4631**	**3125**	**56**		**1207**	**2353**	**3885**	
										-466												

Table 16.16

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085
CAPITAL COST - CURRENT 8683
DOMESTIC FUNDING - BASE CASE

Multilateral Loan 1.40% 100.00% 1.40%
Front end Fee (one time) 0.20% 1.40%

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
2019 - 2020	458					458			0	-458	614	156	156	0	0	0	0	0				
2020 - 2021	856					856			0	-856	853	-3	153	0	0	0	0	0				
2021 - 2022	1292					1292			0	-1292	859	-433	-280	280	280	0	11	291				
2022 - 2023	2065					2065			0	-2065	747	-1318	-1598	1598	1318	0	13	1622				
2023 - 2024	2168					2168			0	-2168	746	-1422	-3020	3020	1422	0	32	3076				
2024 - 2025	1366	0	124	262		1490	107	11	118	-1372	233	-1133	-4153	4153	1133	0		4209	51	-319	-57	-57
2025 - 2026	478	0	131	262		609	119	-101	18	-591		-478	-4631	4631	478	0		4687	62	-438	-176	-232
2026 - 2027	0	0	139	262		139	150	-79	71	-68		0	-4631	4631	0	0		4687	66	-396	-134	-366
2027 - 2028	0	0	148	262		148	167	-54	113	-35		0	0	0	0	0		4687	66	-362	-100	-467
2028 - 2029	0	0	157	262		157	213	-7	206	49		0	0	0	0	0		4687	66	-279	-17	-483
2029 - 2030	0	0	167	262		167	237	93	330	163		0	0	0	0	156		4531	66	-164	-59	-542
2030 - 2031	0	0	177	262		177	304	121	425	248		0	0	0	0	156		4375	63	-78	28	-514
2031 - 2032	0	1125	205	296		1330	339	142	481	-849		0	0	0	0	156		4218	61	-81	-1066	-1580
2032 - 2033	0	0	217	296		217	392	167	559	342		0	0	0	0	156		4062	59	-13	126	-1454
2033 - 2034	0	0	231	296		231	401	184	585	354		0	0	0	0	156		3906	57	1	141	-1313
2034 - 2035	0	0	245	296		245	463	212	675	430		0	0	0	0	156		3750	55	79	219	-1094
2035 - 2036	0	0	261	296		261	472	284	756	495		0	0	0	0	156		3593	52	147	286	-807
2036 - 2037	0	0	277	296		277	551	310	861	584		0	0	0	0	156		3437	50	237	377	-430
2037 - 2038	0	0	295	296		295	562	321	883	588		0	0	0	0	156		3281	48	244	384	-47
2038 - 2039	0	0	314	296		314	651	350	1001	687		0	0	0	0	156		3125	46	345	485	438
2039 - 2040	0	0	334	296		334	664	364	1028	694		0	0	0	0	156		2968	44	354	494	932
2040 - 2041	0	0	356	296		356	770	397	1167	811		0	0	0	0	156		2812	42	473	613	1545
2041 - 2042	0	0	379	296		379	786	412	1198	819		0	0	0	0	156		2656	39	483	623	2168
2042 - 2043	0	0	404	296		404	916	452	1368	964		0	0	0	0	156		2500	37	631	771	2939
2043 - 2044	0	0	431	296		431	935	469	1404	973		0	0	0	0	156		2344	35	642	782	3721
2044 - 2045	0	0	459	319	778	1237	1086	512	1598	361		0	0	0	0	156		2187	33	787	172	3893
2045 - 2046	0	0	490	344	817	1307	1108	532	1640	333		0	0	0	0	156		2031	31	776	146	4039
2046 - 2047	0	0	523	344	0	523	1288	583	1871	1348		0	0	0	0	156		1875	28	976	1164	5203
2047 - 2048	0	0	558	344	0	558	1314	605	1919	1361		0	0	0	0	156		1719	26	991	1179	6382
2048 - 2049	0	0	595	344	0	595	1530	665	2195	1600		0	0	0	0	156		1562	24	1231	1419	7801
	8683	**1125**	**7617**	**7377**	**1595**	**19020**	**15525**	**6945**	**22470**	**1.68%**	**4052**				**4631**	**3125**	**56**		**1207**	**6269**	**7801**	
										3450												

Table 16.17

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085
CAPITAL COST - CURRENT 8683
DOMESTIC FUNDING - BASE CASE

MB 12% 100.00% 12.00%
Multilateral Loan 1.40% 0.00% 0.00%
Front end Fee (one time) 0.20% 12.00%
Tenure of JICA Loan 10+30 Years

Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Income from cess on Property Tax & Stamp Duty	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	24
2019 - 2020	458					458				0	-458	614	156	156	0	0	0	0	0				
2020 - 2021	856					856				0	-856	853	-3	153	0	0	0	0	0				
2021 - 2022	1292					1292				0	-1292	859	-433	-280	280	280	0	26	306				
2022 - 2023	2065					2065				0	-2065	747	-1318	-1598	1598	1318	0	113	1737				
2023 - 2024	2168					2168				0	-2168	746	-1422	-3020	3020	1422	0	277	3436				
2024 - 2025	1366	0	124	273		1490	107	11	0	118	-1372	233	-1133	-4153	4153	1133	0		4569	480	-759	-486	-486
2025 - 2026	478	0	131	273		609	119	12	0	131	-478		-478	-4631	4631	478	0		5047	577	-850	-577	-1063
2026 - 2027	0	0	139	273		139	150	15	0	165	26		0	-4631	4631	0	0		5047	606	-853	-580	-1643
2027 - 2028	0	0	148	273		148	167	17	0	184	36		0	0	0	0	0		5047	606	-843	-570	-2213
2028 - 2029	0	0	157	273		157	213	21	0	234	77		0	0	0	0	0		5047	606	-802	-529	-2741
2029 - 2030	0	0	167	273		167	237	47	0	284	117		0	0	0	0	168		4879	606	-761	-657	-3398
2030 - 2031	0	0	177	273		177	304	61	0	365	188		0	0	0	0	168		4711	585	-671	-566	-3964
2031 - 2032	0	1125	205	307		1330	339	68	0	407	-923		0	0	0	0	168		4542	565	-670	-1656	-5620
2032 - 2033	0	0	217	307		217	392	78	0	470	253		0	0	0	0	168		4374	545	-599	-461	-6081
2033 - 2034	0	0	231	307		231	401	80	0	481	250		0	0	0	0	168		4206	525	-582	-443	-6524
2034 - 2035	0	0	245	307		245	463	93	0	556	311		0	0	0	0	168		4038	505	-501	-362	-6886
2035 - 2036	0	0	261	307		261	472	94	0	566	305		0	0	0	0	168		3869	485	-486	-348	-7234
2036 - 2037	0	0	277	307		277	551	110	0	661	384		0	0	0	0	168		3701	464	-388	-249	-7483
2037 - 2038	0	0	295	307		295	562	112	0	674	379		0	0	0	0	168		3533	444	-372	-233	-7716
2038 - 2039	0	0	314	307		314	651	130	0	781	467		0	0	0	0	168		3365	424	-264	-125	-7841
2039 - 2040	0	0	334	307		334	664	133	0	797	463		0	0	0	0	168		3196	404	-248	-109	-7951
2040 - 2041	0	0	356	307		356	770	154	0	924	568		0	0	0	0	168		3028	384	-123	16	-7934
2041 - 2042	0	0	379	307		379	786	157	0	943	564		0	0	0	0	168		2860	363	-107	32	-7902
2042 - 2043	0	0	404	307		404	916	183	0	1099	695		0	0	0	0	168		2692	343	45	184	-7719
2043 - 2044	0	0	431	307		431	935	187	0	1122	691		0	0	0	0	168		2524	323	61	200	-7518
2044 - 2045	0	0	459	330	778	1237	1086	217	0	1303	66		0	0	0	0	168		2355	303	211	-405	-7924
2045 - 2046	0	0	490	355	817	1307	1108	222	0	1330	23		0	0	0	0	168		2187	283	203	-428	-8351
2046 - 2047	0	0	523	355	0	523	1288	258	0	1546	1023		0	0	0	0	168		2019	262	406	593	-7758
2047 - 2048	0	0	558	355	0	558	1314	263	0	1577	1019		0	0	0	0	168		1851	242	422	609	-7150
2048 - 2049	0	0	595	355	0	595	1530	306	0	1836	1241		0	0	0	0	168		1682	222	663	850	-6299
	8683	**1125**	**7617**	**7652**	**1595**	**19020**	**15525**	**3029**	**0**	**18554**	**-0.27%**	**4052**				**4631**	**3365**	**416**		**11151**	**-7867**	**-6299**	
											-466												

Table 16.18

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085
CAPITAL COST - CURRENT 8683
DOMESTIC FUNDING - BASE CASE

MB	12%	100.00%	12.00%
Multilateral Loan	1.40%	0.00%	0.00%
Front end Fee (one time)	0.20%		12.00%
Tenure of JICA Loan	10+30 Years		

Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Income from cess on Property Tax & Stamp Duty	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	24
2019 - 2020	458					458				0	-458	614	156	156	0	0	0	0	0				
2020 - 2021	856					856				0	-856	853	-3	153	0	0	0	0	0				
2021 - 2022	1292					1292				0	-1292	859	-433	-280	280	280	0	26	306				
2022 - 2023	2065					2065				0	-2065	747	-1318	-1598	1598	1318	0	113	1737				
2023 - 2024	2168					2168				0	-2168	746	-1422	-3020	3020	1422	0	277	3436				
2024 - 2025	1366	0	124	273		1490	107	11	0	118	-1372	233	-1133	-4153	4153	1133	0		4569	480	-759	-486	-486
2025 - 2026	478	0	131	273		609	119	-101	0	18	-591		-478	-4631	4631	478	0		5047	577	-963	-690	-1176
2026 - 2027	0	0	139	273		139	150	-79	0	71	-68		0	-4631	4631	0	0		5047	606	-947	-674	-1850
2027 - 2028	0	0	148	273		148	167	-54	0	113	-35		0	0	0	0	0		5047	606	-914	-641	-2491
2028 - 2029	0	0	157	273		157	213	-7	0	206	49		0	0	0	0	0		5047	606	-830	-557	-3047
2029 - 2030	0	0	167	273		167	237	93	0	330	163		0	0	0	0	168		4879	606	-715	-611	-3658
2030 - 2031	0	0	177	273		177	304	121	0	425	248		0	0	0	0	168		4711	585	-611	-506	-4164
2031 - 2032	0	1125	205	307		1330	339	142	0	481	-849		0	0	0	0	168		4542	565	-596	-1582	-5746
2032 - 2033	0	0	217	307		217	392	167	0	559	342		0	0	0	0	168		4374	545	-510	-372	-6118
2033 - 2034	0	0	231	307		231	401	184	0	585	354		0	0	0	0	168		4206	525	-478	-339	-6457
2034 - 2035	0	0	245	307		245	463	212	0	675	430		0	0	0	0	168		4038	505	-382	-243	-6700
2035 - 2036	0	0	261	307		261	472	284	0	756	495		0	0	0	0	168		3869	485	-296	-158	-6858
2036 - 2037	0	0	277	307		277	551	310	0	861	584		0	0	0	0	168		3701	464	-188	-49	-6907
2037 - 2038	0	0	295	307		295	562	321	0	883	588		0	0	0	0	168		3533	444	-163	-24	-6931
2038 - 2039	0	0	314	307		314	651	350	0	1001	687		0	0	0	0	168		3365	424	-44	95	-6836
2039 - 2040	0	0	334	307		334	664	364	0	1028	694		0	0	0	0	168		3196	404	-17	122	-6715
2040 - 2041	0	0	356	307		356	770	397	0	1167	811		0	0	0	0	168		3028	384	120	259	-6455
2041 - 2042	0	0	379	307		379	786	412	0	1198	819		0	0	0	0	168		2860	363	148	287	-6168
2042 - 2043	0	0	404	307		404	916	452	0	1368	964		0	0	0	0	168		2692	343	314	453	-5716
2043 - 2044	0	0	431	307		431	935	469	0	1404	973		0	0	0	0	168		2524	323	343	482	-5233
2044 - 2045	0	0	459	330	778	1237	1086	512	0	1598	361		0	0	0	0	168		2355	303	506	-110	-5344
2045 - 2046	0	0	490	355	817	1307	1108	532	0	1640	333		0	0	0	0	168		2187	283	513	-118	-5461
2046 - 2047	0	0	523	355	0	523	1288	583	0	1871	1348		0	0	0	0	168		2019	262	731	918	-4543
2047 - 2048	0	0	558	355	0	558	1314	605	0	1919	1361		0	0	0	0	168		1851	242	764	951	-3593
2048 - 2049	0	0	595	355	0	595	1530	665	0	2195	1600		0	0	0	0	168		1682	222	1022	1209	-2383
	8683	**1125**	**7617**	**7652**	**1595**	**19020**	**15525**	**6945**	**0**	**22470**	**1.68%**	**4052**				**4631**	**3365**	**416**		**11151**	**-3951**	**-2383**	
											3450												

Table 16.19

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085 MB 12% 100.00% 12.00%

CAPITAL COST - CURRENT 514 0.00% 100.00% 0.00%

DOMESTIC FUNDING - BASE CASE 12.00%

Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Income from cess on Property Tax & Stamp Duty	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	25
2019 - 2020	121					121				0	-121	34	-87	-87	87	87	0	5	92					-34
2020 - 2021	122					122				0	-122	34	-88	-175	175	88	0	16	196					-34
2021 - 2022	81					81				0	-81	34	-47	-222	222	47	0	24	267					-34
2022 - 2023	102					102				0	-102	34	-68	-290	290	68	0	31	366					-34
2023 - 2024	48					48				0	-48	35	-13	-303	303	13	0	36	415					-35
2024 - 2025	31	0	124	19		155	107	11	0	118	-37	0	-31	-334	334	31	0		446	52	-76	-57	-57	-57
2025 - 2026	7	0	131	19		138	119	12	0	131	-7		-7	-341	341	7	0		453	54	-73	-54	-112	-54
2026 - 2027	0	0	139	19		139	150	15	0	165	26		0	-341	341	0	0		453	54	-48	-29	-140	-29
2027 - 2028	0	0	148	19		148	167	17	0	184	36		0	0	0	0	0		453	54	-37	-18	-158	-18
2028 - 2029	0	0	157	19		157	213	21	0	234	77		0	0	0	0	0		453	54	4	23	-136	23
2029 - 2030	0	0	167	19		167	237	47	0	284	117		0	0	0	0	15		438	54	44	48	-88	48
2030 - 2031	0	0	177	19		177	304	61	0	365	188		0	0	0	0	15		423	53	116	120	32	120
2031 - 2032	0	1125	205	53		1330	339	68	0	407	-923		0	0	0	0	15		408	51	99	-988	-956	-988
2032 - 2033	0	0	217	53		217	392	78	0	470	253		0	0	0	0	15		393	49	151	189	-768	189
2033 - 2034	0	0	231	53		231	401	80	0	481	250		0	0	0	0	15		378	47	150	188	-580	188
2034 - 2035	0	0	245	53		245	463	93	0	556	311		0	0	0	0	15		362	45	212	250	-330	250
2035 - 2036	0	0	261	53		261	472	94	0	566	305		0	0	0	0	15		347	43	209	247	-83	247
2036 - 2037	0	0	277	53		277	551	110	0	661	384		0	0	0	0	15		332	42	289	327	244	327
2037 - 2038	0	0	295	53		295	562	112	0	674	379		0	0	0	0	15		317	40	286	324	568	324
2038 - 2039	0	0	314	53		314	651	130	0	781	467		0	0	0	0	15		302	38	376	414	981	414
2039 - 2040	0	0	334	53		334	664	133	0	797	463		0	0	0	0	15		287	36	373	411	1393	411
2040 - 2041	0	0	356	53		356	770	154	0	924	568		0	0	0	0	15		272	34	481	519	1911	519
2041 - 2042	0	0	379	53		379	786	157	0	943	564		0	0	0	0	15		257	33	478	516	2427	516
2042 - 2043	0	0	404	53		404	916	183	0	1099	695		0	0	0	0	15		242	31	611	649	3076	649
2043 - 2044	0	0	431	53		431	935	187	0	1122	691		0	0	0	0	15		227	29	609	647	3724	647
2044 - 2045	0	0	459	76	778	1237	1086	217	0	1303	66		0	0	0	0	15		211	27	741	24	3747	24
2045 - 2046	0	0	490	101	817	1307	1108	222	0	1330	23		0	0	0	0	15		196	25	714	-17	3730	-17
2046 - 2047	0	0	523	101	0	523	1288	258	0	1546	1023		0	0	0	0	15		181	24	899	985	4715	985
2047 - 2048	0	0	558	101	0	558	1314	263	0	1577	1019		0	0	0	0	15		166	22	897	982	5697	982
2048 - 2049	0	0	595	101	0	595	1530	306	0	1836	1241		0	0	0	0	15		151	20	1120	1206	6903	1206
	512	**1125**	**7617**	**1302**	**1595**	**10849**	**15525**	**3029**	**0**	**18554**	**14.79%**	**171**				**341**	**302**	**112**		**1012**	**8623**	**6903**		**16.17%**
											7705													

Table 16.20

Mumbai Metro Line Wadla (Bhakti Park) to CSMT

CAPITAL COST-FIXED 7085 MB 12% 100.00% 12.00%
CAPITAL COST - CURRENT 727 0.00% 100.00% 0.00%
DOMESTIC FUNDING - BASE CASE 12.00%

Year	Completion Cost	Additional Capital	Running Expenses	Depreciation	Replacement Cost	Total Cost	Fare box Revenue	PD & Advertisement	Income from cess on Property Tax & Stamp Duty	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	25
2019 - 2020	128					128				0	-128	34	-94	-94	94	94	0	6	100					-34
2020 - 2021	139					139				0	-139	34	-105	-199	199	105	0	18	223					-34
2021 - 2022	110					110				0	-110	34	-76	-275	275	76	0	28	327					-34
2022 - 2023	79					79				0	-79	34	-45	-320	320	45	0	36	408					-34
2023 - 2024	182					182				0	-182	35	-147	-467	467	147	0	47	602					-35
2024 - 2025	67	0	124	26		191	107	11	0	118	-73	0	-67	-534	534	67	0		669	76	-108	-82	-82	-82
2025 - 2026	20	0	131	26		151	119	-101	0	18	-133		-20	-554	554	20	0		689	81	-221	-195	-277	-195
2026 - 2027	0	0	139	26		139	150	-79	0	71	-68		0	-554	554	0	0		689	83	-177	-151	-428	-151
2027 - 2028	0	0	148	26		148	167	-54	0	113	-35		0	0	0	0	0		689	83	-144	-118	-545	-118
2028 - 2029	0	0	157	26		157	213	-7	0	206	49		0	0	0	0	0		689	83	-60	-34	-579	-34
2029 - 2030	0	0	167	26		167	237	93	0	330	163		0	0	0	0	23		666	83	55	58	-521	58
2030 - 2031	0	0	177	26		177	304	121	0	425	248		0	0	0	0	23		643	80	142	145	-377	145
2031 - 2032	0	1125	205	60		1330	339	142	0	481	-849		0	0	0	0	23		620	77	139	-949	-1325	-949
2032 - 2033	0	0	217	60		217	392	167	0	559	342		0	0	0	0	23		597	74	207	244	-1081	244
2033 - 2034	0	0	231	60		231	401	184	0	585	354		0	0	0	0	23		574	72	222	259	-821	259
2034 - 2035	0	0	245	60		245	463	212	0	675	430		0	0	0	0	23		551	69	301	338	-484	338
2035 - 2036	0	0	261	60		261	472	284	0	756	495		0	0	0	0	23		528	66	369	406	-78	406
2036 - 2037	0	0	277	60		277	551	310	0	861	584		0	0	0	0	23		505	63	460	497	420	497
2037 - 2038	0	0	295	60		295	562	321	0	883	588		0	0	0	0	23		482	61	467	504	924	504
2038 - 2039	0	0	314	60		314	651	350	0	1001	687		0	0	0	0	23		459	58	569	606	1530	606
2039 - 2040	0	0	334	60		334	664	364	0	1028	694		0	0	0	0	23		436	55	579	616	2146	616
2040 - 2041	0	0	356	60		356	770	397	0	1167	811		0	0	0	0	23		413	52	699	736	2881	736
2041 - 2042	0	0	379	60		379	786	412	0	1198	819		0	0	0	0	23		390	50	709	746	3627	746
2042 - 2043	0	0	404	60		404	916	452	0	1368	964		0	0	0	0	23		367	47	857	894	4522	894
2043 - 2044	0	0	431	60		431	935	469	0	1404	973		0	0	0	0	23		345	44	869	906	5428	906
2044 - 2045	0	0	459	83	778	1237	1086	512	0	1598	361		0	0	0	0	23		322	41	1015	297	5725	297
2045 - 2046	0	0	490	108	817	1307	1108	532	0	1640	333		0	0	0	0	23		299	39	1004	272	5996	272
2046 - 2047	0	0	523	108	0	523	1288	583	0	1871	1348		0	0	0	0	23		276	36	1205	1290	7286	1290
2047 - 2048	0	0	558	108	0	558	1314	605	0	1919	1361		0	0	0	0	23		253	33	1220	1305	8591	1305
2048 - 2049	0	0	595	108	0	595	1530	665	0	2195	1600		0	0	0	0	23		230	30	1461	1546	10137	1546
	725	**1125**	**7617**	**1477**	**1595**	**11062**	**15525**	**6945**	**0**	**22470**	**14.92%**	**171**				**554**	**459**	**135**		**1536**	**11840**	**10137**		**16.25%**
											11408													

CHAPTER – 17

ECONOMIC APPRAISAL

17.0 ALIGNMENT DESCRIPTION AND ISSUES

Traffic study was conducted for CSMT to Gaimukh Metro Corridor and ridership was estimated. Revenue earning length of the entire section is 47.764 km. In the present chapter, the section namely Wadala(Bhakti Park)-CSMT Metro (Line-11, length 12.774 km), which is an extended part of the Metro Line 4 (Wadala to Gaimukh) is considered for the economic appraisal. Traffic input will be the boarding on the stations within the section and the passenger km travelled within the section. All other parameter values will remain unchanged.

At March-2018 price level estimated cost with all taxes, duties & land cost (Rs/Crore) is derived as Rs. 7446 Cr. which is the sum of different cost components such as Civil Construction, Rolling Stock, Electrical Work, Signalling, Electronics and telecommunication equipments, land cost etc. Recurring costs include Power consumption, Staff Cost and Other Maintenances. These are distributed year wise known as cost stream. Details may be seen in the Financial appraisal chapter.

17.1 INTRODUCTION TO ECONOMIC APPRAISAL METHODOLOGY

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 17.1**) 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 the fuel and vehicle maintenance cost which are estimated from market cost. Economic factors which are used for each component are also given in table 17.1. Overall economic value of benefit components is 100% of the estimated value.

Table 17.1: 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	100%
5	Annual Vehicle Operating Cost Saved by Metro Passengers	100%
6	Emission Saving Cost	100%
7	Accident Cost	100%

	Cost/Benefit Components	Economic Factors
8	Annual Time Cost Saved by Road Passengers	100%
9	Annual Fuel Cost Saved by Road Passengers	100%
10	Annual Infra Structure Maintenance Cost	100%

17.2 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 17.2.

Table 17.2: Values adopted for some important variables

	Values	Important variables
1	Rs. 1.50/min (2017 value)	Weighted value of Time is taken from Line-7 DPR
2	Market rate of fuel cost	Adopted value of Petrol, Diesel and CNG.(table 17.3 bottom row)
3	Table 17.3	Vehicle Operating Cost per km (Derived from Life Cycle Cost of different passenger vehicles)
4	Table 17.4	Emission (gm/km as per CPCB and UK Norms) Emission Saving Cost (adopted for Indian conditions in Rs/ton).
5	Table 17.5	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	13.26%	Passenger km – Vehicle km conversion factor derived from House Hold Survey and Modal Split survey within study area
7	Graph 17.1	Fuel Consumption of vehicles at a given speed is derived from Road User Cost Study Model (CRRI-2010)
8	Rs. 1.0/vehicle km	Infra Structure Maintenance Cost is derived from published values on annual expenditure on roads and traffic and annual vehicle km
9	3.59 min/km	Average Time Saved for average trip length (km) journey after Shifting (Derived from modal split -Table 17.7 and speed and delay survey) and then multiplied by mode wise journey discomfort factor
10	24.54 kmph	Average Journey Speed (Speed and delay Survey)

Table 17.3: 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 charge is taken as Rs. 8 per KWH.

Table 17.4 Journey Time, VOC and Time Cost

Mode	Initial Fare	Running Fare	VOC /passenger km (Rs.)	Time Cost /passenger km (Rs.)
Bus	10	0.5	0.66	0.826
Train	10	0.1	0.05	1.042
Two Wh.	10	2	1.67	1.291
Four Wh.	25	12.5	5.69	9.326
Three Wh.	20	10	2.60	9.358
Private Bus & Others	10	0.6	0.70	0.885

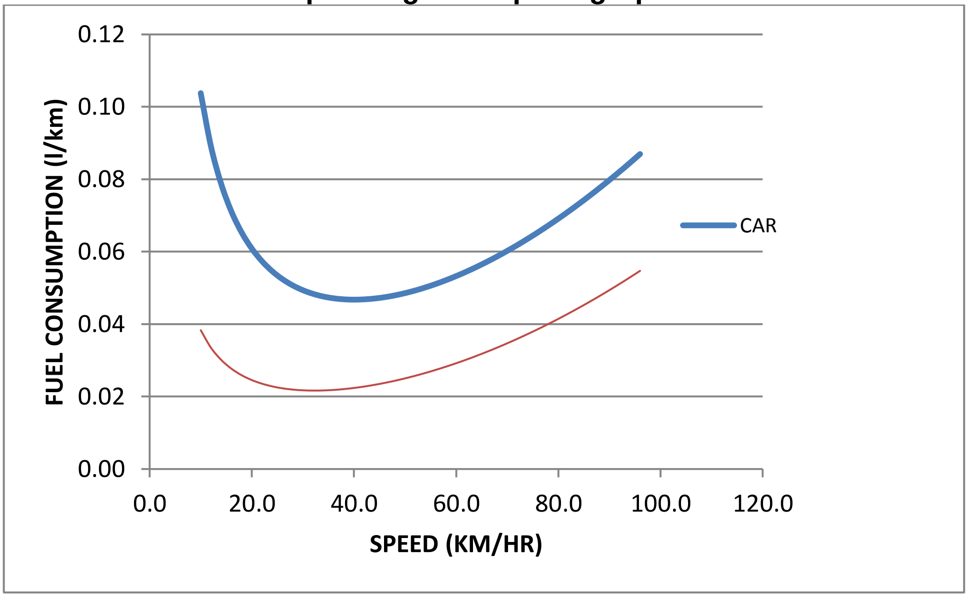
Table 17.5: Vehicle Emission 2011-2021(CPCB) and Cost in Rs.

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 17.6: 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 17.1 Fuel Consumption/against speed graph for Car and two wheeler



Traffic demand estimates used for economic analysis are given in tables 17.7.

Table 17.7: Summary of the Ridership for Mumbai Line 4 Extension (Wadala to CSMT Metro)

Particulars	2024	2031	2041
Trips/day	165000	351000	428000
Section Length	12.77	12.77	12.77
Average Trip length	9.06	8.42	8.42
Passenger km	1495017	2953911	3601920
Passenger km/km	117073	231316	282061

Source: Traffic Study Report

In this area, public transport system is good (passenger - train 27.64%, Bus 49.90%). Personalised mode passenger (car and two wheelers)-trips are 18.09% and IPT modes are carrying 4.37% passengers. Vehicular trips made by Public modes is 12% and 15% by IPT modes and 73% are private transport.*(Source: Comprehensive Transportation Study for Mumbai Metropolitan Region, April 2008, Lea Associates-derived from table 3-2)*. 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% and the share is shown in table 17.8.

Table 17.8 Mode Share in the Study Area

Modes	Vehicle	Passenger
Bus	7.53%	39.92%
Train	0.07%	27.64%
Two Wh.	37.63%	7.49%
Four Wh.	35.11%	10.60%
Three Wh.	14.96%	4.37%
Private Bus & Others	4.70%	9.98%
	100.00%	100.00%

17.3 ECONOMIC BENEFIT STREAM

For deriving the values of economic indicators (EIRR, NPV, BCR), cost and benefit stream table is constructed in terms of money value. Socio-Economic Benefits are first quantified and converted in to money cost. Tables 17.9, show components of benefit values (economic).

Table 17.9 Stream of Economic Benefit Values for MUMBAI Line 11 (Wadala to CSMT Metro)

From	To	Annual Time Cost Saved by Metro Passengers in Cr. Rs.	Annual Fuel Cost Saved by Metro Passengers in Cr. Rs.	Annual Vehicle O&M 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
2024	2025	461	34	60	3	0.5	19	0.30	8	586
2025	2026	547	38	70	3	0.6	22	0.34	9	690
2026	2027	649	41	81	4	0.6	26	0.39	10	813
2027	2028	770	46	95	4	0.7	31	0.44	12	958
2028	2029	913	50	110	5	0.9	36	0.50	14	1130
2029	2030	1083	56	128	6	1.0	42	0.91	16	1333
2030	2031	1285	61	148	7	1.1	50	1.03	19	1572
2031	2032	1525	68	174	8	1.3	59	1.17	22	1859
2032	2033	1656	71	189	9	1.4	66	1.24	24	2017
2033	2034	1799	73	206	9	1.5	73	1.30	26	2189
2034	2035	1955	75	223	10	1.6	81	1.37	28	2376
2035	2036	2123	78	243	11	1.7	90	1.44	31	2578
2036	2037	2307	80	264	12	1.9	100	1.52	33	2799
2037	2038	2506	83	286	13	2.0	110	1.59	36	3038
2038	2039	2722	86	311	14	2.2	122	1.67	39	3299
2039	2040	3084	92	349	16	2.4	140	1.90	44	3729
2040	2041	3494	98	392	18	2.7	159	2.16	49	4215
2041	2042	3959	104	440	20	2.9	181	2.46	55	4765
2042	2043	4485	111	494	23	3.3	207	2.80	62	5388
2043	2044	5081	119	554	25	3.6	236	3.18	70	6092
2044	2045	5757	127	622	28	4.0	269	3.61	78	6889
2045	2046	6523	135	698	32	4.5	307	4.11	88	7791
2046	2047	7390	144	783	36	5.0	350	4.67	99	8811
2047	2048	8372	154	879	40	5.5	399	5.31	111	9966
2048	2049	9486	164	986	45	6.1	455	6.03	124	11273

17.4 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 central tax and yearly escalation cost applied on fixed cost. Analysis period is taken from 2019-20 to 2048-49 out of which 5 years (2019-2023) are marked as construction period. In 2044-46 major repairing and replacement cost is envisaged. Operation is expected to start in 2024-25 (5th Year).

Cost stream generated are shown in **Table 17.10.**

Table 17.10: Completion Cost stream

		Completion Cost	
Year	Year	Capital Cost	Recurring Cost
Start	Ending	Cr. Rs.	Cr. Rs
2019	2020	458	0
2020	2021	856	0
2021	2022	1292	0
2022	2023	2065	0
2023	2024	2168	0
2024	2025	1366	124
2025	2026	478	131
2026	2027	0	139
2027	2028	0	148
2028	2029	0	157
2029	2030	0	167
2030	2031	0	177
2031	2032	1125	205
2032	2033	0	217
2033	2034	0	231
2034	2035	0	245
2035	2036	0	261
2036	2037	0	277
2037	2038	0	295
2038	2039	0	314
2039	2040	0	334
2040	2041	0	356
2041	2042	0	379
2042	2043	0	404
2043	2044	0	431
2044	2045	778	459
2045	2046	817	490
2046	2047	0	523
2047	2048	0	558
2048	2049	0	595

17.5 ECONOMIC PERFORMANCE INDICATORS

After generating the cost and benefit stream table, values of economic indicators are derived and are given in **Table 17.11.** Project period is 2019-2048,

On the basis of **completion** cost, EIRR is **14.93%,** B/C Ratio is 5.10 and NPV is 77134 Cr, which shows that the project is economically viable. With 12 % discount, EIRR (completion cost) is **2.62%** and B/C ratio is 1.3. NPV is Rs 2641 Cr.

Table 17.11: Economic Indicator Values

WADALA-CSMT Metro	(Completion Cost Basis)	
	WITHOUT DISCOUNT	WITH DISCOUNT (12%)
Cumulative cost (Cr.)	19020	7547.48
Cumulative benefit(Cr.)	96155	10188
Benefit Cost Ratio	5.1	1.3
NPV(Cr.)	77134	2641
EIRR	14.93%	2.62%

17.6 SENSITIVITY ANALYSIS FOR WADALA-CSMT METRO

Sensitivity of EIRR and B/C ratios both with and without discount was carried out and the output is given in the **table 17.12** (Completion Cost basis). 2048-49 is taken for the year of comparison.

Table 17.12 Sensitivity of EIRR (Completion Cost)

SENSITIVITY		WITHOUT DISCOUNT			WITH DISCOUNT		
TRAFFIC	COST	EIRR	B/C	COST	EIRR	B/C	COST
0%	0%	14.93%	5.06	19020	2.62%	1.35	7547.48
-10%	0%	14.07%	4.64	19020	1.85%	1.24	7547.48
-20%	0%	13.15%	4.21	19020	1.03%	1.13	7547.48
0%	10%	13.97%	4.60	20923	1.76%	1.23	8302.22
0%	20%	13.12%	4.21	22825	1.00%	1.12	9056.97
-10%	10%	13.14%	4.21	20923	1.01%	1.13	8302.22
-20%	20%	11.42%	3.51	22825	-0.52%	0.94	9056.97

Sensitivity analysis in **table 17.12** 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 11.42%.

17.7 QUANTIFIED BENEFITS

Benefits which are shown in previous tables are money value of the benefits. These benefits are first quantified and then converted into money value. For brevity, only 5 year estimates (2024-2028) are shown in **table 17.13** (Reduction of Vehicle gas Emission). It is seen that reduction of CO2 will be 11328 tons in 2024 and particulate matters (PM) is reduced by 6.7 tons in 2024.

Table 17.13 Environmental Benefits Quantified

Tons/Year	2024	2025	2026	2027	2028
CO	111	121	133	145	158
HC	25	27	29	32	35
NOX	60	66	72	78	85
PM	6.7	7.3	8.0	8.7	9.5
SO2	0.38	0.42	0.45	0.50	0.54
CO2	11328	12356	13478	14702	16037
Total Emission Saved	11531	12578	13720	14966	16324

From **Table 17.14**, it may be seen that in 2024, due to shifting, metro passengers time saving will be 2.64 Cr. (10 million) hour, fuel saving by metro passengers will be 5.53 thousand tons. Amount of travel in terms of passenger km reduced due to shifting to Metro Rail is 2.08 thousand KM which is equivalent to reduction of 3851 vehicles from the road. About 1.67 fatal accidents and 12.16 other accidents may be avoided. Hence it is expected that there will be some improvement of the overall ambience of the area.

Table 17.14 Travel Benefits Quantified

Quantified Benefits in Horizon Years	2024	2025	2026	2027	2028
Annual Time Saved by Metro Passengers in Cr. Hr.	2.64	2.94	3.27	3.65	4.06
Annual Fuel Saved by Metro Passengers in thousand Tons.	5.53	6.10	6.72	7.42	8.19
Daily vehicles reduced (off the road)	3851	4200	4582	4998	5452
CO2 reduced in thousand tons	11.33	12.36	13.48	14.70	16.04
Other gases reduced in thousand tons	0.203	0.222	0.242	0.264	0.288
Reduced No of Fatal Accidents in Year	1.67	1.80	1.95	2.10	2.27
Reduced No of Other Accidents in year	12.16	13.12	14.16	15.29	16.50
Annual Vehicle km Reduced in Thousand Km.	2.08	2.27	2.48	2.70	2.95

CHAPTER – 18

IMPLEMENTATION

18.1 INTRODUCTION

Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) is already under implementation. It is South-West extension of this Line to Chhatrapati Shivaji Maharaj Terminus (CSMT) Metro at Wadala (Bhakti Park) end. Length of this extension is 12.774km, out of which 8.765 km is underground and remaining 4.009 km is elevated. There are total 10 stations out of which 2 are elevated and 8 are underground.

Estimated Cost of the project at March 2018 price level is Rs. 7085 crores inclusive of all taxes & duties and land cost. Completion cost with all taxes & duties and land cost and escalation at 5% p.a. is estimated to be Rs. 8683 Crores.

MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2.

18.2 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.

18.3 THE RECOMMENDED FINANCIAL MODEL FOR LINE-11 FROM WADALA (BHAKTI PARK) TO CSMT METRO

World over Metro projects cannot be financially viable and depend upon generous concessions and subsidies. The financial internal rate of return for this corridor with all taxes and without additional PD income and with additional PD income works out to **(-) 0.27% and 1.68%%.**

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 km 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 this Line (Line-11).

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.

18.4 INSTITUTIONAL ARRANGEMENTS

The State Govt. of Maharashtra will have to approve the implementation of the project by Mumbai Metropolitan Region Development Authority (MMRDA).

18.5 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) and Swami Samarth Nagar to Vikhroli (EEH) Corridor has been handed over to DMRC on a turnkey basis for implementation. Similarly, the this Line may be handed over to DMRC 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.

18.6 CONTRACT PACKAGES FOR IMPLEMENTATION OF THE PROJECT

The project may be implemented in ten packages as under.

Package –1: Underground section starting from chainage -530m (Dead End of CSMT Metro Station) to null point of ramp excluding Underground Stations.

Package - 2: Elevated section starting from Null point of ramp to chainage 12244.115 m (450m before Center line of Wadala (Bhakti Park) Station) including Elevated Stations.

Package – 3&4: Underground Stations in 2 packages of 4 stations each by Cut and Cover Method.

Package - 5: Detailed design consultant for corridor including augmentation of Depot.

Package - 6: Augmentation of Depot such as construction of stabling lines etc.

Package – 7: System Contracts: Supply and installation of traction power system (3rd bay) including sub-station.

Package – 8: Supply and installation of signaling system (CBTC)

Package - 9: Supply and installation of AFC System.

Package - 10: Supply and commissioning of rolling stock.

Any other small package may be decided at the time of implementation of the Project.

18.7 IMPLEMENTATION SCHEDULE

A suggested project implementation schedule for Project Implementation is given in Table 18.1

Table 18.1 Project Implementation Schedule

Sl. No.	Item of Work	Completion Date
1	Submission of Final DPR to State Govt.	D
2	Approval of DPR by State Government	D+0.5 month
3	Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+1 month
4.	Sanction of Project by GOI	D+2 months
5.	Selection of GC	D+12 months
6.	Tendering	D+24 months
7.	Implementation of the project	D+58 months
8.	Testing and Commissioning	D+59 months
9.	CMRS Sanction	D+60 months
10.	ROD	D+60 months

18.8 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.

18.9 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.
- GST on all indigenously manufactured rolling stock and other indigenously finished goods required for the project.
- GST on all purchases made for implementation of the project whether directly by the project implementation authority or by the contractors executing the project.
- GST 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 State Goods and Services Tax (SGST) to this Metro project. It should also exempt the following:

MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2. Maharashtra State Government may pursue the Central government to extend the same benefit to MMRDA.

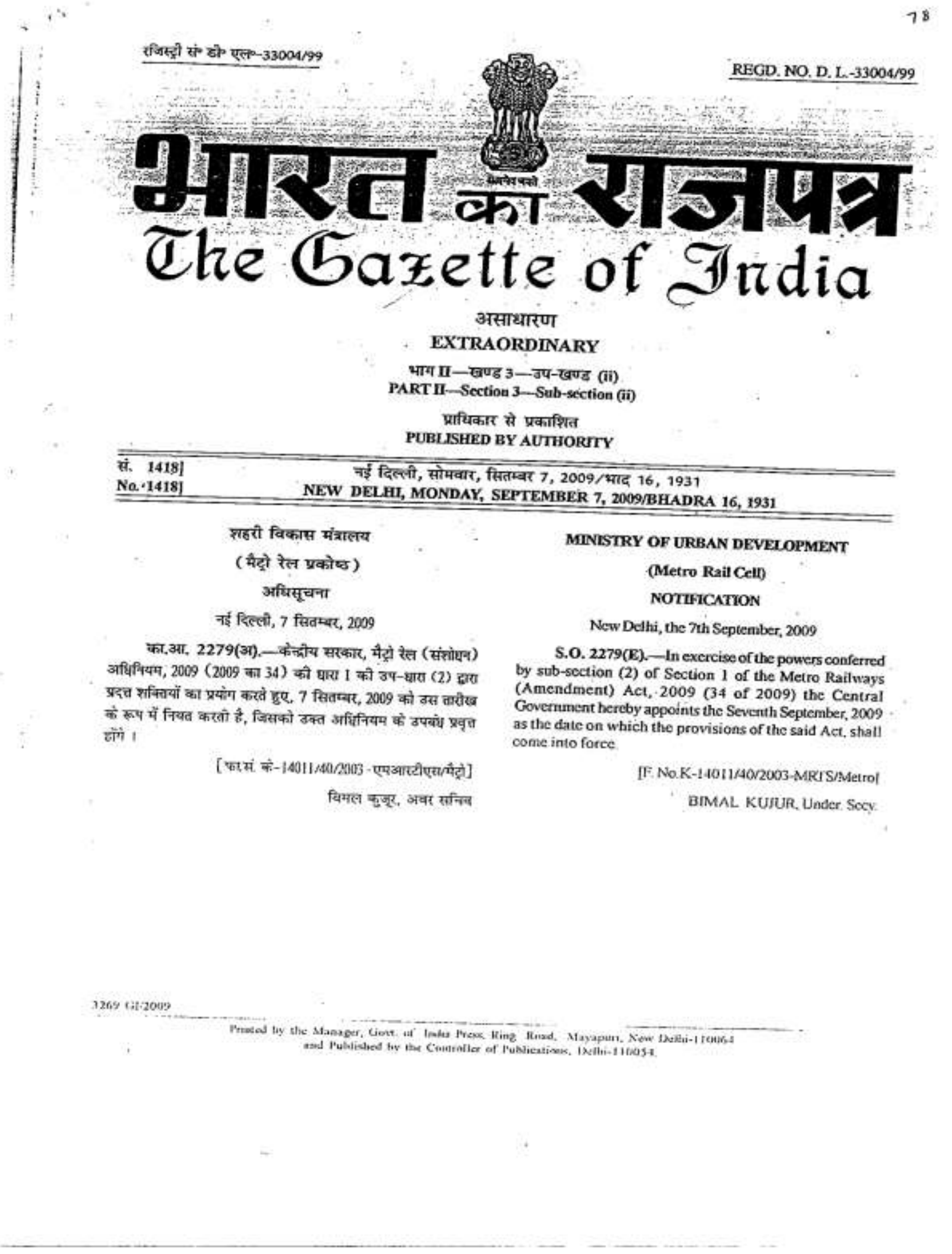
In the case of Delhi Metro project, the Union Government has granted exemption from payment of Custom Duty and Excise Duty while the Delhi Government has agreed to give exemption from payment of Sales Tax and on works contracts. Delhi

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.

18.10 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.



रजिस्ट्री सं॰ डी॰ एल॰-33004/99

REGD. NO. D. L.-33004/99

भारत का राजपत्र
The Gazette of India

असाधारण

EXTRAORDINARY

भाग II—खण्ड 3—उप-खण्ड (ii)

PART II—Section 3—Sub-section (ii)

प्राधिकार से प्रकाशित

PUBLISHED BY AUTHORITY

सं. 1418] नई दिल्ली, सोमवार, सितम्बर 7, 2009/भाद्र 16, 1931

No. 1418] **NEW DELHI, MONDAY, SEPTEMBER 7, 2009/BHADRA 16, 1931**

शहरी विकास मंत्रालय

(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

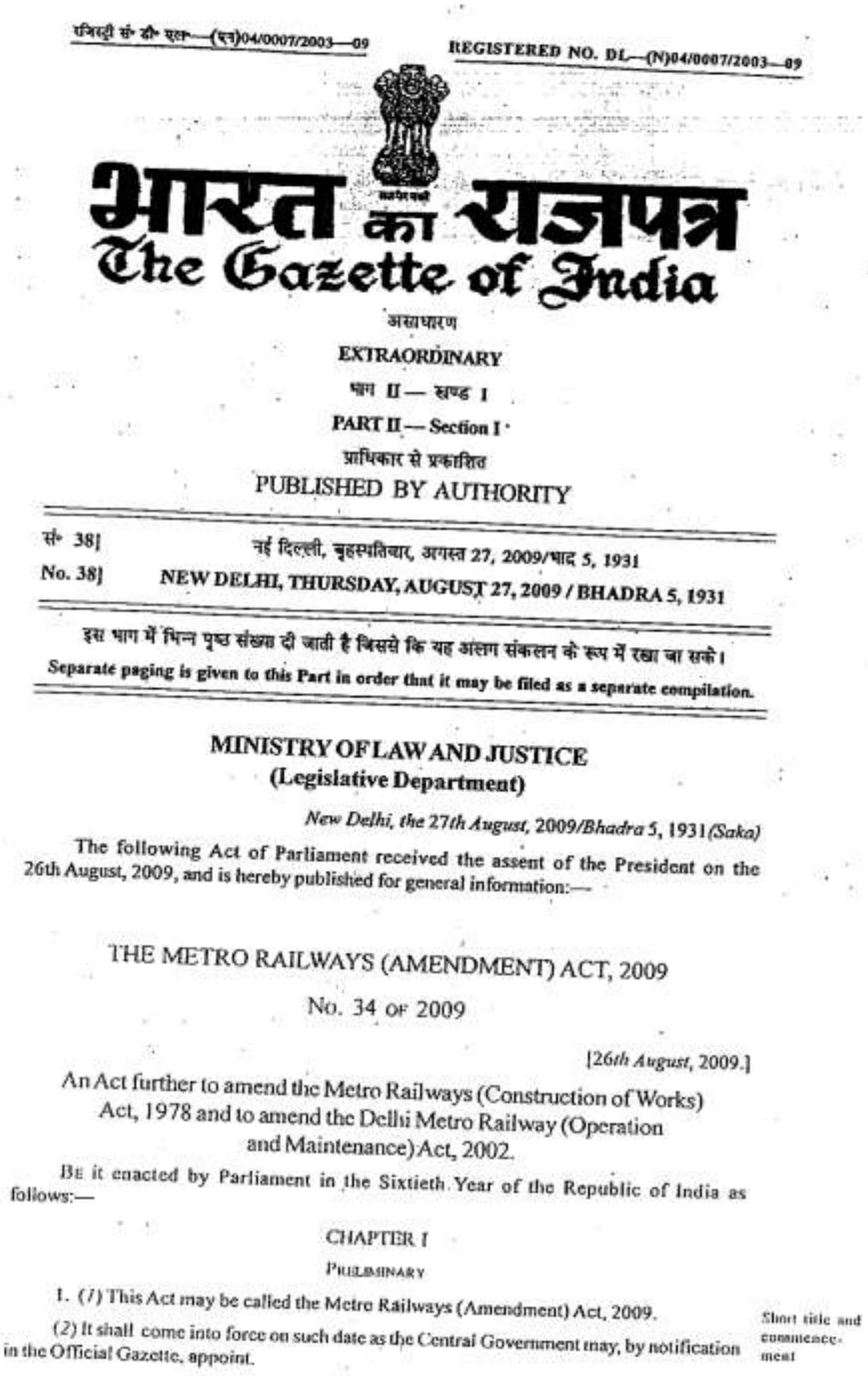
S.O. 2279(E).—In exercise of the powers conferred by sub-section (2) of Section 1 of the Metro Railways (Amendment) Act, 2009 (34 of 2009) the Central Government hereby appoints the Seventh September, 2009 as the date on which the provisions of the said Act, shall come into force.

[F. No. K-14011/40/2003-MRTS/Metro]

BIMAL KUJUR, Under Secy.

3269 GI/2009

Printed by the Manager, Govt. of India Press, Ring Road, Mayapuri, New Delhi-110064
and Published by the Controller of Publications, Delhi-110054.



रजिस्ट्री सं॰ डी॰ एल॰—(एन)04/0007/2003—09 REGISTERED NO. DL—(N)04/0007/2003—09

भारत का राजपत्र
The Gazette of India

असाधारण
EXTRAORDINARY
भाग II — खण्ड 1
PART II — Section I
प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

सं॰ 38] नई दिल्ली, बृहस्पतिवार, अगस्त 27, 2009/भाद्र 5, 1931
No. 38] NEW DELHI, THURSDAY, AUGUST 27, 2009 / BHADRA 5, 1931

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

[26*th 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.

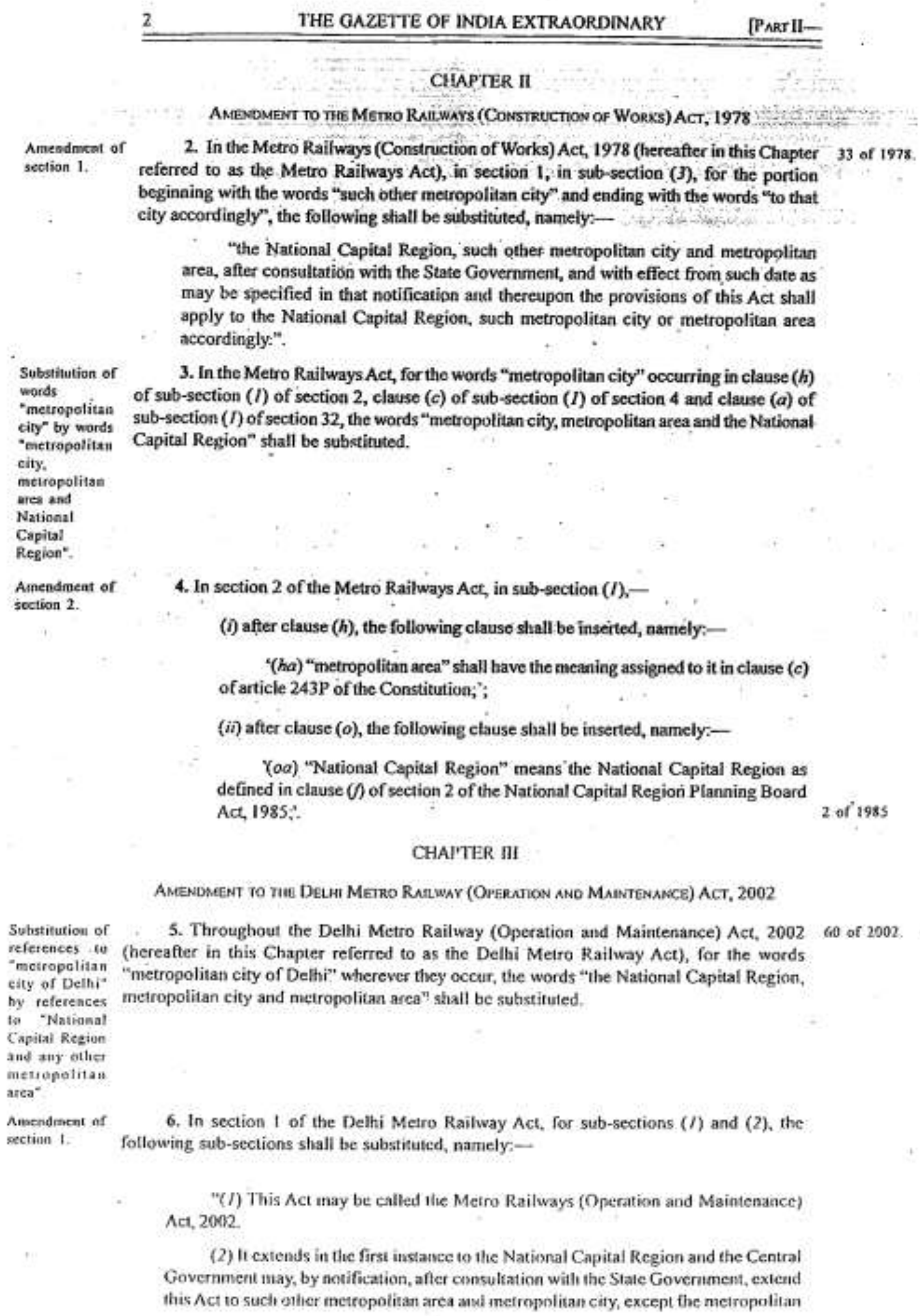
BE it enacted by Parliament in the Sixtieth Year of the Republic of India as follows:—

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.



2 THE GAZETTE OF INDIA EXTRAORDINARY [PART II—

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

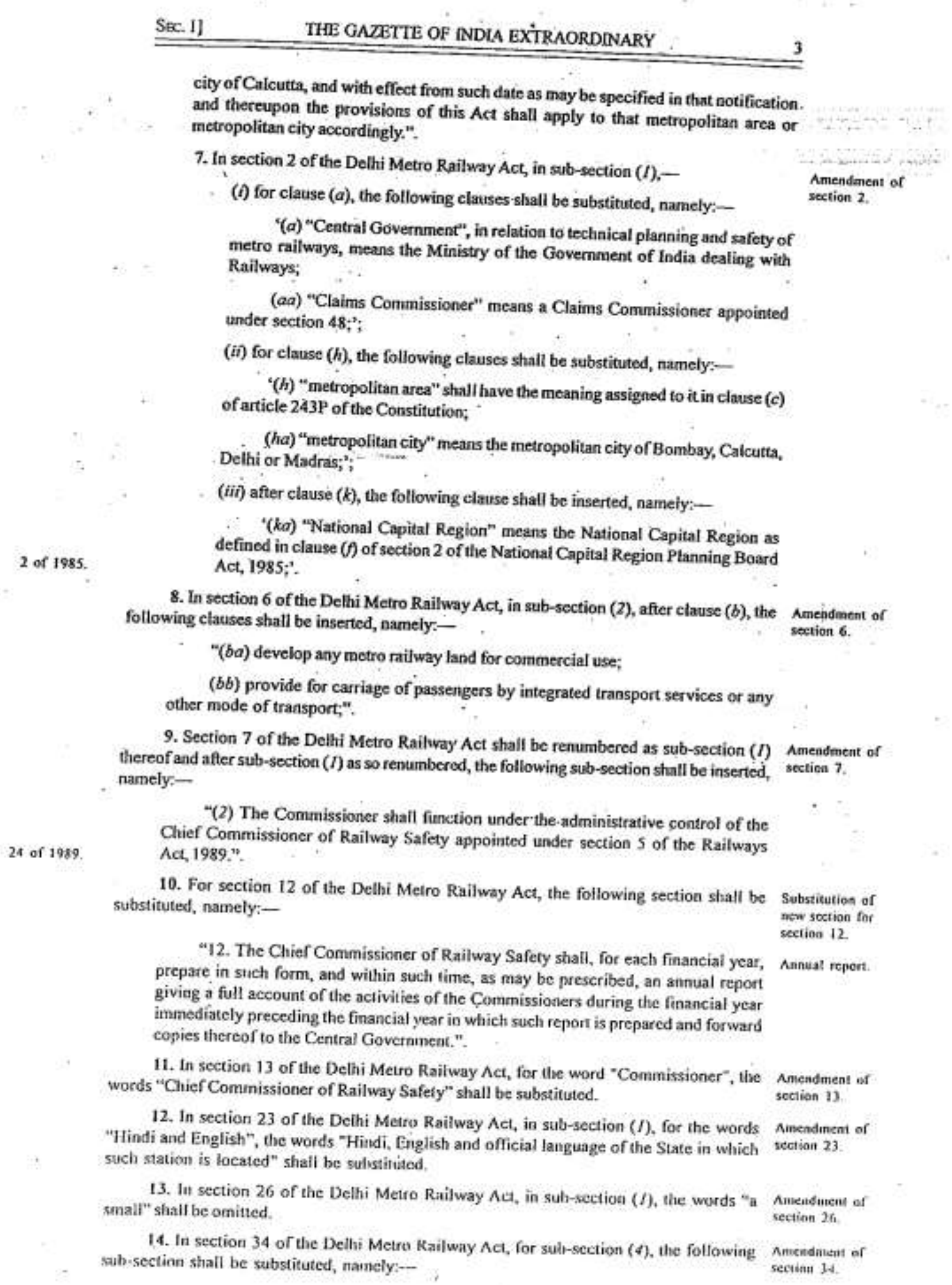
Substitution of references to "metropolitan city of Delhi" by references to "National Capital Region and any other metropolitan area"

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



SEC. 1] THE GAZETTE OF INDIA EXTRAORDINARY 3

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.".

Amendment of section 2.

7. In section 2 of the Delhi Metro Railway Act, in sub-section (*1*),—

(*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:—

'(*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;'. 2 of 1985.

Amendment of section 6.

8. In section 6 of the Delhi Metro Railway Act, in sub-section (*2*), after clause (*b*), the following clauses shall be inserted, namely:—

"(*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;".

Amendment of section 7.

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:—

"(*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.". 24 of 1989.

Substitution of new section for section 12.

10. For section 12 of the Delhi Metro Railway Act, the following section shall be substituted, namely:—

Annual report.

"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.".

Amendment of section 13.

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 23.

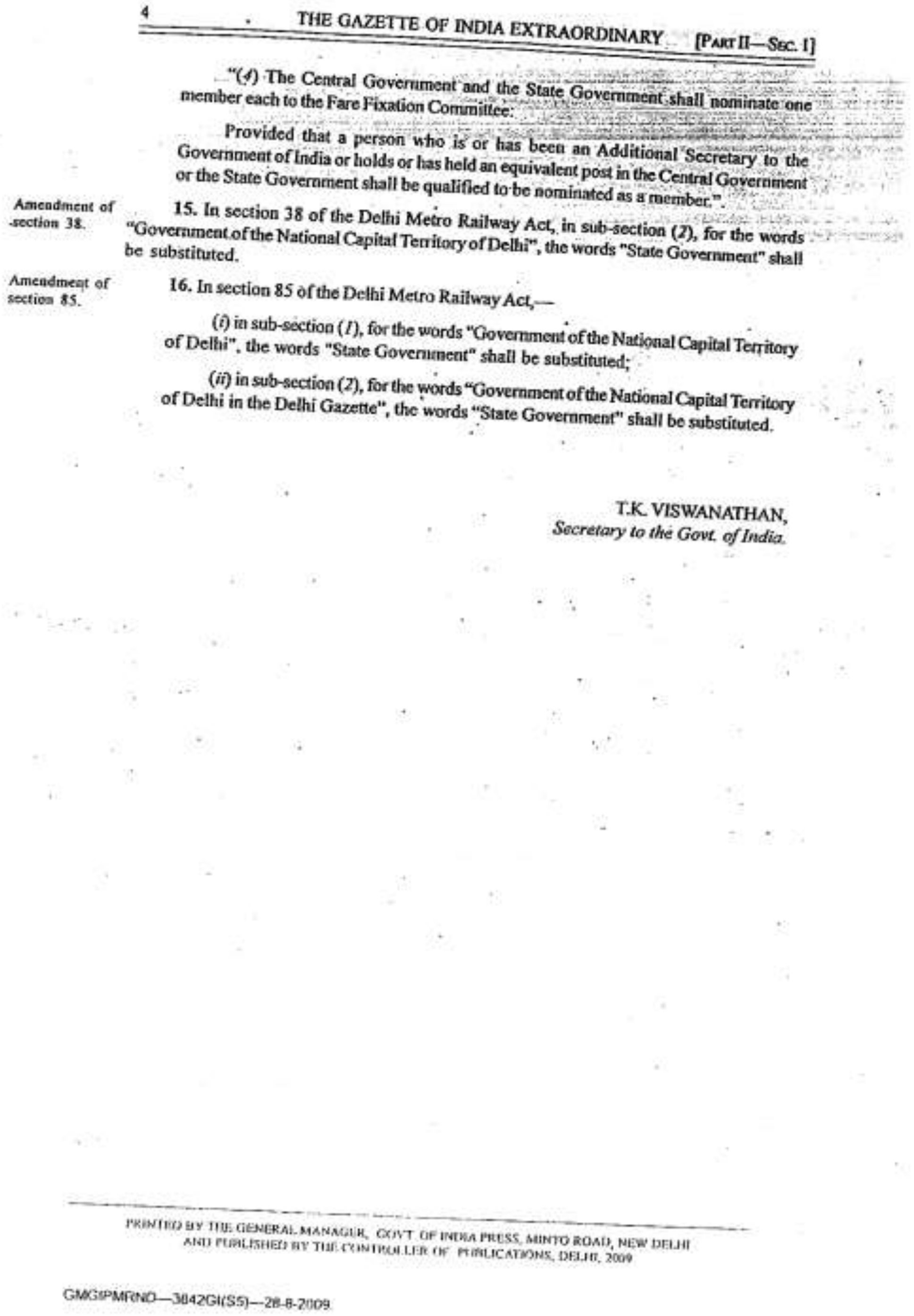
12. In section 23 of the Delhi Metro Railway Act, in sub-section (*1*), for the words "Hindi and English", the words "Hindi, English and official language of the State in which such station is located" shall be substituted.

Amendment of section 26.

13. In section 26 of the Delhi Metro Railway Act, in sub-section (*1*), the words "a small" shall be omitted.

Amendment of section 34.

14. In section 34 of the Delhi Metro Railway Act, for sub-section (*4*), the following sub-section shall be substituted, namely:—



"(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 (*1*), 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.

PRINTED BY THE GENERAL MANAGER, GOVT. OF INDIA PRESS, MINTO ROAD, NEW DELHI
AND PUBLISHED BY THE CONTROLLER OF PUBLICATIONS, DELHI, 2009

GMGIPMRND—3842GI(S5)—28-8-2009

CHAPTER – 19

CONCLUSIONS AND RECOMMENDATIONS

19.1 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 extend Mumbai Metro Line-4 from Gaimukh to Wadala (Bhakti Park) to CSMT Metro at Wadala (Bhakti Park) end 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 March 2018 price level is 7085 Crore with land and all the taxes and duties and completion cost at 5% p.a. escalation is estimated to be Rs.8683 Crores including land and all the taxes and duties, but excluding IDC. It is Rs. 8739 Crore including IDC.

19.2 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.

19.3 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.

19.4 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 14% every two years.

19.5 As in the case of Delhi Metro, the State Government should exempt/reimburse the State Goods and Services Tax (SGST) to MMRDA. It should also exempt the following:

- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

19.6 MOUD vide letter no. F.No. K-14011/03/2017-UT-V-Part(1) dated 6th July 2017 has proposed for sharing of overall Goods and Service Tax (GST) in the ratio of 1:2. Maharashtra State Government may pursue the Central Government to extend the same benefit to MMRDA.

19.7 Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR)

The Financial Internal Rate of Return (FIRR) for the project has been assessed as **1.68% (With additional PD income from 10 Ha land)**. The Economic Internal Rate of Return (EIRR) works out to **14.93%.**

19.8 Meanwhile the State Government should freeze all future developments along the proposed route to avoid in-fructuous expenditure.

19.9 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

MMRDA’s Comments/Observations & DMRC’s Responses on Mumbai Metro Line-11.

Sr. No.	Comments/Observations	DMRC’s response
	Executive Summary	
1	This ML should be read as ML 11 instead of ML 4A.	Complied
2	Sewri station to be named as Sewri Metro	Complied
3	Pg 23 has stn 4 named as Wadi Tower, to be corrected as Wadi Bunder. Also the line 4 stn names are not updated in this table. Refer the updated stn names included in salient features.	1. Complied 2. Names of Line-4 stations are as per the DPR already submitted.
4	Chhatrapati Shivaji Terminus name needs to be corrected as CSMT Metro. This station will be integrated station with CST Metro Station of ML 3. However, CST station has been renamed as Chhatrapati Shivaji Maharaj Terminus i.e. CSMT, therefore, ML 11 station to be named as CSMT Metro	Complied
5	Pg 23, Mention CSMT Metro Station as Interchange stn.	Complied
	Ch 2	
6	This chapter should mention the alignment passing through MbPT area which will undergo major redevelopment. Projected population and employment figures received from MbPT are attached as annexure A. These projections are already considered while assessing ridership.	Complied
7	Also mention CST-Panvel Elevated Corridor. DPR of the same is already with DMRC	Complied
	Ch 3, 6 & 8	
8	There are two Train operation loops proposed i.e. CSTM to Gaimukh in one loop and Bhakti Park (Wadala) to Gaimukh in second loop. This is not a preferred option flow of public travel in Mumbai on Central route. This needs to be improved to two loops as follows: CSTM to Gaimukh as first loop and Kapurwadi to Bhakti Park (Wadala) as second loop.	Noted, the train operation plan (TOP) has been prepared accordingly. Reversal facility shall be provided at Bhakti Park and Kapurwadi
9	Initially train composition will be 6 cars and will later be augmented to 8 cars. In chapter 6, initial train composition shown as 8 cars need correction to 6 cars.	Noted, initial 6 car configuration has been considered for the year 2021 and 8-car configuration has been proposed for the year 2031. Rolling Stock Chapter revised accordingly
10	Powering will be 66 % to begin with 6 cars composition.	Noted, the powering has been considered as 66.67% initially with 6 car configuration
11	Para 4.1.3: Design Speed mentioned as 80 km/h needs correction to 90 kmph. Design speed is 90 kmph and Operational speed is 80 kmph.	Design Speed is not mentioned in Para 4.1.3 rather Maximum Sectional Speed is mentioned as 80kmph in para 4.1.4 which is correct

Sr. No.	Comments/Observations	DMRC’s response
12	It is mentioned under Clause 0.12 that "“Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons”, 1998 and 2013 edition (under revision by MoUD) whereas revised version is already issued by MoHUA now. Same may be quoted now.	Complied
13	In chapter 8, 2 *25 kv traction system is suggested for whole alignment whereas, we have 10 stations as underground. 2 * 25 kv system is neither technically desirable for level of ridership expected in this line nor commercially viable. Besides, it has issues at construction in U/G section due to need of higher tunnel bore dia. Hence 25 KV system(AC) is better included as the only option.	Complied
14	Now a days , 65 sq. mm size of catenary wire is not used though included in DPR.	End to End section from CSTM to Gaimukh Corridor, headway is considered 3.75 min, hence Traction Power requirement is about 1 MVA per km for this section. Hence 65 sq. mm Catenary wire is sufficient. Final sizing of Catenary may be decided at the time of Detailed Design Stage as per the simulation study.
15	Inter station spacing wherever more than 1.7 km-will necessitate provision of Mid term shaft from TVS point of view and considering CBTC designed for 90-100 sec headway.	From CSTM to Wadala, the inter-station distance between two underground stations varies from 0.85 km to 1.58 km. Hence, Mid-shaft has not been considered in Ventilation and Air-Conditioning System Chapter. Provision of Mid-Shaft needs many other variables such as frequency of train, SES Analysis, no. of train with the given speed in tunnel section, etc.
16	With new technologies available, we can optimise length of Station box (particularly for UG station) .	May be examined at Detailed Design Stage
17	PSD in UG section will be of Full height and on elevated of half height.	In the cost estimate Full Height PSDs have already been considered for UG section and Half Height for Elevated section
	Ch 4	
18	Submit the land requirements and detailed dwg of section where the alignment is going from Elevated to underground	It is marked on the alignment plan. Same may please be referred.
	Ch 5	
19	Propose integrated concourse of proposed CSMT Metro Station with ML 3 CST Metro stn.	CSMT Station has been planned in integration to concourse of ML-3
	Ch 7.	
20	If entire corridor is considered, then how much more area of Depot land will be required. Please submit the detailed Depot dwg	Length of entire corridor i.e. between CSMT & Shivaji Chowk will be more than 45km. Total land required for depot will be about 35 Ha. Layout of depot depends on the shape of the land plot. Hence depot layout can't be provided unless location, shape and size of the plot is known
	Ch10.	
21	Pt 10.6.2 & 10.6.3 have mentioned the	Complied

Sr. No.	Comments/Observations	DMRC's response
	project length as 13.5km. Kindly correct it to 12.774km	
22	Map on Pg 276 is not readable. Kindly update the readable map.	Updated
23	Pt 10.7 states the entire corridor is elevated. Kindly chk.	Corrected
	Ch17	
24	Pt 17.4, the construction cost of Metro to be calculated from yr 2019-2024	Corrected